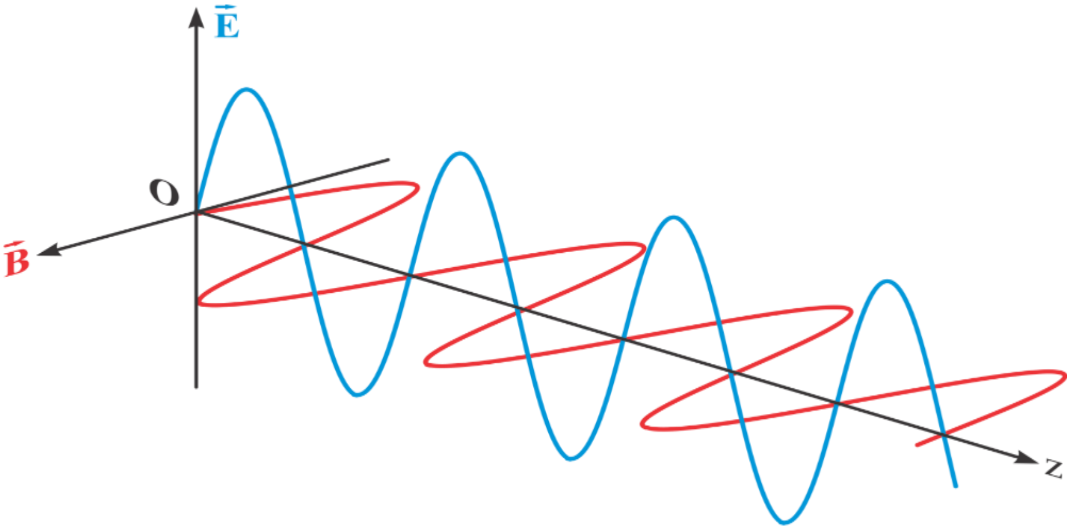
Mirela Nicolov Zoltan Szabadai

Watz Claudia

PHARMACEUTICAL PHYSICS

Part II:



Electricity, Magnetism, Electromagnetism, Sound and ultrasound, Radioactivity, Lasers, Optics

Editura „Victor Babeş"

Timisoara, 2023

Editura "Victor Babeş"

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ISBN 978-606-786-325-3 GENERAL

ISBN 978-606-786-327-7 Vol 2

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INTRODUCTION

The electromagnetic field is one of the various objects of the physical system that **can exist inside the body, as well as in a vacuum** . It is an inseparable whole constituted by the electric field and the magnetic field generated by the organs which are in certain conditions or have an independent existence.

The theory of the electromagnetic field is a synthesis of the experimental results designed to take into account the maximum of the facts.

Interest in studying the electromagnetic field come from the desire to understand the behaviors of different devices and devices, to predict their performance for certain purposes.

At the same time, it is necessary to understand the propagation of electromagnetic energy in space and the significance of its emission and reception . To obtain all this these electromagnetic phenomena must be studied both theoretically and practically. Thus, experience and theory offer us two ways of solving the electromagnetic field. These means are not completely distinct. The theory takes into account previous experiences and any practical realization is based on preparatory work, which uses theoretical knowledge before putting all the means to work (raw materials, machining, installation, testing, maintenance). Furthermore, the continuous improvement of the theoretical model to reflect increasingly true reality is confirmed by experience.

The enormous amount of experimental results accumulated over the last hundred years has led to the assumption that electromagnetic phenomena at the macroscopic scale are governed by Maxwell's equations. So **the classical electromagnetic field theory is the theory of Maxwell's equations** . The study of these equations is carried out in order to deduce the structure and properties of the electromagnetic field, both for itself and with respect to its source. The justification of the hypotheses made will reveal a continuous coherence between the theoretical deductions and the experience.

The practical study of electromagnetic phenomena involves applying practical Maxwell's equations to real-life problems. For every technical problem of electromagnetism there is a solution. However, we cannot have any solution. It should be noted that the practical means used to find it are much less expensive if more theoretical knowledge is used.

Gilbert studied the phenomenon of electrification, discovering that there are many bodies with these properties. He calls the phenomenon ELECTRIFICATION, after the electron - the name of amber in Greek. **Gilbert also discovered the phenomenon of attraction and repulsion of magnetic poles and the phenomenon of magnetization by induction.**

In the following, a brief history is presented, taking into account **the statement made by Lord Kelvin:** ***"When you can measure what you say and express in numbers, then you know something about what you have measured; but when you can't measure and you can't express it in numbers, your knowledge is unsatisfactory".***

After Gilbert, are worth mentioning Gray, who discovers the influence and conduction of static electricity, Dufay, who discovered the two kinds of electricity, Franklin, who develops the theory explaining qualitatively almost all the facts known to the era and invented the lightning rod, etc. To. It can be said, however, that you enter into electricity and magnetism with the work of Coulomb. Coulomb invented a device to determine very weak forces, called torsion balance, which explains the law of electrostatic force.

Thus, **in 1785, Coulomb showed that the force between two electric charges is proportional to the electricity and respectively inversely proportional to the square of the distance between them** . The same law was studied independently by Cavendich, who did not publish his results. The results regarding the inverse-square law of proportionality of the distance electrostatic force between pregnancies were left to Cavendish in his papers and Maxwell had them published in 1879. Also others before Coulomb, such as Volta, constructed simple devices. Thus, Volta built in 1775 a sensitive electrometer with hair, but without knowing the intensity of the force acting on the hair.

To generate electricity in the eighteenth century, scientists rubbed glass with cat fur, used the contact potential between metals, lifted kites, and more. Then, **Volta** , professor of physics at the University of Pavia (Italy), understanding the importance of Galvani's discovery on "animal electricity" in the early 1800s, **invented the voltaic pile (battery consisting of pairs of zinc-copper discs in direct contact, each pair being separated from the next by wet cardboard), giving scientists very important new equipment.** You could make sparks wherever you wanted, the wires could be heated to make new experiences.

It is probable that since the first third of the 18th century people sought to see if there was a link between magnetism and electricity. In the first decades of the 19th century, at the University of Copenhagen, Professor Oersted hoped to obtain a new effect of electricity, by placing a wire by passing an electric current near a needle of the magnetic compass. His experiments were published, stating that the magnetic effect of photovoltaic electricity was discovered.

The quantitative study of the interaction between magnets and currents was carried out by Biot and Savart and the law of Biot and Savart was formulated by Laplace.

At the meeting of the French Academy of Sciences, when Oersted presented his work, Ampère also participated, who decided to extend the results.

Ampere, a man with particular expertise in a number of areas found that an electric current passing through one wire exerts a force on another wire through which a current flows, even without a magnet.

In a study he had presented to the French Academy, on September 18, 1820, Ampère said: **"The solenoid action appears in two types of effects** which I want to distinguish according to a precise definition. I I will name **the first electric tension and the second electric power."**

Thus, he had discovered the difference between electric voltage and currents and had used his mathematical skills to show that the intensity of the magnetic field produced by a current passing through a wire is proportional to the electric current and inversely proportional to the distance from the thread.

Ampère also introduced the current molecular theory, and in 1827 presented the mathematical theory of electrodynamic phenomena, deduced solely from experience.

The next major contribution to the theory of electromagnetism was made by **FARADAY** . He studied at the Royal Institution. In 1819 he was received by Davy in his laboratory and in August 1831 had great success.

FARADAY made an iron ring, which has two coils without interconnection. He connected a battery to one of the coils and a galvanometer to the other. When the battery was disconnected, the galvanometer needle moved, and when he reconnected the battery, the galvanometer needle moved in the opposite direction. Subsequently, **Faraday discovered several ways to obtain currents induced by the variation of the magnetic field . Faraday developed the idea that an induced current is always the result of a change in magnetic lines of force** . The idea of Faraday's lines of force occupying all space was lively controversial by most physicists of his time. **Following a hypothesis of Weber** , physicists believed that electric and magnetic forces act at a distance, in a straight line and, moreover, enter any space with infinite speed. Maxwell 's genius **theoretically verified Faraday's lines of force** and Hertz's genius **experimentally verified Maxwell's work.**

In addition, **Faraday has excellent results on the phenomena of electrolysis, dielectric polarization, rotating magnetic polarization** etc.

During this period, we must remember the discovery of the above-mentioned law bearing his name, by Ohm, in 1826-1827. Ohm's law was verified quantitatively by Fechner in 1829 and then by Pouillet in 37. **Kirchhoff extends Ohm's theory and has a great contribution to the development of electrokinetics.**

The synthesis of electromagnetism is made by Maxwell . James Clerk Maxwell shows from his childhood a great interest in maths and at the age of 15 years writes the work entitled "description of oval curves", published in the Edinburgh Proceedings of the Royal Society. Maxwell's passion for math would increase and with it increase his interest in Faraday's work of electromagnetism, trying to translate his ideas about lines of force into mathematical formula. In 1857, Maxwell wrote to Faraday, commenting on his work. Faraday responded to him and encouraged him with some new ideas.

In 1873, after 5 years of hard work **, Maxwell PUBLISHED "THE TREATISE ON ELECTRICITY AND MAGNETISM". Maxwell compiled all the knowledge about electricity and magnetism into a group of simple equations, specifying the propagation of electromagnetic wave, calculating the speed of light and explaining its propagation as an electromagnetic wave phenomenon. His book became the electromagnetic basis for all devices** , as an overview, which due to its mathematical intuition of Maxwell **, represents the unification of experiments made over 150 years into a coherent theory.** Because Maxwell's theory was radically different from the rules accepted until then it took another 25 years until Heinrich Hertz demonstrated the correctness of Maxwell's equations

Heinrich Hertz confirms the validity of Maxwell's theory develops it for bodies in motion. He set out the theory in two studies which arrived in 1890: "On the Fundamental Equations of the Electrodynamics of Bodies at Rest" and "On the Fundamental Equations of the Electrodynamics of Bodies in Motion Early in the theory of electrons , it is to be noted JJ Thomson, but the one who has a conception is greater than that of the physicists of the English school is Lorentz, who explains in his book "The theory of electrons" almost all the electrical, magnetic and optical phenomena known to that time.

The experiments performed by X-ray, Einchenwald and Wilson invalidated some results of Hertz's theory and are the basis of Lorentz's theory. Rowland's convection current experiment confirms Hertz's theory.

The electron hypothesis was confirmed by JJ Thomson in 1897 and HA Wilson in 1901. The electron charge was determined experimentally by Millikan in 1911.

The special relativity elaborated by A Einstein in 1905 shows the validity of Maxwell's equations also for moving environments (Maxwell-Minkowski equations) and for large relative velocities, comparable to the speed of light and, moreover, proves the electromagnetic phenomena

In 1928, Dirac, Heisenberg and Pauli approached the quantification of the electric field.

Quantum electrodynamics, the perfect form of the theory, at the present stage of the development of electromagnetism, was written in the years 1946-1950 by Tomonaga, Schwinger and Dyson

ELECTRICAL PHENOMENA

The theory of action at a distance expresses the force of interaction between two electric charges or between two magnetic dipoles.

Contiguous action theory: It there is an electromagnetic field which propagates little by little with a finite speed, in vacuum this speed is equal to the speed of light

The microscopic theory of electromagnetic phenomena (from Lorentz electron theory) is based on the existence of a discrete electric charge, the electron is the first elementary particle discovered.

The relativistic theory of electromagnetic phenomena was initiated to reformulate the theory of Maxwell and Lorentz in accordance with the principles of special relativity. It is also known as relativistic electrodynamics.

The quantum theory of electromagnetic phenomena (quantum electrodynamics) deals with Fine Structure of atomic systems produced by quantum fluctuations of the electromagnetic field and the interaction of these fields with the substance consisting of particles with an electric charge

INTRODUCTION TO ELECTROSTATICS.THE ELECTRIC CHARGE

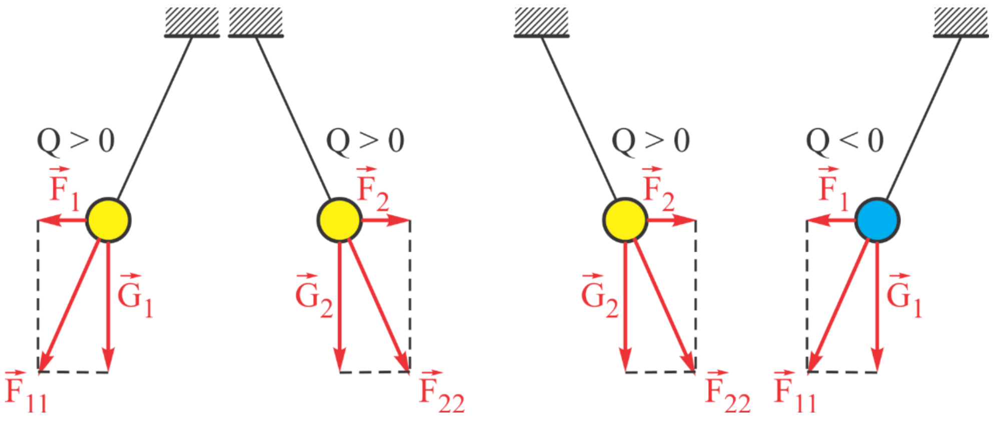


Figure 1: Electric forces and charges

Even early studies of static electricity pointed out that there are two types of electric charge, classically designated (+) and (-).

Between electric charges of the same sign a repulsive force manifests itself.

Between electrical charges of opposite signs there is a force of attraction.

THE ELECTRIC CHARGE: the unit of measurement in SI: Coulomb

The definition of the Coulomb unit of measurement (C): Coulomb is a derived quantity, it is the electric charge which passes through a section of conductor for one second, if the current in the conductor is 1 ampere (ampere - unit base IS).

1 C = $6.241 \cdot 10^{18}$ elementary electric charge

(are $6.241 \cdot 10^{18}$ or the electric charge of the electron)

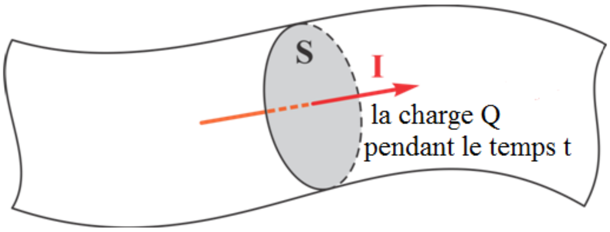


Figure 2: The count I, the load Q during time t

$$I = \frac{Q}{t}$$

Q(Coulomb) = I(Amper)• t(second)

PROPERTIES AND CHARACTERISTICS OF PUNCTIFORM ELECTRIC CHARGE

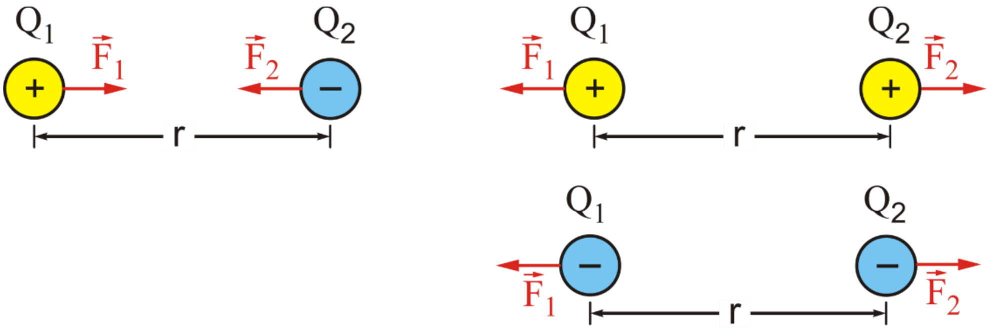
Electric charge : scalar quantity; SI derived unit;

Unit of measurement: "Coulomb" (C)

Electric charge is positive and negative

The interaction force (Coulomb force) between two point charges Q1 and Q2:

it is a vector quantity



Coulomb 's law (ε: environmental permittivity)

THE ELECTRIC CHARGE

Electric charge is a scalar quantity that measures the state of electrification by electric charge. It characterizes bodies to create an electric field and produce ponderomotive forces when other bodies are placed in the electric field.

Electric charge is of several types: positive, negative, zero, and fractional.

The elementary electric charge is discrete: e= -1.6.10 $^{-19}$ C

The electric charge is a scalar invariant and satisfies a conservation law.

The electric charge is negative or positive depending on whether the atoms have an excess of elemental negative charge (ie electrons).

The electron (1897 - JJ Thomson) is a measure of the charge of elementary particles.

Specific charge $\frac{e}{m} = 1{,}758796 \cdot 10^{11} \frac{C}{kg}$

rest mass $m_0 = 9{,}1091 \cdot 10^{-31} kg$

Elementary electric charge $e = 1{,}60210 \cdot 10^{-19} C$

Electric charge (Q or q) has three fundamental properties :

1. **Electric charge is conserved** - the law of conservation of electric charge: the algebraic sum of the charges of isolated physical systems is constant.

2. **Electric charge is quantized:** elementary particles have only three possible values of electric charge + e, 0, -e: Q = Ne, [± (2/3) e] or [± (1/3) e]

The possible amount of electric charge is an integer multiple of elementary charges:

The Quark is a subparticle of the split charge. The Quark charge:

- The proton is composed of: two charge quarks [+ (2/3) e] and one charge quark [- (1/3) e]

-The neutron is composed of: one charge quark [+(2/3)e] and two charge quarks [-(1/3)e]

3. **The electric charge of bodies is relatively invariant, it does not depend on speed.**

ELECTRICAL CHARGE DISTRIBUTIONS

Linear distribution of electric charge is the charge distributed per unit length

$$\lambda = \frac{dQ}{dl} \qquad \lambda = \frac{Q}{L}$$

$$[\lambda]_{S.I.} = 1\frac{C}{m}$$

Distribution superficial of the electric charge is the distributed charge per unit of surface

$$\sigma = \frac{dQ}{dS} \qquad \sigma = \frac{Q}{S}$$

$$[\sigma]_{S.I.} = 1\frac{C}{m^2}$$

ou

$$Q = \oint_{\Sigma} \sigma \, dS$$

Volume distribution of the electric charge of the electric charge is the charge distributed per unit volume

$$\rho = \frac{dQ}{dV} \qquad \rho = \frac{Q}{V}$$

$$[\rho]_{S.I.} = 1\frac{C}{m^3}$$

ou

$$Q = \oiiint \rho \, dV$$

COULOMB'S LAW

In this law it is about interaction of the punctiform charge.

Consider two point charges Q1 and Q2 at a distance r from each other:

$$F \approx \frac{q_1 q_2}{r^2} \quad \text{ou} \quad F = k\frac{q_1 q_2}{r^2}$$

if

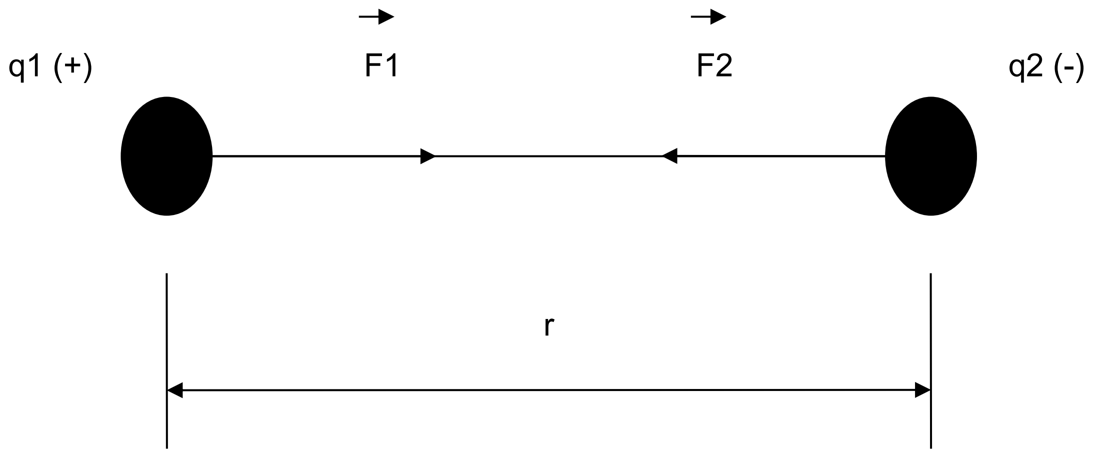


Figure 4: Coulomb 's Law

The Coulomb force in vectorial form is: $\vec{F} = k.\frac{q_1 q_2}{r^3}\vec{r}$

$\vec{u} = \frac{\vec{r}}{r}$ *unity vector*

$k = \frac{1}{4.\pi\varepsilon_0} \cong 9.10^9 \frac{m}{F}$ proportionnality factor

$\varepsilon_0 = \frac{10^{-9}}{36.\pi}\frac{F}{m} \cong 8{,}83.10^{-12}\frac{F}{m}$ *electric* permittivity

- For linear charge distribution

$$dq = \lambda dl$$

$$\vec{F} = \frac{q_0}{4\pi\varepsilon_0}\int \lambda \frac{dl}{r^2}\vec{n}$$

For surface charge distribution

$$dq = \sigma\, dS$$

$$\vec{F} = \frac{q_0}{4\pi\varepsilon_0}\int \sigma \frac{dS}{r^2}\vec{n}$$

- For volumic charge distribution

$$dq = \rho dV$$

$$\vec{F} = \frac{q_0}{4\pi\varepsilon_0}\int \rho \frac{dV}{r^2}\vec{n}$$

ELECTRIC FIELD INTENSITY

The presence of electric charges gives the surrounding space new physical properties than those that exist in the absence of the field (electric field).

We consider q the point load (the sample load). On this charge there is a force $\vec{F} = q.\vec{E}$ (which is called ponderomotive force and ponderomotive law of action.

Electric field strength : $\vec{E} = \frac{\vec{F}}{q}, [E]_{S.I.} = 1\frac{N}{C}$

The intensity of the electric field is a physical quantity which represents the lines of force of the space which acts

- If charge is (+) all field lines start at outward charge
- If the load is (-) all the lines of the field gather in the load

Using the expression for Coulomb's law force given above, the form of the ponderomotive force is:

$$\vec{F} = \frac{1}{4.\pi.\varepsilon_0}.\frac{q_0 q}{r^2}.\vec{n}$$

then Electric Field Strength will be: $\vec{E} = \frac{1}{4.\pi.\varepsilon_0}.\frac{q}{r^2}.\vec{n}$

- For linear load distribution

$$dq = \lambda dl$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \lambda \frac{dl}{r^2}\vec{n}$$

For surface load distribution

$$dq = \sigma\, dS$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \sigma \frac{dS}{r^2}\vec{n}$$

- For bulk load distribution

$$dq = \rho dV$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \rho \frac{dV}{r^2}\vec{n}$$

ELECTRIC FIELD: the intensity of the electric field is a vector quantity; In SI is derived unit a measure of height: Volt/meter (V/m)

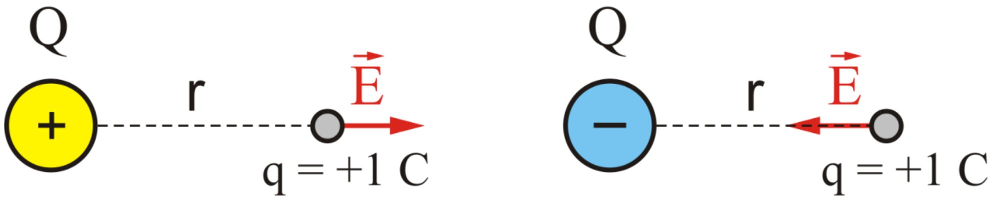
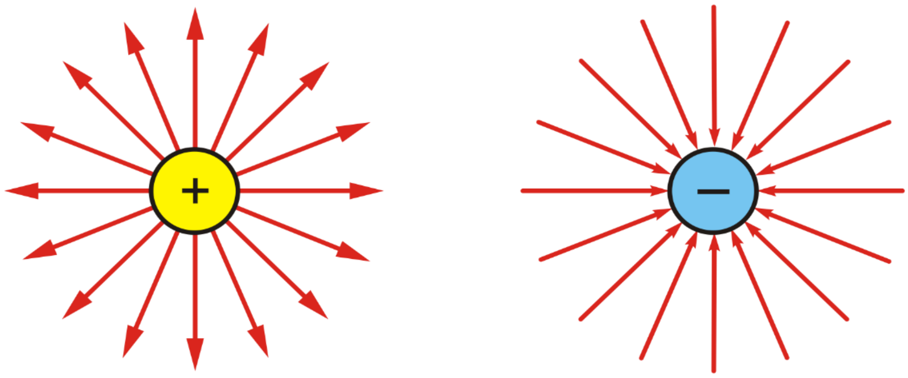


Figure 5: The electric field strength at a distance "r" from a point-like charge "Q"

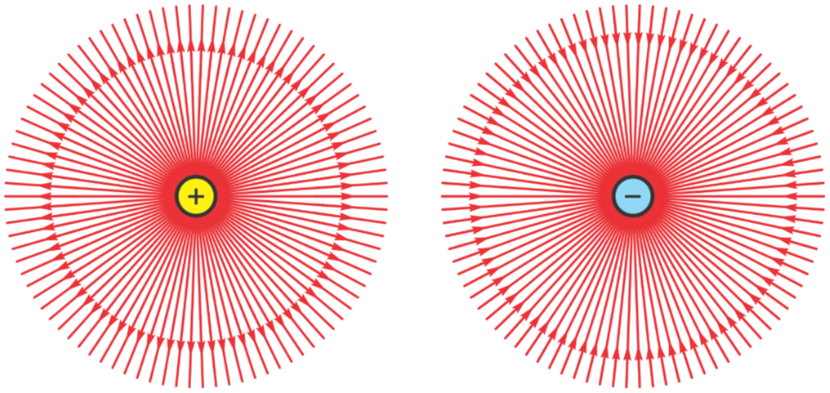
The intensity of the electric field at a distance "r" from a point-like charge "Q" is numerically equal to the force exerted on a body of point-like evidence with the electric charge q = + 1 C

The electric field lines are the trajectories followed by the set of evidence (with charge q = + 1 C) due to the interaction with the electric charge (Q) of the studied body.



A **B**

Figure 6: A: The field lines of a positive point-like charge;B: Field lines for a negative point charge

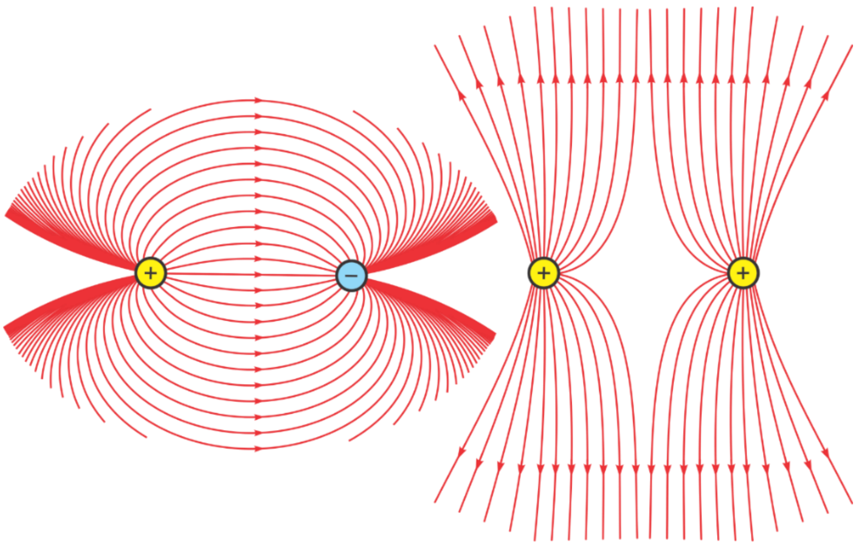


A **B**

Figure 7: A: The field lines of a positive point-like charge;B: Field lines for a negative point charge

ELECTRIC FIELD LINES OF A PAIR

PUNCTIFORM CHARGE



A **B**

Figure 8: A: Power lines of a pair of point charges of opposite sign; B: Electric lines of a pair of point charges of the same sign

THE ELECTRIC POTENTIAL IN THE VICINITY OF THE PUNCTIFORM CHARGES(Q)

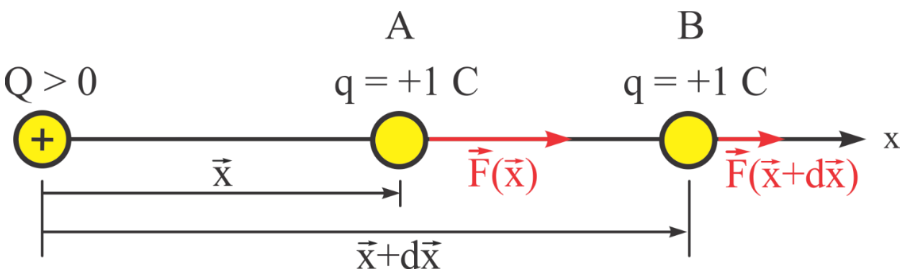


Figure 9: Electric charges and forces (Q>0)

The elementary mechanical work (dW) done by the system while the test charge q = 1 C moves in the electrical field to the charge (Q > 0) from point (A) to point (B) in a infinitesimal distance dx:

$$dW = \vec{F} \cdot d\vec{x}$$

$$\text{parce que} \quad \cos\left(\vec{F}, d\vec{x}\right) = 1$$

$$\Rightarrow \quad W = F.dx$$

The system can be said to perform mechanical work

At a finite displacement (from point A to point B), the work done by the system is:

$$W_{AB} = \int_{x_A}^{x_B} \frac{Q}{4\cdot\pi\cdot\varepsilon\cdot x^2}\cdot dx = \frac{Q}{4\cdot\pi\cdot\varepsilon}\int_{x_A}^{x_B}\frac{dx}{x^2}$$

$$W_{AB} = \frac{Q}{4\cdot\pi\cdot\varepsilon}\cdot\left(-\frac{1}{x}\right)_{x_A}^{x_B} = -\frac{Q}{4\cdot\pi\cdot\varepsilon}\left(\frac{1}{x_B}-\frac{1}{x_A}\right)$$

The electric potential near the point of charge Q> 0 (in point A) is equal to the work done by the system consisting of a punctiform charge Q and a test charge (q = + 1 C).

while the test load moves from point A an infinite distance from the load Q.

The potential of point A is positive.

$$W_{AB} = -\frac{Q}{4\cdot\pi\cdot\varepsilon}\left(\frac{1}{x_B}-\frac{1}{x_A}\right)$$

si $x_B \to \infty$

alors :

$$W_{A\infty} = -\frac{Q}{4\cdot\pi\cdot\varepsilon}\left(-\frac{1}{x_A}\right) = \frac{Q}{4\cdot\pi\cdot\varepsilon}\cdot\frac{1}{x_A} = V_A$$

$$W_{AB} = -\frac{Q}{4\cdot\pi\cdot\varepsilon}\left(\frac{1}{x_B}-\frac{1}{x_A}\right)$$

si $x_B \to \infty$

alors :

$$W_{A\infty} = -\frac{Q}{4\cdot\pi\cdot\varepsilon}\left(-\frac{1}{x_A}\right) = \frac{Q}{4\cdot\pi\cdot\varepsilon}\cdot\frac{1}{x_A} = V_A$$

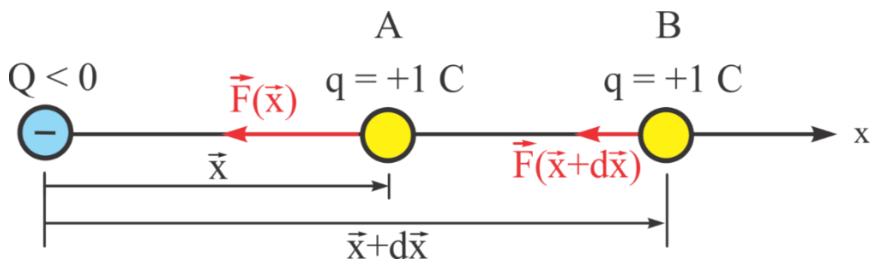


Figure 10: Electric charges and forces (Q<0)

$$dW = \vec{F}\cdot d\vec{x}$$

Parce que $\cos(\vec{F}, d\vec{x}) = -1 \Rightarrow dW = -F.dx$

The environment performs mechanical work on the system

$$W_{AB} = -\int_{x_A}^{x_B} \frac{Q}{4\cdot\pi\cdot\varepsilon\cdot x^2}\cdot dx = -\frac{Q}{4\cdot\pi\cdot\varepsilon}\int_{x_A}^{x_B}\frac{dx}{x^2}$$

$$W_{AB} = -\frac{Q}{4\cdot\pi\cdot\varepsilon}\cdot\left(-\frac{1}{x}\right)_{x_A}^{x_B} = \frac{Q}{4\cdot\pi\cdot\varepsilon}\left(\frac{1}{x_B}-\frac{1}{x_A}\right) < 0$$

Si $x_B \to \infty$ *, alors …*

$$W_{A\infty} = -\frac{Q}{4\cdot\pi\cdot\varepsilon}\cdot\left(-\frac{1}{x}\right)_{x_A}^{x_B} = \frac{Q}{4\cdot\pi\cdot\varepsilon}\left(-\frac{1}{x_A}\right) < 0 \quad W_{A\infty} = V_A < 0$$

ELECTRIC DIPOLE

Is characterized by a derived quantity called electric moment p:

$$\vec{p} = q(x_2 - x_1)\vec{i} \quad + q(y_2 - y_1)\vec{j} \quad + q(z_2 - z_1)\vec{k}$$

- Q is the absolute value of the electric charge
- X1, y1, z1 represent the coordinates of the negatively charged material
- x2, y2, z2 are the coordinates of the positively charged matter.

Electric dipole - is a set of two punctiform bodies located relative to each other, at distance (lower) l, electrically charged with charges equal in absolute value and of opposite signs

In a homogeneous electric field

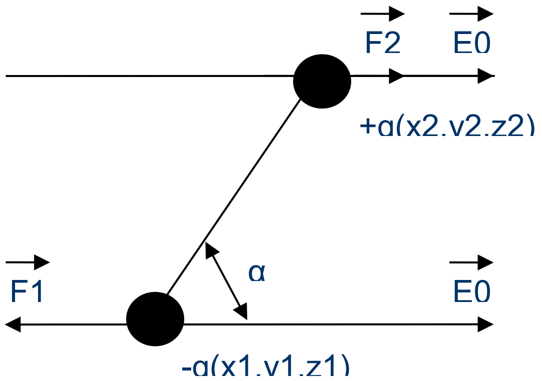


Figure 11: Electric dipole

The electric dipole supports the action of a couple of forces whose value is: $C = \frac{F_2}{\sin\alpha}$ $\quad \vec{C} = \vec{p} \times \vec{E}_o$

In an inhomogeneous electric field

- The electric field has different values: $\vec{E}'_o$ et $\vec{E}_o$

$$\vec{F} = q(\vec{E}'_o - \vec{E}_o)$$

E_o' can be decomposed in series, with respect to Eo

$$\vec{F} = q(x_2 - x_1)\frac{\partial E_{ox}}{\partial x}\vec{i} + q(y_2 - y_1)\frac{\partial E_{oy}}{\partial y}\vec{j}$$

$$+ q(z_2 - z_1)\frac{\partial E_{oz}}{\partial z}\vec{k}$$

$$\vec{F} = \frac{\partial}{\partial x}(p_x E_{ox})\vec{i} + \frac{\partial}{\partial y}(p_y E_{oy})\vec{j} + \frac{\partial}{\partial z}(p_z E_{oz})\vec{k}$$

ou $\vec{F} = \mathrm{grad}(\vec{p} \cdot \vec{E}_o)$

Polarization of dielectrics

Dielectric bodies, although not electrically charged, produce an electric field.

Dielectric bodies placed in an electric field undergo ponderomotive actions. These objects are called polarized bodies:.

The behavior of dielectrics requires the electrical size p characterizing the state of polarization.

Polarization P: $P = P_p + P_t$

Pp= permanent electric moment (independent of the existence of an electric field)

Pt = temporary electric moment (determined by the external electric field)

The behavior of polarized bodies such as a dipole suggests the idea the polarization of a body is equivalent to a distribution chosen by an electric charge called polarization charge

$q_p = \sigma_p \cdot A$

$p = q_p.l$

$p = \sigma_p \cdot A.l$

σ_p - surface density of bias charge

A - base area

L - distance between the two bases

THE INTENSITY OF THE ELECTRIC FIELD IN A DIELECTRIC

The introduction of a test body into a dielectric is equivalent to the appearance of discontinuity surfaces (surfaces formed between the sample and the dielectric body).

After direct contact with the dielectric of the field the charged test body undergoes the action of a new force of a special type,

called **Electrostriction Force** .

The force exerted on the dielectric: $F = F_{el} + F_{sp} + F_{elstr}$

Fel= force exerted by the electric field

Fsp= Force exerted by the additional polarization charges

Felstr = Electrostriction Force

Electrostriction can be suppressed by avoiding direct contact between the sample and the dielectric body, which is possible if a cavity is kept empty in the dielectric and if the test body is introduced into this cavity.

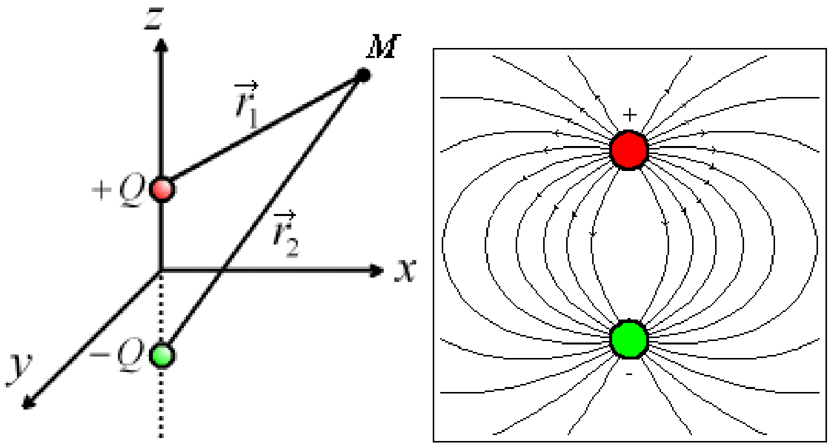


Figure 12: The electric field in a dielectric

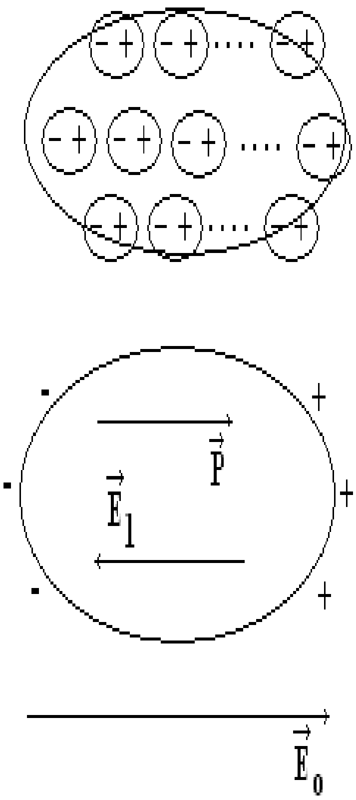
The applied electric field is generated by electric charges external to the dielectric.

In dielectric point, the total field is the superposition of this field with the field created by all the tasks within the solid.

A solid dielectric is a set of very large numbers of polarizable unit atoms or molecules. Under the action of the external field, the solid becomes a distribution of dipoles.

The electric dipole is a source of electrostatic potential, and therefore of the electric field. In Figure 13A is shown the geometry of the dipole moment for the two electric charges.

In FIG. 13 B are represented the electric field lines generated by a dipole in three dimensions plane zx , and in FIGS. 2 and 3 are represented the possible distributions of the lines and of the field lines generated by such a dipole.



A

B

Figure 13:

A: the geometry of the dipole moment for the two electric charges. ;

B: the electric field lines generated by a dipole

Before proceeding to the evaluation of the electric field in the dielectric, we make the following clarifications:

- in a solid, there are many free (free electrons) and charges (ionic nuclei and the electrons of atoms participating in the chemical bond between them);
- under the action of an external electric field, the electric charge is subjected to the drift of free flow (by which one makes the transport of the charge in the solid), and the charge is polarized (elementary dipole moments are induced and induced polarization on a macroscopic scale).

In what follows, we consider solid dielectrics without free charges so that the polarized dielectric solid can be imagined as a set of a large number of elementary dipoles, preferably oriented parallel to the field.

Inside the dielectric, the fields created by the dipoles cancel each other out, but the fields created by the marginal dipoles of the surface of the macroscopic sample remain active. The image is that of a single dielectric dipole, the task of which is distributed according to the geometry of the surface. This "dipole" creates a field, which is opposite to the applied field called the depolarization field,

On a certain zone, imagined inside the dielectric, the charge of the marginal dipoles will also be found distributed.

The molecular (or atomic) dipoles oscillate at a frequency located in the optical spectral domain (IR + visible) with frequencies in the range $\nu \in (10^{11}, 10^{15})$Hz.

The domain will be created in such wavelength in the range

$\lambda \in (10^{-1}, 10^{3})$ µm

ELECTRICAL CAPACITY. CAPACITORS

The electrical capacity of a body - the ability of the organism to store an electrical charge

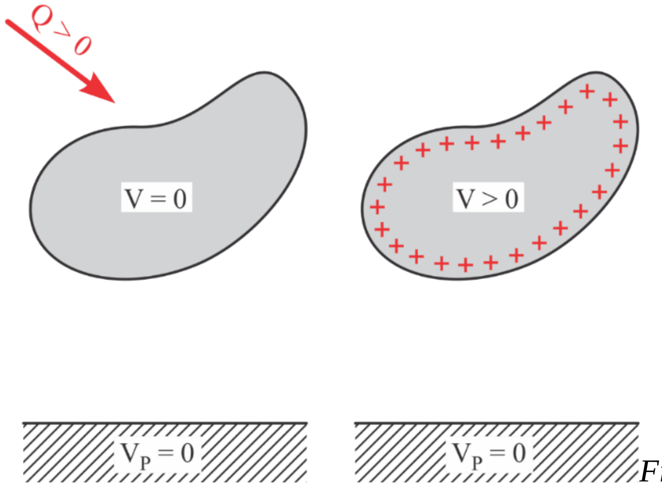


Figure 14: The electrical capacitance of a body

$$\frac{Q_1}{V_1} = \frac{Q_2}{V_2} = \cdots = C$$

C = the electrical capacitance of a body

The unit of electrical capacity in SI: "Fahrad" (F): $1F = \frac{1C}{1V}$

In practice - subunits : microfahrad (10^{-6} F), picofahrad (10^{-12} F) etc.

THE ELECTRICAL CAPACITY OF A SPHERICAL CONDUCTOR

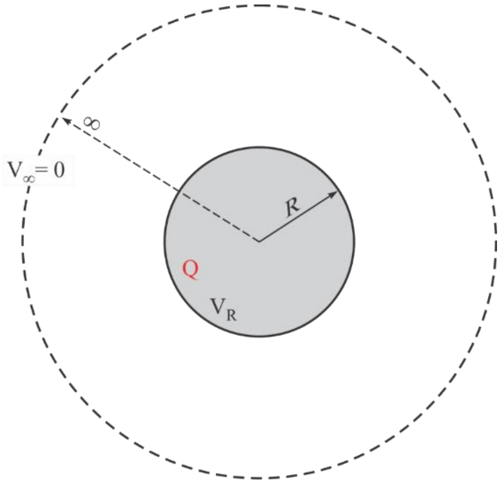


Figure 15: The electrical capacitance of a spherical conductor

$$C = \frac{Q}{V} = \frac{Q}{\frac{Q}{4 \cdot \pi \cdot \varepsilon \cdot R}} = 4 \cdot \pi \cdot \varepsilon \cdot R$$

Earth's capacity:

The electric capacity of the Earth (R ≈ 6370 km = $6370 \cdot 10^{6}$ m)

If the middle is empty (e_0), then

$$k = \frac{1}{4 \cdot \pi \cdot \varepsilon_0} = 9 \cdot 10^9 \ \frac{N \cdot m^2}{C^2}$$

Earth's capacity:

$$C_P \frac{1}{k} \cdot R = \frac{6{,}370 \cdot 10^6}{9 \cdot 10^9} = 707{,}7 \cdot 10^{-6} \ F = 707{,}7 \ \mu F$$

THE ELECTRICAL CAPACITY OF A CAPACITOR

The capacity of a body or a set of objects depends on the geometric characteristics of the conductive bodies. In practice, capacities greater than those of the Earth are achieved by using a set of objects. ex. The planar capacitor - consisting of two conductive plates(fittings insulated with a layer of non-conductive material (dielectric).

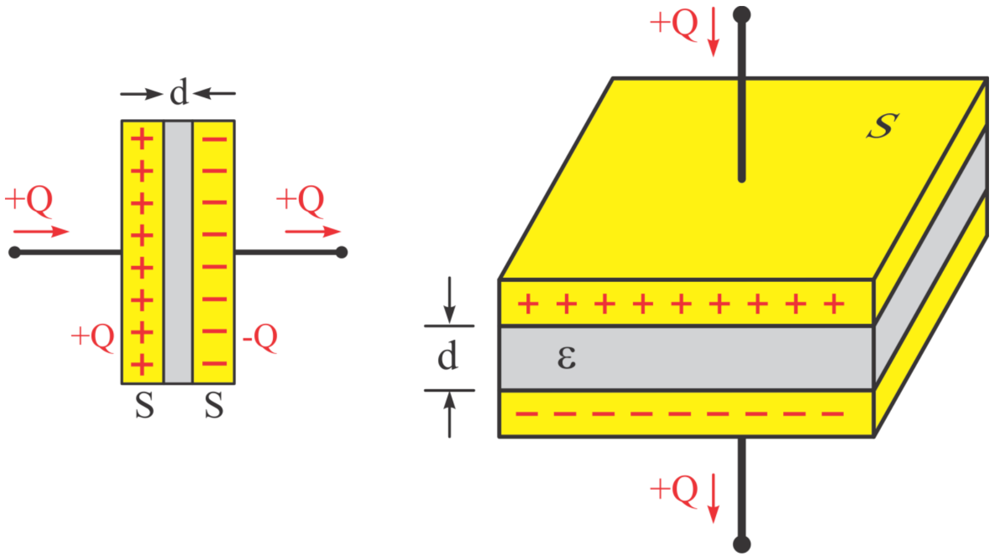


Figure 16: The electrical capacity of a capacitor

$$C = \varepsilon_0 \cdot \varepsilon_r \cdot \frac{S}{d}$$

e $_0$ = vacuum permittivity

$$\varepsilon_0 = 8{,}854 \cdot 10^{-12}\ \frac{F}{m}$$

Relative permittivity **e** $_r$ of some materials

dielectric	**er** _
empty	1
air	1.00059
tephlon	2.1
Water	80.4
glass	5 -19

THE ELECTRICAL CAPACITY OF A SPHERICAL CONDUCTOR (CONCENTRIC SPHERES)

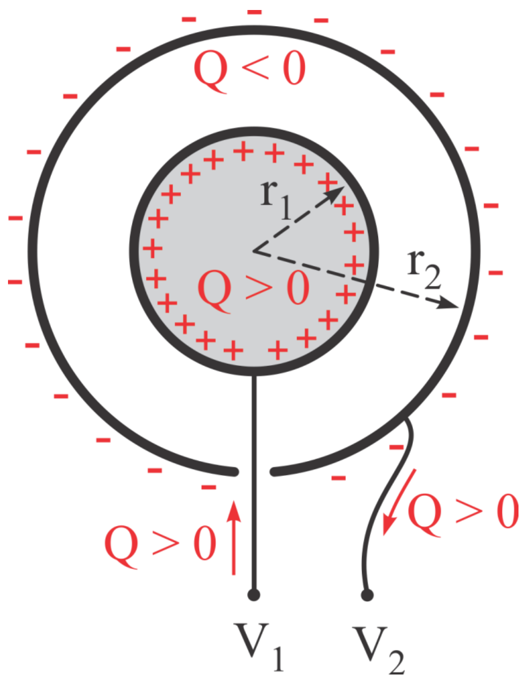


Figure 17: The electrical capacity of a spherical conductor

The potential difference U12 = V1 - V2

between the surface of the armature is equal to the difference of the potential points carrying the same electric charge Q.

$$V_1 = \frac{Q}{4 \cdot \pi \cdot \varepsilon \cdot r_1} ; V_2 = \frac{Q}{4 \cdot \pi \cdot \varepsilon \cdot r_2}$$

$$U_{1,2} = V_1 - V_2 = \frac{Q}{4 \cdot \pi \cdot \varepsilon} \cdot \left(\frac{1}{r_1} - \frac{1}{r_2} \right)$$

$$C = \frac{Q}{U_{1,2}} = \frac{4 \cdot \pi \cdot \varepsilon}{\frac{1}{r_1} - \frac{1}{r_2}}$$

THE EQUIVALENT ELECTRICAL CAPACITY OF A SET OF CAPACITORS

Capacitors connected in series

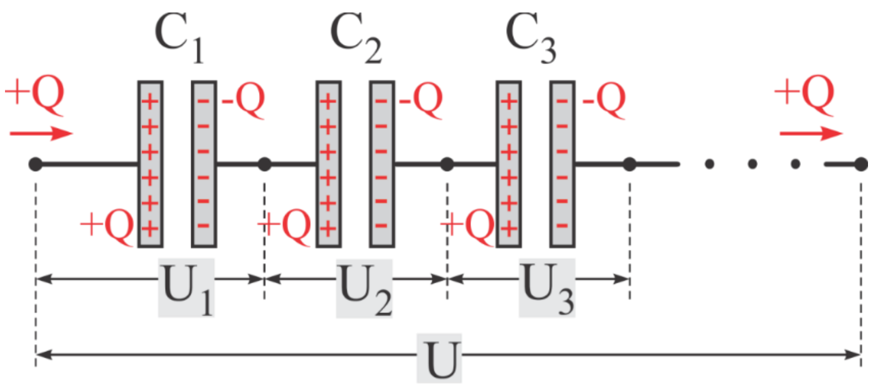
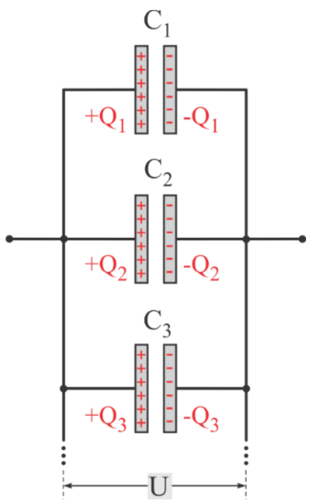


Figure 18: Capacitors connected in series

$$U = U_1 + U_2 + U_3 + \cdots$$

$$\frac{Q}{C_S} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} + \cdots$$

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$$



Capacitors connected in parallel

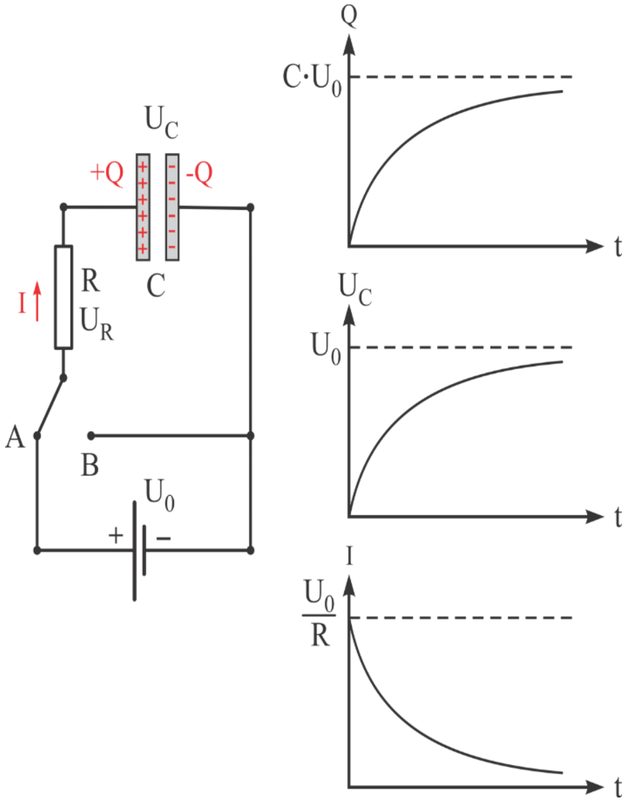
$$Q = Q_1 + Q_2 + Q_3 + \cdots$$

$$C_P \cdot U = C_1 \cdot U + C_2 \cdot U + \cdots$$

$$C_P = C_1 + C_2 + C_3 + \cdots$$

Figure 19: Capacitors connected in parallel

CHARGING A CAPACITOR



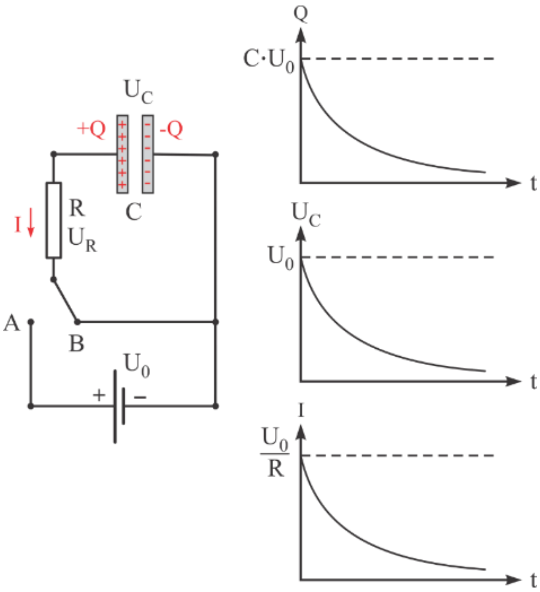
$$Q = C \cdot U_0 \cdot \left(1 - e^{-\frac{t}{R \cdot C}}\right)$$

$$U_C = U_0 \cdot \left(1 - e^{-\frac{t}{R \cdot C}}\right)$$

$$I = \frac{U_0}{R} \cdot e^{-\frac{t}{R \cdot C}}$$

Figure 20: Charge of a capacitor

DISCHARGING OF A CAPACITOR



$$Q = C \cdot U_0 \cdot e^{-\frac{t}{R \cdot C}}$$

$$U_C = U_0 \cdot e^{-\frac{t}{R \cdot C}}$$

$$I = \frac{U_0}{R} \cdot e^{-\frac{t}{R \cdot C}}$$

Figure 21: Discharging a capacitor

THE ENERGY OF A CHARGED CAPACITOR

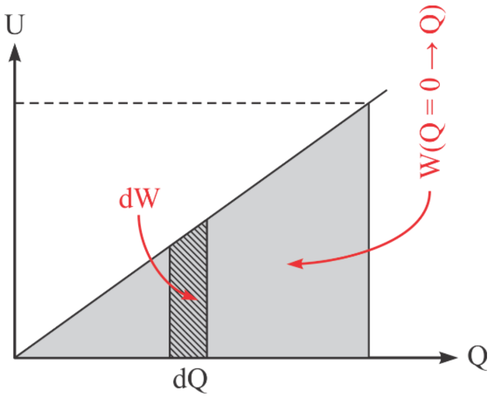


Figure 22: The Energy of a Charged Capacitor

$$dW = U \cdot dQ$$

$$W = \int_0^Q U(Q) \cdot dQ = \int_0^Q \frac{Q}{C} \cdot dQ = \frac{1}{C} \int_0^Q Q \cdot dQ$$

$$W = \frac{1}{C} \cdot \frac{Q^2}{2} \quad ; \quad Q^2 = C^2 \cdot U^2 \;\; ; \;\; W = \frac{1}{2} \cdot C \cdot U^2$$

2. ELECTRODYNAMICS

Electrodynamics studies the phenomena related to the movement of charges and the physical phenomena caused by the movement of charge.

The movement of the charge carriers is the electric current.

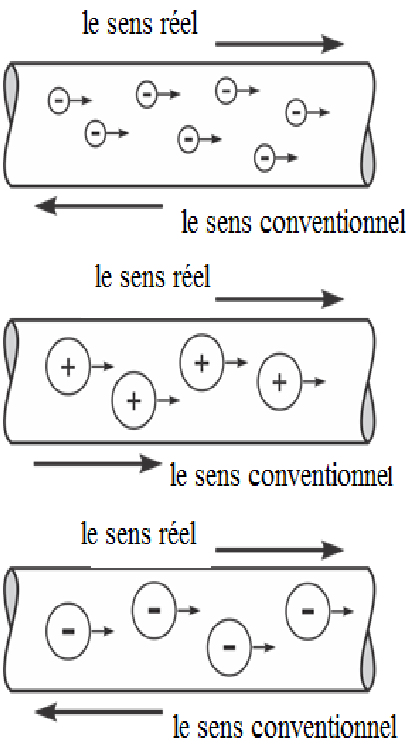
The movement of charge carriers in a conductor occurs due to a difference in potential (voltage) between the ends of the conductor.

Charges:

- Electrons in the case of metallic conductors;
- Negative / positive ions in the case of semiconductors, electrolyte solutions, molten electrolytes, gases, etc.

The True or Conventional Meaning of Electric Current.

The conventional direction corresponds to the direction of movement of the positive charge carriers.



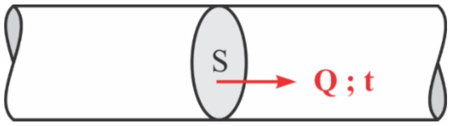
If the charge carriers are electrons, the conventional direction of electric current is opposite to the direction of the real direction.

If the charge carriers are positive ions, then the classical direction of electric current coincides with a real direction.

If the charge carriers are negative ions, then the conventional direction is opposite to the direction of actual electric current.

Figure 23: Charge carriers and the direction of electric current

INTENSITY OF ELECTRIC CURRENT



The amount of electric charge that passes through the section of the conductor in a unit of time defines the unit of measurement of electric current (ampere).

$$I = \frac{Q}{t}$$

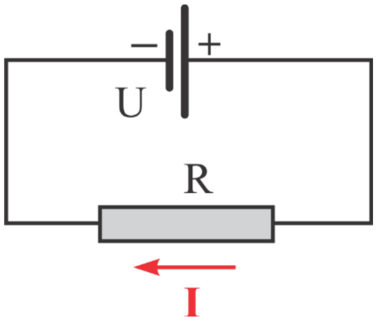
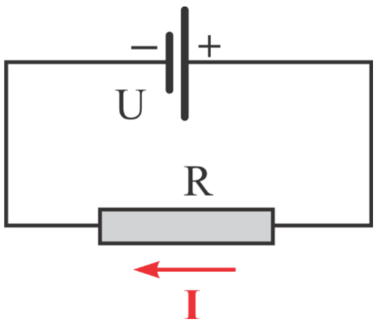


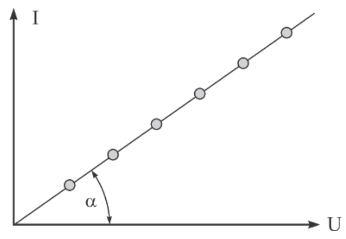
Figure 24: Electric circuit traversed by a current of intensity I

Electric charges pass through a conductor if between the ends of the conductors there is a potential difference (voltage).

Electrical conductors exhibit resistance to the movement of charge carriers.

THE ELECTRICAL CIRCUIT. THE RESISTANCE OF A RESISTOR. OHM'S LAW.





A B

Figure 25:A) the simple electrical circuit; B) the representation of Ohm's law.

$$tg\alpha = \frac{1}{R}; I = \frac{U}{R}$$

R = **The electrical resistance of a conductor**

$$[R]_{SI} = \text{"ohm"} = \Omega$$

RESISTANCE EQUIVALENT TO A SET OF RESISTANCES

RESISTANCES IN SERIES:

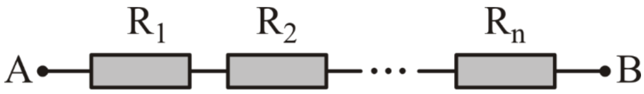


Figure 26: series resistors

$$R_{AB} = \sum_{i=1}^{n} R_i$$

The dependence of strength on geometric characteristics.

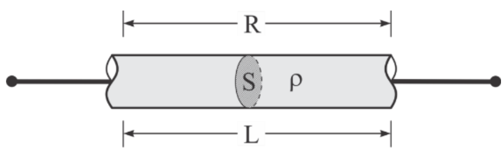


Figure 27: Strength and geometric characteristics.

The intrinsic property of a conductor:

$$R = \rho \cdot \frac{L}{S}$$

R = resistance (Ohm, W)

S = cross-sectional area (m ^{2})

r = the specific resistance (W•m)

PARALLEL RESISTANCES:

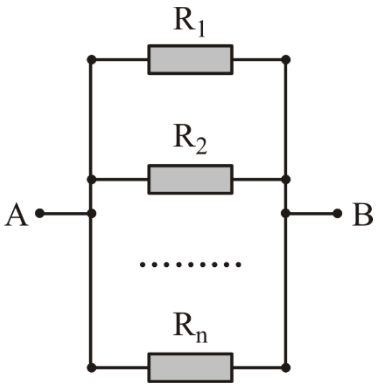


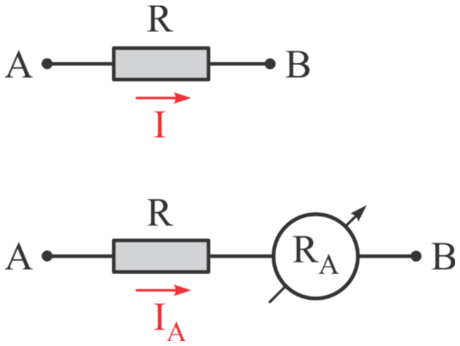
Figure 28: Resistors in parallel:

$$\frac{1}{R_{AB}} = \sum_{i=1}^{n} \frac{1}{R_i}$$

Measurement of the current intensity in a branch circuit and the voltage of the electrical circuit between two nodes

Intensity of electric current in branch AB ammeter (Linked in series with branch circuit elements involved)

THE IDEAL OHMMETER has "zero resistance R_A"



$$U_{AB} = I \cdot R = I_A \cdot (R + R_A)$$

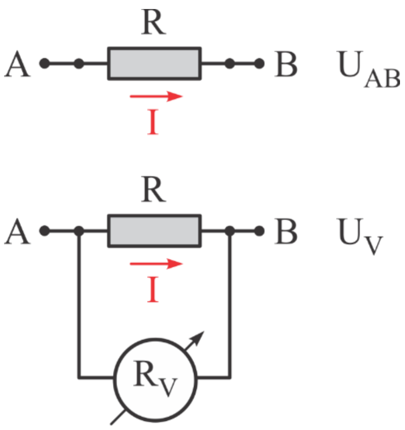
$$I = I_A \cdot \left(1 + \frac{R_A}{R}\right)$$

$$\frac{R_A}{R} \to 0 \; ; \; I_A \to I$$

Figure 29: Measurement of current intensity in a circuit with The ideal ammeter

Voltage between two nodes (A and B): Voltmeter (tied in parallel to the branch circuit elements associated with the pair of nodes)

ideal voltmeter a "R $_V$ of infinite resistance"

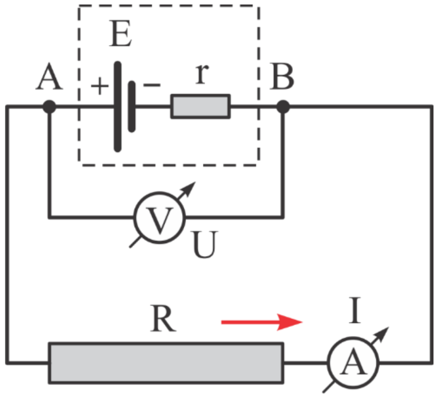


$$I = \frac{U_{AB}}{R} = U_V \cdot \left(\frac{1}{R} + \frac{1}{R_V} \right)$$

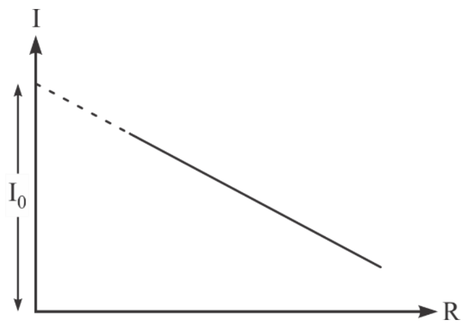
$$R_V \to \infty \ ; \ U_V \to U_{AB}$$

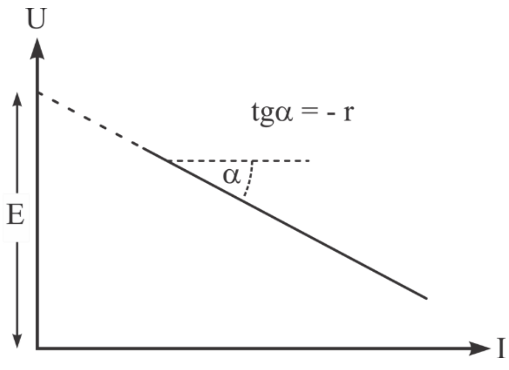
Figure 30: Measurement of the voltage between two nodes (A and B) in a circuit with the Ideal Voltmeter

OHM'S LAW FOR THE ENTIRE CIRCUIT



AT





B C

Figure 31: A) The entire circuit; B) Variation: I=I(R);C) Variation U=U(I)

The characteristics of a direct current source:

- The electromotive voltage (E): $E = I \cdot R + I \cdot r$

- Internal resistance (r)

$$I = \frac{E}{R + r}$$

$$U = E - I \cdot r$$

$I_0 = \frac{E}{r}$: I_0 = intensity of the short-circuit current

MEASUREMENT OF THE ELECTROMOTIVE VOLTAGE OF A SOURCE. POGGENDORFF ASSEMBLY

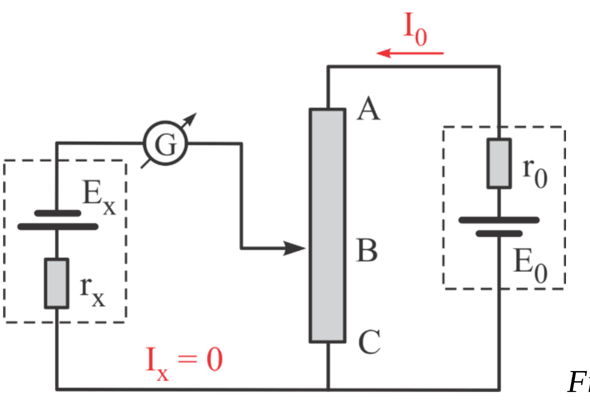


Figure 32: Poggendorff assembly

$$I_0 = \frac{E_0}{r_0 + R_{AC}} \quad ; \quad U_{BC} = R_{BC} \cdot \frac{E_0}{r_0 + R_{AC}} = E_x$$

$$\frac{E_x}{E_0} = \frac{R_{BC}}{r_0 + R_{AC}} \quad ; \quad E_x = E_0 \cdot \frac{R_{BC}}{r_0 + R_{AC}}$$

KIRKHOFF'S LAWS

Analysis of the circuits traversed by the direct current -

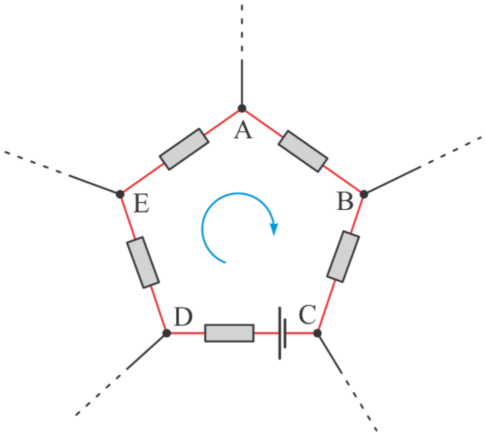


Figure 33: The circuit through which the direct current flows.

AT ; B; VS ; D; E = nodes

AB; BC; CDs; OF ; EA – side

ABCDE = loop (“eye”)

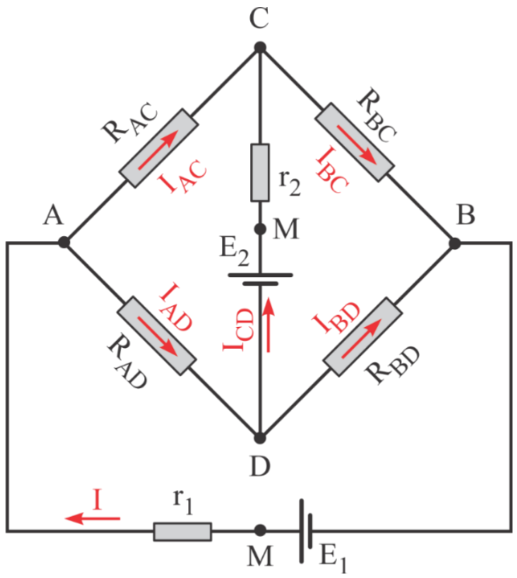
(i) the algebraic sum of the intensities of the currents which come together in a network node is zero.

(ii) Along the outline of a loop (an "eye") of the network, the algebraic sum of the electric voltage sources is equal to the algebraic sum of the product of the current and the total resistance on each side.

ANALYSIS OF CIRCUITS CROSSED BY DIRECT CURRENT – EXAMPLE

Purpose : The expression of the intensity of the direct current on each side as a function of the resistors and the characteristics of the sources (electromotive force and internal resistance).

(1) In each branch is arbitrarily chosen a positive effect for the corresponding current.



(2) If the network contains "p" nodes then for "p – 1" nodes Kirchoff's law (I) applies.

Currents entering the node are considered positive, currents leaving the node have a negative sign.

Figure 34: Analysis of the circuits traversed by the direct current

The network has four nodes, so applying law (I) leads to three equations:

(A): $I - I_{AC} - I_{AD} = 0$

(B): $- I + I_{BC} + I_{BD} = 0$

(C): $I_{AC} + I_{CD} - I_{BC} = 0$

(3) A number of independent loops are chosen (arbitrarily) and for each chosen loop is defined (arbitrarily) a scroll direction. The currents of a loop, which have a significance equal to the scroll direction of the loop , are positive; the others are negative. The sources of electrical voltages are positive if the direction of scrolling

chosen coincides with the direction imposed by the current source; otherwise they are negative

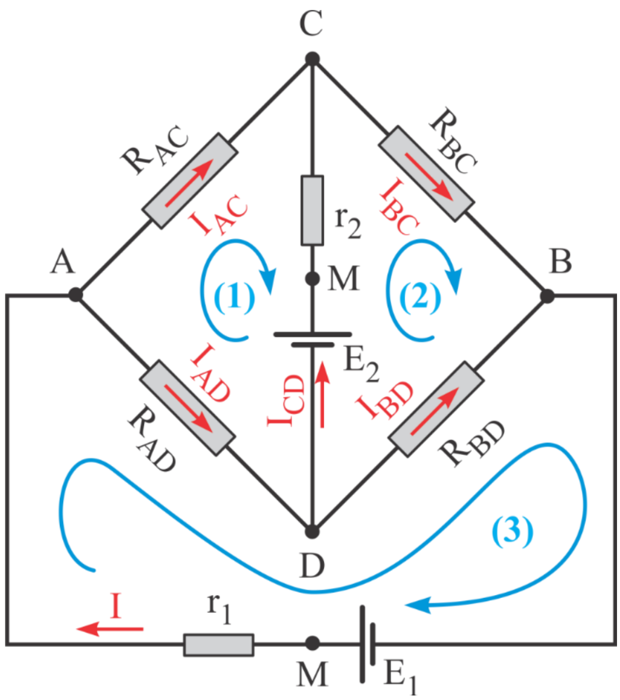


Figure 35: Analysis of the circuits traversed by the direct current

Loop (1) (ACDA loop):

$I_{AC} \cdot R_{AC} - I_{CD} \cdot r_2 - I_{AD} \cdot R_{AD} = -E_2$

Loop (2) (CBDC loop):

$I_{BC} \cdot R_{BC} - I_{BD} \cdot R_{BD} + I_{CD} \cdot r_2 = E_2$

Loop (3) (ADBMA loop):

$I \cdot r_1 + I_{AD} \cdot R_{AD} + I_{BD} \cdot R_{BD} = E_1$

(4) The 6 equations are solved with respect to the 6 unknowns (the currents I, I_{AC}, I_{AD}, I_{CD}, I_{BC} and I_{BD}. If in a real problem for one of the currents a negative value was obtained this means that the (arbitrary) choice of the direction of the current was not correct.

WHEATSTONE BRIDGE

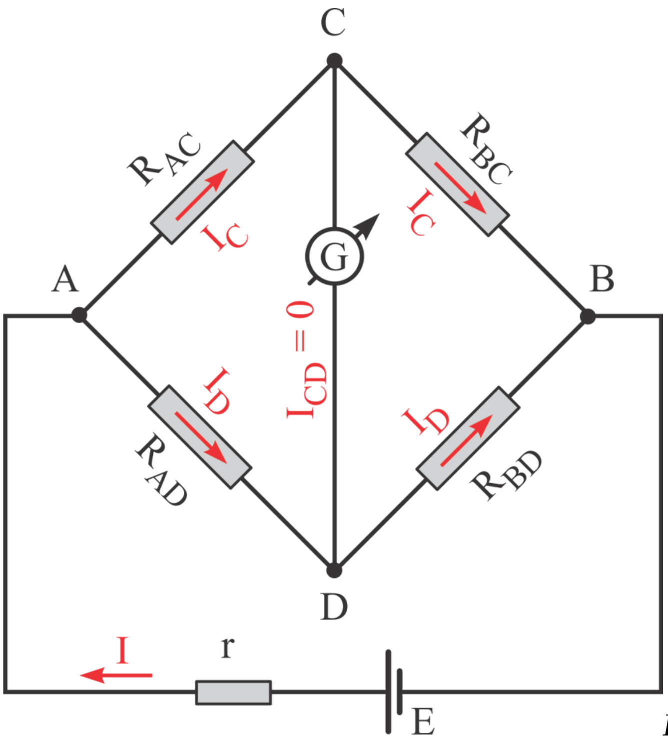


Figure: 36: Wheatstone Bridge

If the "G" galvanometer indicates zero current then:

$I_{CD} = 0$

⇨ $U_{AC} = U_{AD}$ and

$U_{CB} = U_{BD}$

$I_C \cdot R_{AC} = I_D \cdot R_{AD}$

$I_C \cdot R_{BC} = I_D \cdot R_{BD}$

$$\rightarrow \frac{R_{AC}}{R_{BC}} = \frac{R_{AD}}{R_{BD}}$$

POWER DISSIPATED IN RESISTANCE – THE JOULE-LENZ RELATIONSHIP

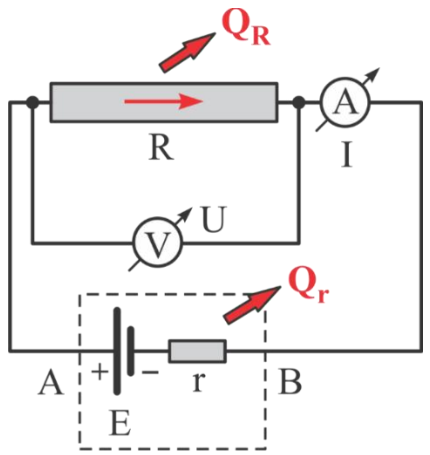


Figure 37: The heat dissipation (Q_R) on R of external resistance

The heat dissipation (Q_R) on R of external resistance in time t:

$$Q_R = U \cdot I \cdot t$$

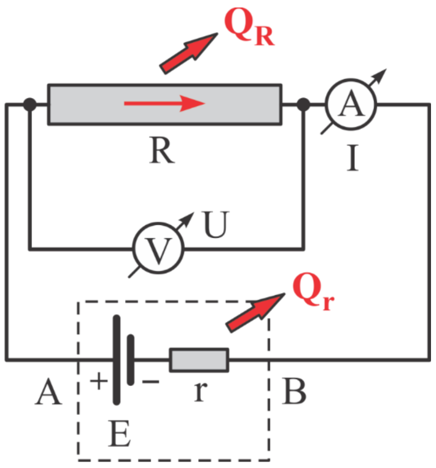
The power dissipated (P_R) on the external resistance R:

$$P_R = \frac{Q_R}{t} = U \cdot I = \frac{U^2}{R} = I^2 \cdot R$$

The power dissipated (P_{R+r}) on the complete circuit:

$$P_{R+r} = \frac{Q_{R+r}}{t} = E \cdot I = \frac{E^2}{R+r}$$

THE MAXIMUM AMOUNT OF POWER DISSIPATED IN THE RESISTANCE OF AN EXTERNAL CIRCUIT



The power dissipated (P_R) **in the external resistance** R:

$$P_R = \frac{Q_R}{t} = U \cdot I = \frac{U^2}{R} = I^2 \cdot R$$

Figure 38: Heat dissipation (Q_R) on external resistance R

Issue:

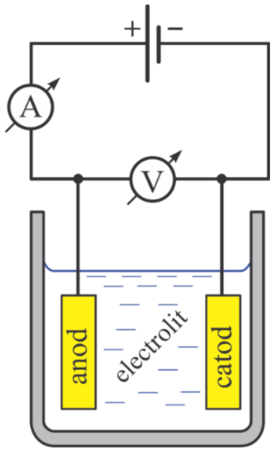
What is the optimum value of the resistance R_{opt} for which the external power (PR) dissipated on this resistor is maximum and what value has maximum dissipated power (Pmax)?

solution: $P_R = I^2 \cdot R = \frac{E^2 \cdot R}{(R+r)^2} = \frac{E^2 \cdot R}{(R-r)^2 + 4 \cdot R \cdot r}$

For all possible values the term $(R - r)^2$ is positive (or neutral). The minimum value of the denominator (ie maximum value for P_R) is carried out for the case where R = r ,

and in this case $P_{max} = \frac{E^2}{4 \cdot r}$

3.ELECTROLYSIS



ELECTROLYTE:

- salt solution

- melted salt

Figure 39: Electrolysis

Charge carriers: ions

The passage of electric current through the electrolyte: electrode processes

- Primary
- Secondary

$$MA \leftrightarrows M^{+p} + A^{-p}$$

$$M^{+p} \xrightarrow{+pe^{-}} M \longrightarrow M^{*} \qquad A^{-p} \xrightarrow{-pe^{-}} A \longrightarrow A^{*}$$

primary process of electrodes

ELECTROLYSIS LAW

$$m_{A^{-}} = \frac{Q}{F} \cdot \frac{M_{A^{-}}}{p}$$

$$m_{M^{+}} = \frac{Q}{F} \cdot \frac{M_{M^{+}}}{p}$$

Where F = the *Faraday* constant (96485 C/mol)

The mass of a substance (m), formed by electrolysis is directly proportional to the amount of charge (Q) that passes through the system.

If I = const. (t = electrolysis time)

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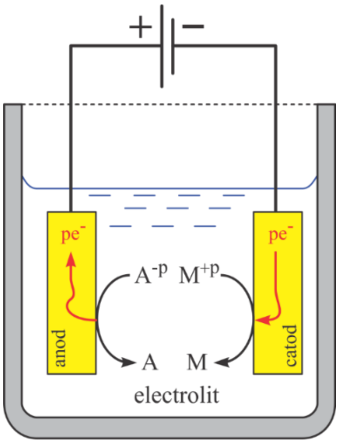


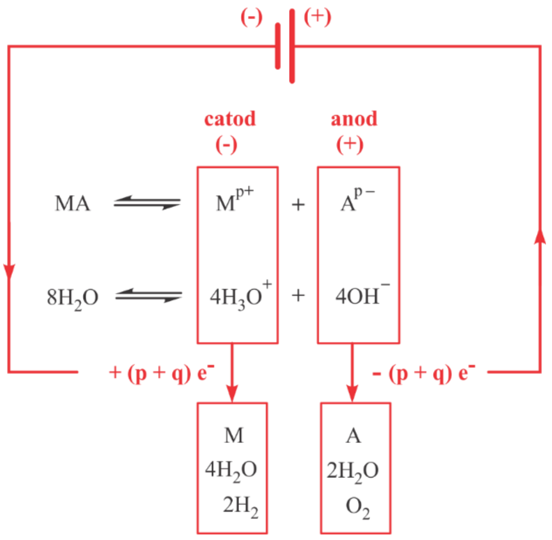
Figure 40: Electrolysis

$$m_{A^-} = \frac{I \cdot t}{F} \cdot \frac{M_{A^-}}{p} \;\; ; \;\; m_{M^+} = \frac{I \cdot t}{F} \cdot \frac{M_{M^+}}{p}$$

If I = variable (t = t = electrolysis time)

$$m_{A^-} = \frac{M_{A^-}}{F \cdot p} \cdot \int_0^t I(t) \cdot dt \;\; ; \;\; m_{M^+} = \frac{M_{M^+}}{F \cdot p} \cdot \int_0^t I(t) \cdot dt$$

THE CURRENT PERFORMANCE OF ELECTROLYSIS



Process secondary of electrodes

Figure 41 : Electrolysis

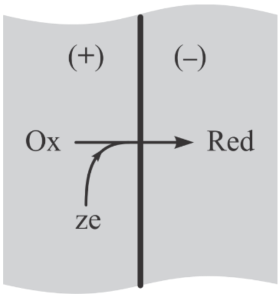
$$\eta = \frac{p}{p+q}$$

h = The current efficiency of the electrolysis of the MA electrolyte

$$m_{A^-} = \frac{I \cdot t}{F} \cdot \frac{M_{A^-} \cdot \eta}{p+q}$$

$$m_{M^+} = \frac{I \cdot t}{F} \cdot \frac{M_{M^+} \cdot \eta}{p+q}$$

ELECTRODE’S POTENTIAL - NERNST EQUATION



If a substance can exist in two redox forms (oxidized form - "Ox" and the reduced form "RED") in two media separated by a surface, then the passage of the redox forms through the separation surface generates a potential difference between media separated by the surface.

Figure 42: Oxidized form - "Ox" and the reduced form "RED")

$$E = E^0 + \frac{R \cdot T}{z \cdot F} \cdot \ln \frac{[Ox]}{[Red]} \quad \textit{équation de Nernst}$$

E^0: standard potential for the couple Ox / Red

[Ox] and [Red]: concentrations of oxidized and reduced forms

F: Faraday number

z: number of changed electrons of a molecule (ion)

T: absolute temperature

R: universal gas constant

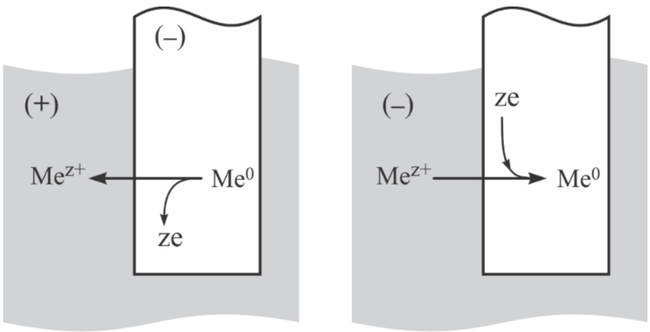


Figure 43: Representation of équation de Nernst

$$E = E^0 + \frac{R \cdot T}{z \cdot F} \cdot \ln \frac{[Me^{z+}]}{[Me^0]} = E^0 + \frac{R \cdot T}{z \cdot F} \cdot \ln[Me^{z+}] - \frac{R \cdot T}{z \cdot F} \cdot \ln[Me^0]$$

$$E = E^{0*} + \frac{R \cdot T}{z \cdot F} \cdot \ln[Me^{z+}]$$

TRANSMEMBRANAR POTENTIAL

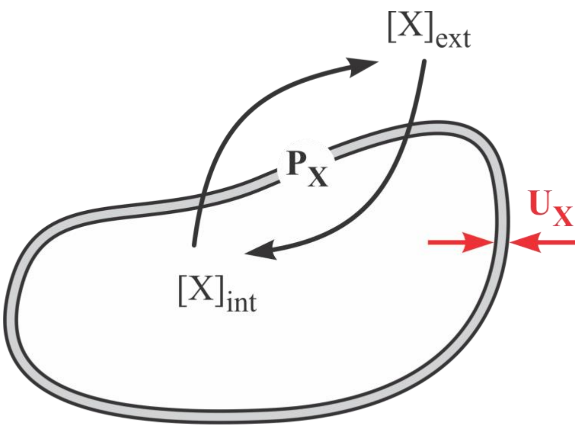


Figure 44: Representation of the transmembrane potential.

$$U_X = \frac{R \cdot T}{z \cdot F} \cdot \ln \frac{[X]_{ext}}{[X]_{int}}$$

Several ions (Goldman-Hodgkin-Katz equation) :

- Monovalent cations: M_i^+; (i = 1 , 2 , . . . , N)
- Monovalent anions: A_j^-; (j = 1 , 2 , . . . , M)

$$E_m = \frac{R \cdot T}{F} \ln \left[\frac{\sum_i^N P_{M_i^+} \cdot [M_i^+]_{ext} + \sum_j^M P_{A_j^-} \cdot [A_j^-]_{int}}{\sum_i^N P_{M_i^+} \cdot [M_i^+]_{int} + \sum_j^M P_{A_j^-} \cdot [A_j^-]_{out}} \right]$$

$P_{M_i^+}$ $P_{A_j^-}$

Permeability of the membrane in comparison with the ions M_i^+ si A_j^- (m/s)

THERMOELECTRIC EFFECTS AT THE INTERFACE BETWEEN CONDUCTORS

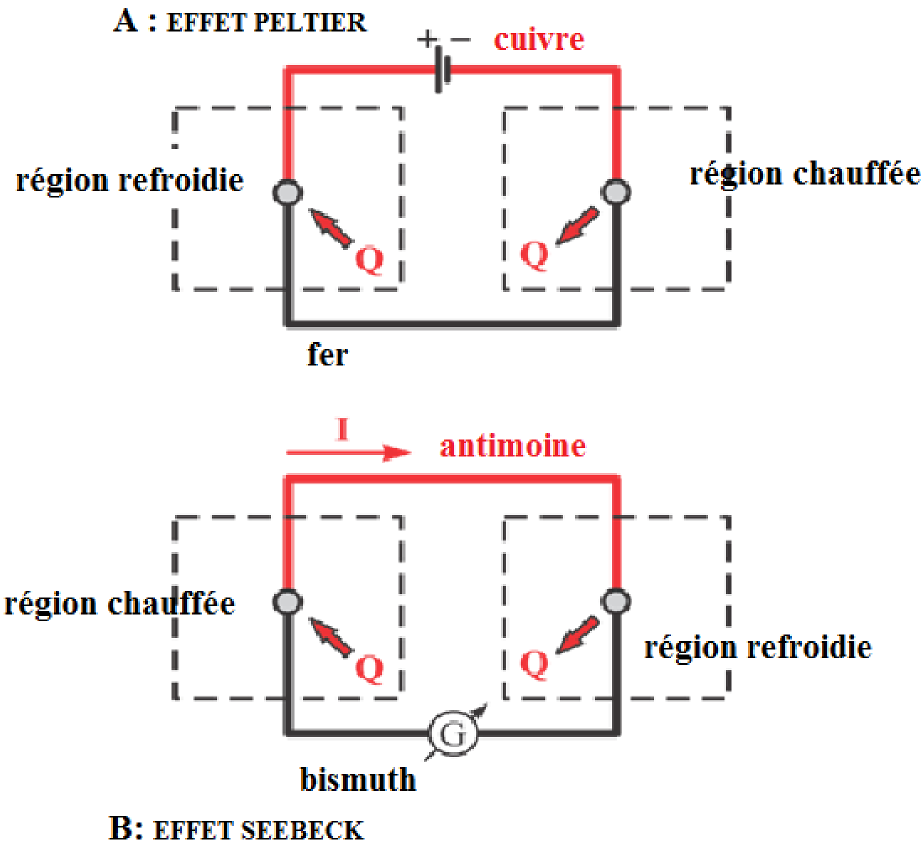


Figure 45: A) Peltier effect; B) Seebeck effect

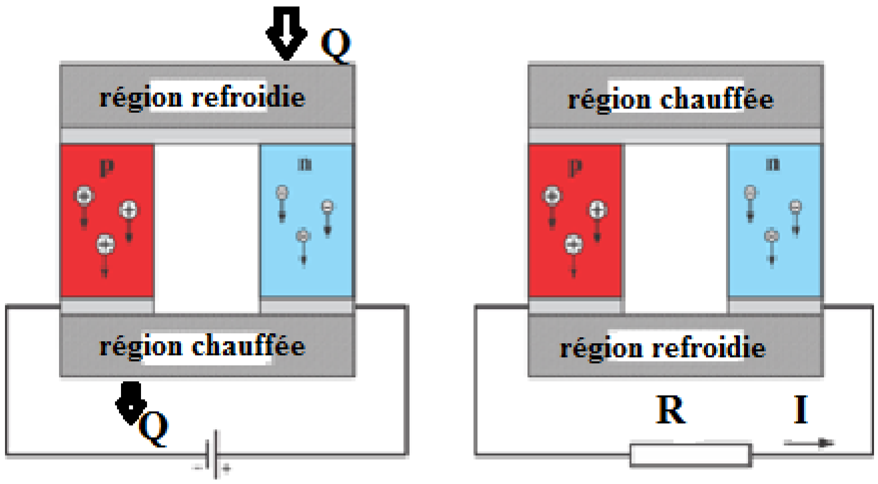
A: PELTIER EFFECT

One of the points of contact between two conductors traversed by the direct current, one is cooled and the other is heated.

B: **SEEBECK EFFECT**

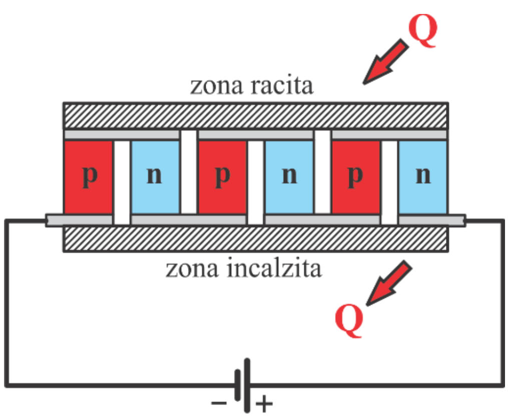
If the contact points between two conductors are kept at different temperatures in the circuit, an electric current is generated.

The intensity of the effect depends on the characteristics of the conductors.



A: Effect *Peltier* *B:* Effect *Seebeck*

Figure 46: A) Peltier effect; B) Seebeck effect



Q = (P $_A$ -P $_B$). It

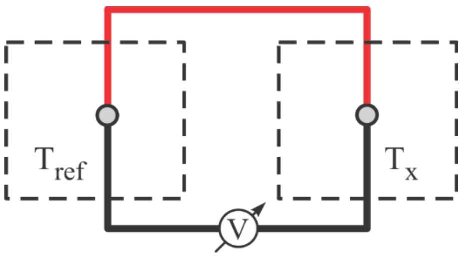
Q = amount of heat "pumped" in a period of time "t"

PA; PB = Peltier coefficients of conductors "A" respectively "B"

I = intensity of the electric current

Figure 47: Measuring temperature with the thermocouple (the application of the Seebeck effect)

Seebeck coefficients for conductor pairs



Within a limited temperature range:

V= -S. ΔT

V = the generated voltage

S = Seebeck coefficient

DT = temperature difference

Tip	**Conductor couple**	***Seebeck* coefficient S (mV/K)**
E	chromel–constantan	60
J	iron - constantan	51
T	copper - constantan	40
K	chromel - alumel	40
NOT	nicrosil - nisil	38
S	Pt (10% Rh) – Pt	11
B	Pt (30% Rh) – Pt (6% Rh)	8
R	Pt (13% Rh) – Pt	12

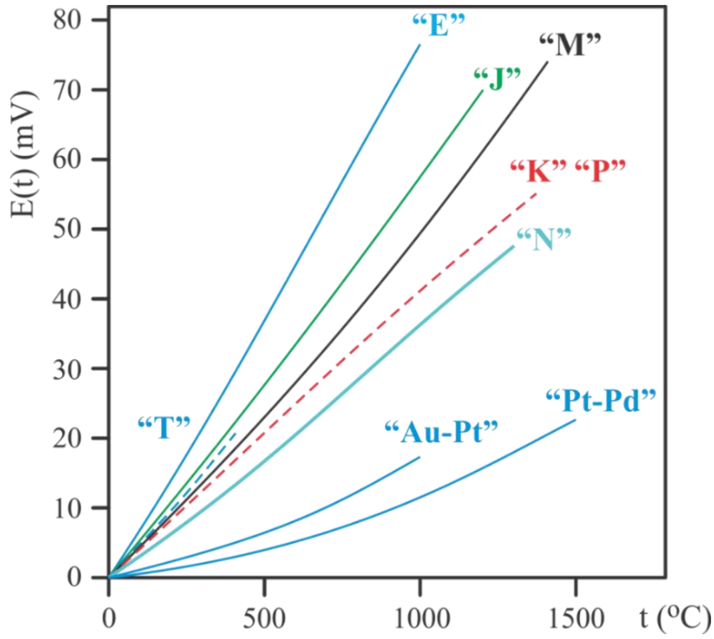


Figure 48: Couple of conductors

4.MAGNETISM

- **Magnetite - iron oxide** in the form of crystals - has the property of attracting small iron objects from its proximity.
- This gives the space around it special properties and creates a magnetic field.
- The magnetic field manifests itself at maximum intensity near certain areas of the mineral matter, arranged in pairs which are called **magnetic poles** .
- We know that **an electric field** is opened mainly **by the intensity E determined** forces acting on a load q at rest or in motion.
- **A magnetic field** acts on electric charges only if they are moving and their velocity is not parallel to the direction of the field.

$$R = \frac{mv}{qB}$$

MAGNETOSTATIC AND MAGNETODINAMIC

There is a connection between the electric current and the magnetic field. This connection manifests itself in several ways.

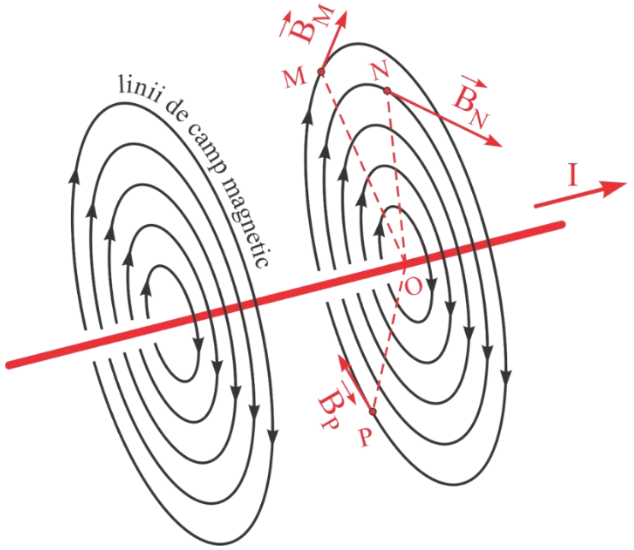


Figure 49: Magnetic field lines

Around a conductor crossed by a continuous linear current (I) generates a magnetic field represented by the field lines. These lines are in fact (closed) curves located in the plane perpendicular to the linear conductor.
Field lines are associated with a direction of movement
("spin rule").
Each point in the magnetic field around the wire is characterized (size, direction and direction) by the magnetic induction vector
$(\vec{B}_M, \vec{B}_N, \vec{B}_P)$
The magnetic induction vector at a point (i.e. point "N") has an orientation tangent to the field line passing through this point and has the direction of the field line corresponding to this point. The magnetic induction vector depends on the distance of the considered point from the conductor traversed by the current, the intensity of the current and the characteristics of the environment in which the phenomenon occurs ("magnetic permeability of the environment").
It is believed that, through a particular process, a uniform magnetic field has been created in an area of space, that is, a magnetic field which has identical properties at every point in the range. If in such a domain is sent at speed v, in different directions, a particle of mass m and electric charge q is observed (Figure 50);
in the magnetic field there is a privileged direction where the particle does not modify the velocity vector v and therefore no force in the field does not act on it (Fig. 50);if the particle is sent to the area in a contained direction in a plane perpendicular to the privileged direction, the trajectory of the particles is circular (fig. 50), the absolute value of the speed remains constant.

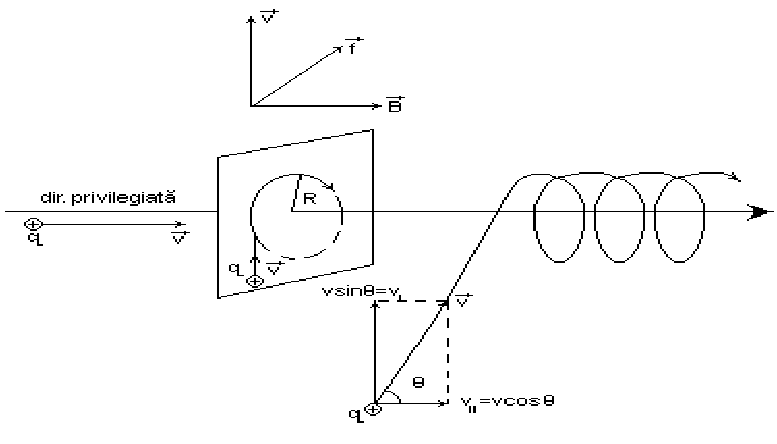


Figure 50: The movement of a particle in a magnetic field

This means that in this case, on a particle acts a constant force
and normal at all points,
trajectory and preferred direction

i.e. a centripetal force.

It has been found that the radius R of the circular path is proportional to the mass m and to the speed v is inversely proportional to the charge q:

$$R = \frac{mv}{qB}$$

When 1/B is a proportionality factor.

If we constantly keep the values of m, q and v, but we modify the magnetic field the value of the radius R of the trajectory changes. This shows that the quantity B in equation (2) characterizes the magnetic field.

By definition, is called **magnetic induction** , the vector whose value in any point in the field is equal to B, whose direction coincides with the direction of the field and whose principal direction, by convention, is the positive direction of the Oy axis, in a rectangular coordinate system where the OX axis has the direction and sense of the velocity vector v of a positively charged particle and the Oz axis is the direction and sense of the force acting on the particle in field

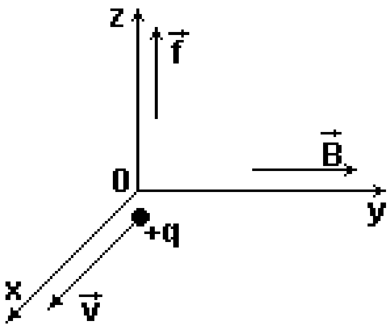


Figure 51: Magnetic induction, velocity and electric charge

$$f = \frac{mv^2}{R} = qvB$$

For the centripetal force is given the equation: $f = \frac{mv^2}{R} = qvB$ (2)

Now given the amount of vector v, f, and B. $\vec{f} = q\vec{v}x\vec{B}$ (3)

It is the force with which the magnetic field with induction B acts on a particle of charge q moving at speed v in the field

, called **the Lorentz force.**

If the particle enters the field with a speed v which makes an angle with B, its movement - before entering the field - can be considered as a result of two movements: one with a speed v cos, parallel to B and another with velocity v sin , perpendicular to B.

The first is not influenced by the presence of the magnetic field and the second field is a circular movement in a plane perpendicular to the path of movement B. The resulting product is a line parallel to the axis of the helix B (figure 1), the particle wraps around the lines of vector B.

The force given by (3) is, at all times, being a normal trajectory, does not work on the motion of the particles and therefore does not produce a variation in the absolute value of the velocity v and the kinetic energy of the charged particles . This is the case with the time-constant magnetic field: however, a time-dependent magnetic field accelerates charged particles.

For the angular velocity of the resulting circular path motion or, for the period T, we can write the relation $\omega = \frac{qB}{m}$ $\qquad T = \frac{2\pi}{\omega} = \frac{2\pi}{q.B} m$

period does not depend on the velocity of the particle in a uniform field.

It is used in the charged particle accelerator called the cyclotron.

BIOT-SAVART RELATIONSHIP

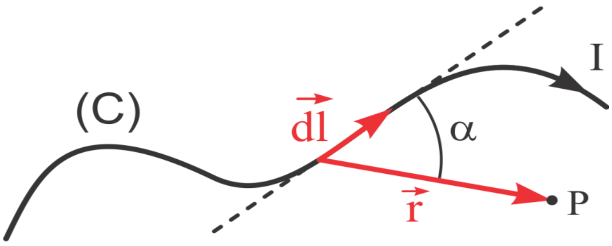


Figure 52: The magnetic induction vector (BP) produced in the point P by the current in the infinitesimal part of the conductor (dl),

The magnetic induction vector (B P) produced in the point P by the current in the infinitesimal part of the conductor (dl), is:

$$d\vec{B}_P = \frac{\mu_0 \cdot \mu_r \cdot I}{4 \cdot \pi} \cdot \frac{d\vec{l} x \vec{r}}{r^3} \;\; ; \;\; dB_P = \frac{\mu_0 \cdot \mu_r \cdot I}{4 \cdot \pi} \cdot \frac{\sin\alpha}{r^2} \cdot dl$$

$$\vec{B}_P = \frac{\mu_0 \cdot \mu_r \cdot I}{4 \cdot \pi} \cdot \int_C \frac{d\vec{l} x \vec{r}}{r^3}$$

$$B_P = \frac{\mu_0 \cdot \mu_r \cdot I}{4 \cdot \pi} \cdot \int_C \frac{dl \cdot \sin\alpha}{r^2}$$

$$B_P = \frac{\mu_0 \cdot \mu_r \cdot I}{2 \cdot \pi \cdot r_P}$$

Or

BP = magnetic induction in point "P"

rP = the distance from point "P" of the linear conductor

m $_0$ = magnetic permeability of vacuum

m $_r$ = relative permeability of the environment

$[B]_{SI} = Tesla\ (T)$

$\mu_0 = 4 \cdot \pi \cdot 10^{-7} \ \frac{V \cdot s}{A \cdot m}$

MAGNETIC INDUCTION IN THE CENTER OF A CIRCULAR CONDUCTOR (OF RADIUS R)

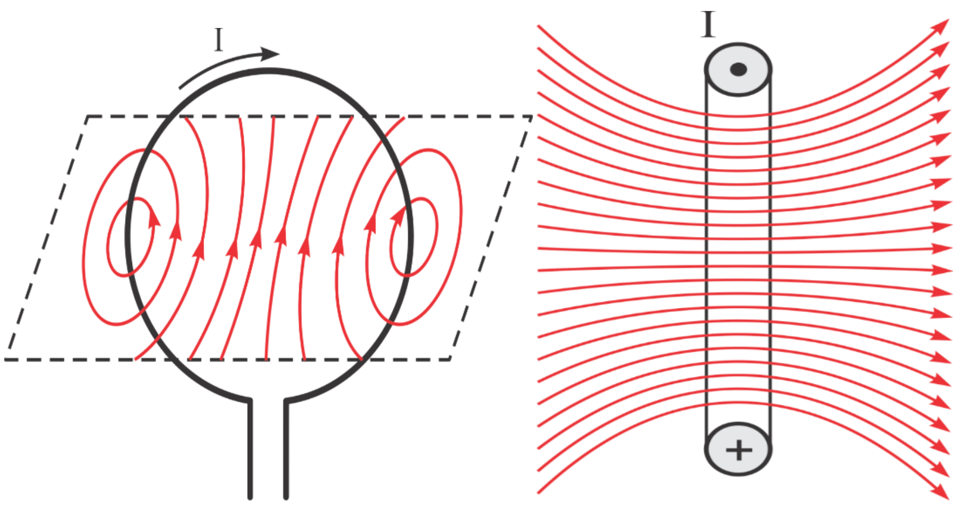


Figure 53: The "spin rule" magnetic field lines

The direction of magnetic field lines "twist rule"

$B = \mu_0 \cdot \mu_r \cdot \frac{I}{2 \cdot R}$

R = the radius of the circular conductor

MAGNETIC INDUCTION INSIDE A SOLENOID

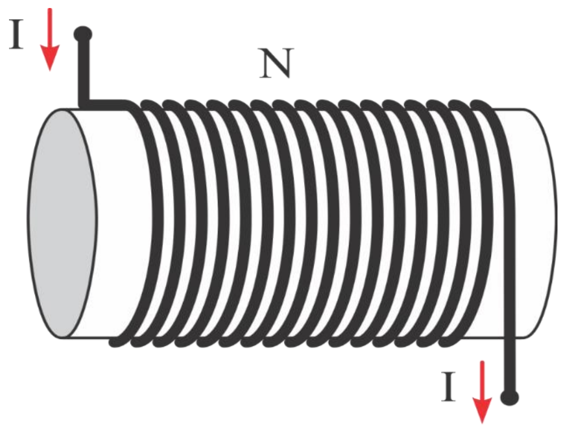


Figure 54: Magnetic induction inside a solenoid

$$B = \mu_0 \cdot \mu_r \cdot \frac{I \cdot N}{l}$$

I = intensity of the current passing through the solenoid

N = number of turns

l = length of the electromagnet

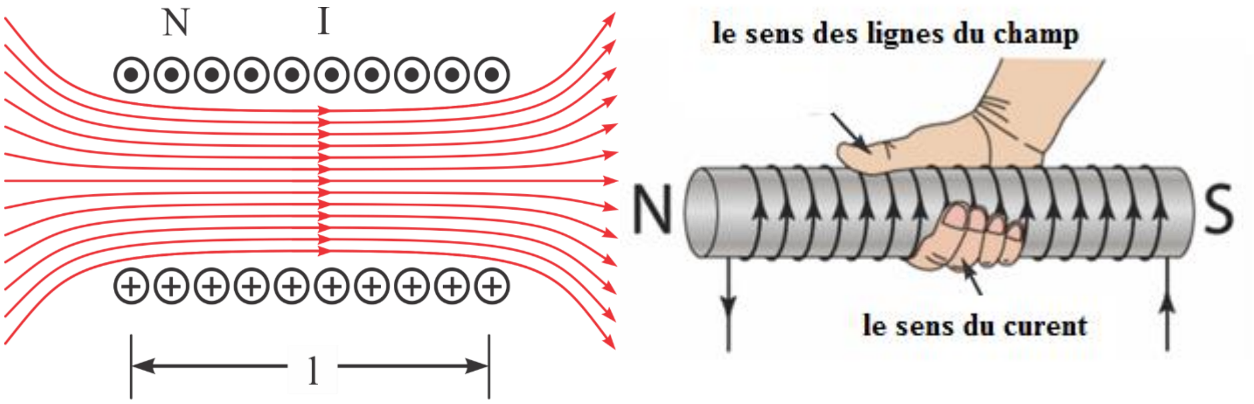
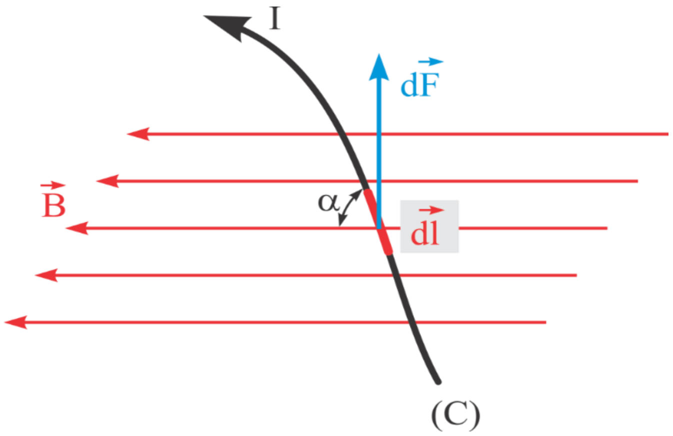


Figure 55: The direction of the field lines and the direction of the curent.

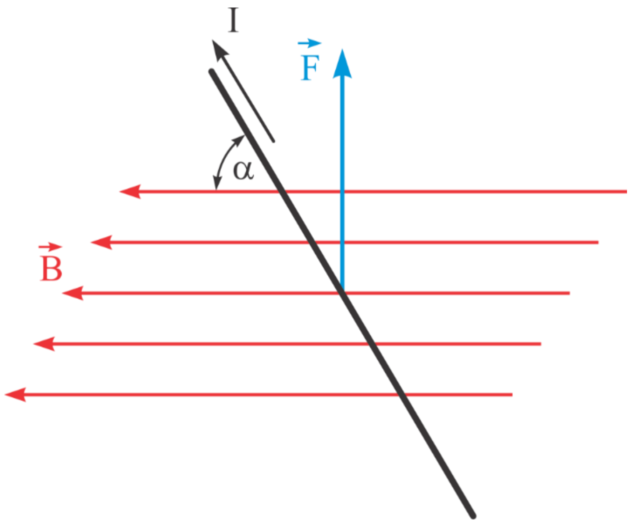
Correlation of direction of magnetic lines and direction of electric current through solenoid "right hand rule"

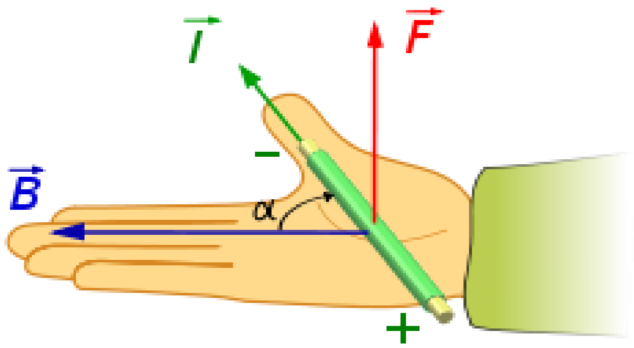
MAGNETIC INDUCTION - ELECTRIC CURRENT - LORENTZ FORCE INTERACTION



$$d\vec{F} = I \cdot d\vec{l} x \vec{B}$$

$$F = I \cdot \int_C B \cdot \sin\alpha \cdot dl$$





The right hand rule

$$F = I \cdot B \cdot l \cdot \sin\alpha$$

$$\vec{F} \perp \vec{B} \quad et \quad \vec{F} \perp I$$

Figure 56: The right hand rule for Lorentz Force

INTERACTION OF MAGNETIC INDUCTION - ELECTRIC CURRENT AND LORENTZ FORCE

The Lorentz force is represented by a vector perpendicular to the plane defined by the direction of the lines of the magnetic field and the electric current. The direction of the Lorentz force is determined in correlation with the direction and significance of the (classical) electrical lines of the magnetic field.

Magnetized organisms have two poles:

The "north" pole and the "south" pole are oriented outside the body

Field lines are oriented from the "North" pole to the "South" pole and inside the body the magnetic lines are oriented from the "South" pole to the "North" pole.

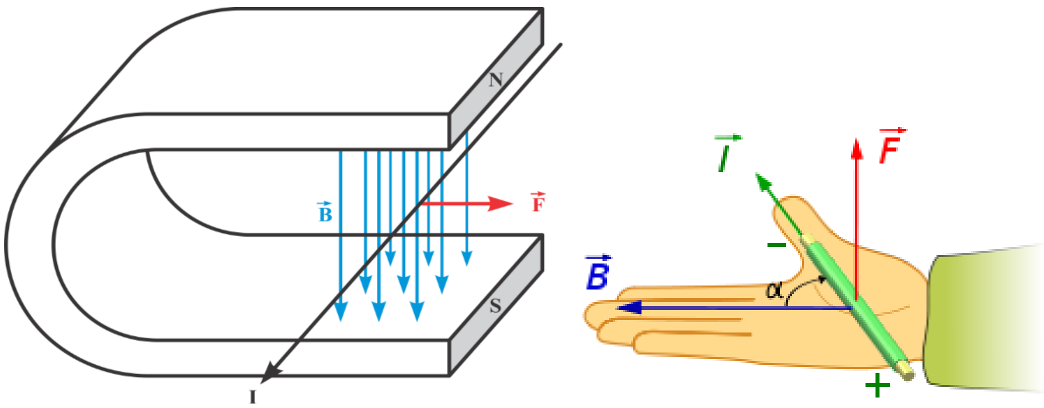
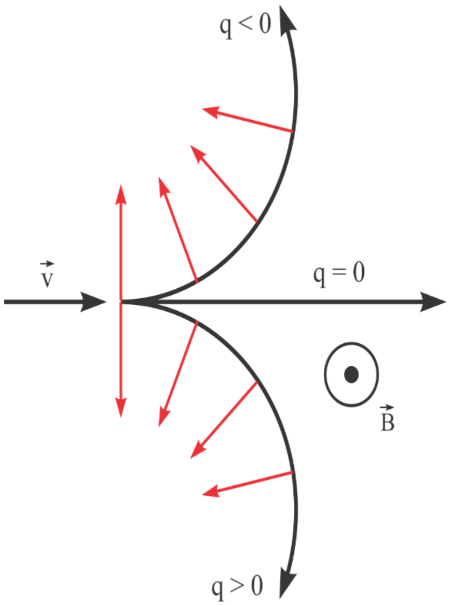


Figure 57: The right hand rule for Lorentz Force

THE TRAJECTORY OF A CHARGED PARTICLE IN A MAGNETIC FIELD – LORENTZ FORCE



On an electric charge, which moves in a magnetic field, a force is exerted perpendicular to the direction field lines and in the momentary direction of displacement (Lorentz force).

$$\vec{F} = q \cdot \vec{v} \cdot \vec{B}$$

Since the Lorentz force is always perpendicular to the momentary direction of displacement of the charged particle, the trajectory of the particles is circular (radius R).

Because sina = 1 , it results that:

$$\frac{m \cdot v^2}{R} = q \cdot v \cdot B \text{ And } R = \frac{m}{q} \cdot \frac{v}{B}$$

THE RIGHT HAND RULE FOR PUNCTIFORM (POSITIVE) DISPLACEMENT IN THE HOMOGENEOUS MAGNETIC FIELD

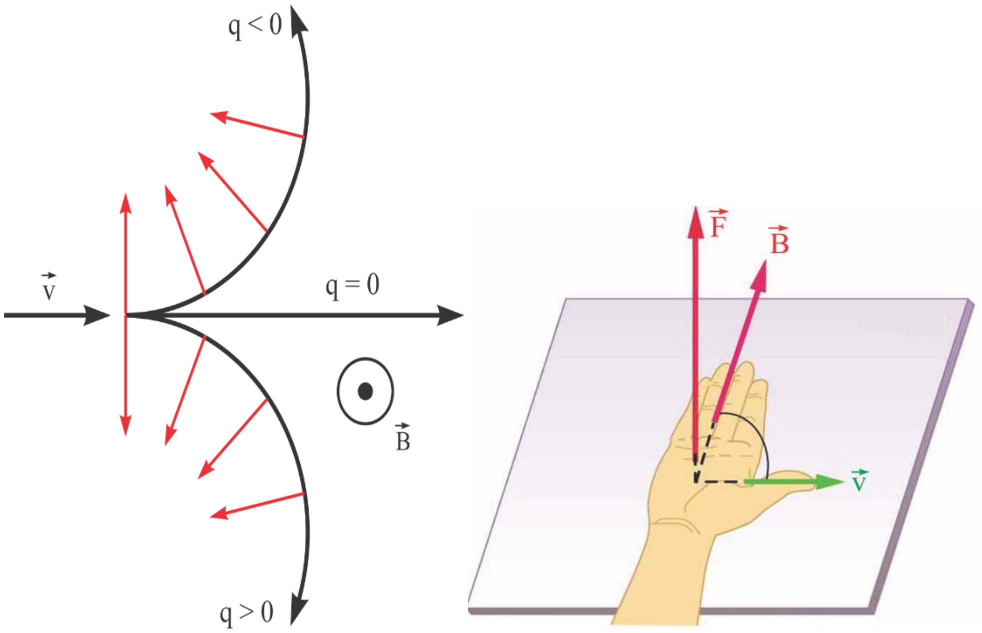


Figure 57: The right hand rule for Lorentz Force

APPLICATIONS OF FERROMAGNETIC FLUIDS IN THE TRANSPORT OF MEDICATION THROUGH THE BODY

One of the prerequisites for success in the application of chemotherapeutic agents for the treatment of localized diseases is the development of efficient means of transporting the drug to the target site in an organism.

In the mid-1970s, a new concept of targeted drug delivery was introduced, based on the use of external magnetic systems and biocompatible ferromagnetic particles as drug carriers.

Experiments conducted in the 1980s in numerous biomedical research centers and clinics clearly indicate that most investigated magnetic carrier systems - both chemotherapeutic.

Agents containing microspheres and ferrofluidic compositions - can be concentrated in predetermined places using a sufficiently strong magnetic field.

At the same time, all these drug transport systems have definite physical, physicochemical and biochemical characteristics, very often controversial:

- The particles of the magnetic fluid stabilized by biocompatible substances must have appropriate shapes and sizes (approximately a few □m) to pass through the capillary systems of the organs and tissues without posing the threat of vessel embolism.

-Compositions containing both ferrofluids and chemotherapeutic agents must have sufficiently high magnetization.

- Magnetically guided support systems must be able to transport the required amounts of pharmacologically active compounds and must be an efficient mechanism for releasing the drug from the carrier to the target site.

- All components of the drug-carrying system must be non-toxic, biodegradable and removable from the reticulo-endothelial system.

Research has been done in this field in the following directions:

- in oncology,
- in the treatment of heart and blood vessel diseases and
- in the treatment of hollow organ diseases, and also
- in the field of cell separation and the creation of biospecific magnetic absorbents.

There are three types of magnetic particle suspensions, whose interaction with magnetic fields can be used in medicine:

- magnetic fluids (particles 0.01-0.1 μm),
- unstable suspensions of larger ferroparticles (1-10 μm) and

- magnetic microspheres (complex constructions of 0.1-10 μm).particles containing dispersed magnetic materials and drugs).

Magnetic colloidal solutions (magnetic fluids or ferrofluids) are stable suspensions of ultradispersed particles of magnetic materials with dimensions of 0.01-0.1 □m, which are subjected to thermal molecular motion to prevent their sedimentation in gravitational and magnetic fields.

Each particle is a single-domain region with a constant magnetic moment (away from the Curie point). To prevent their aggregation, the particles must be coated with a surfactant.

Due to the mechanism of viscous friction, magnetic fluid droplets can move as a whole fluid body in a non-uniform magnetic field, although they act magnetic forces only on the suspended magnetic particles.

This fact is very important for medical purposes because we can simply dissolve pharmacologically active substances (non-magnetic!) in this fluid and transport, hold, capture or locate it desirably in parts of blood vessels or hollow organs with the help of a non-uniform external magnetic field.

In our previous studies, the conditions required to hold or trap a ferrofluid droplet in water, solution and blood streams were investigated in model systems and "in vivo" [11-13].

We have come to the conclusion that these conditions are highly dependent on the magnetization of the ferrofluid and the viscosity, the flow velocity and the magnetic field intensity gradient.

For example, to make possible the magnetic trapping of the ferrofluid-drug composition with magnetization J = 1-10 G from the blood flow in an occluded vessel, a magnetic field gradient $|\nabla H|$=0,3-1,0 kOe/cm, i.e. specific volume magnetostatic force f= I(J ∇)HI must be greater than 300 dyn/cm^2 at physiological blood flow velocities in unoccluded vessels.

A possible application of ferrofluids is in the treatment of hollow organ diseases.

An interesting approach was tested on patients with problems with different types of fistulas. The fistula channel was closed with a drug-carrying ferrofluid composition that was injected into the channel and held with a special ring-shaped magnet

E.K. Ruuge and A.N. Rusetski , Magnetic fluids as drug carriers: Targeted transport of drugs by a magnetic field, Journal of Magnetism and Magnetic Materials 122 (1993) 335-339

The second type of suspension is a well-dispersed system containing magnetic multi-domain particles of 1-10 □m, ten times larger than the particles in magnetic fluids.

In this case, the energy of dipole-dipole interactions is greater than the thermal fluctuation energy, which leads to the creation of a rigid spatial structure of magnetic particles in the presence of a sufficiently strong magnetic field.

This type of magnetic suspension is mainly used for the formation of thrombi in desired regions of the body for the selective occlusion of blood vessels that feed tumor-damaged organs or tissues to induce tumor cell necrosis .

Another application of such suspensions is for targeted hyperthermal necrosis of tumor tissues, using the selective absorption of high-frequency electromagnetic radiation energy by these well-dispersed magnetic particles .

The third type of magnetic suspension is magnetic microsphere. Microspheres are complex systems comprising a special matrix (albumin or polysaccharide) or container (liposomes or red blood cells) carrying a magnetic material and a drug.

The saturation magnetic moment of such microspheres is typically in the range 10 ~ 2-1 (I L) Gcm ~. From our theoretical estimates and experimental results , a magnetic field gradient of 1-20 koe is necessary to keep such microspheres on the wall of a blood vessel under normal conditions of blood flow in a desired region of the body.

Ferrofluid-containing red blood cells are the closest to the body's native components and appear promising as potential drug-carrying systems.

An erythrocyte can be viewed as a biocompatible container that can be loaded with drug and a magnetic compound. For example, aspirin-loaded red cells have been used for the local prevention of thrombosis in animal arteries .

In this paper we try to show the main dependencies of the process of magnetic retention of a ferrofluid droplet on the wall of a tube (model blood vessel) in the current of a non-magnetic liquid medium. The transport process was also studied "in vivo" by holding a drop of ferrofluid in a rabbit stomach.

THE EARTH'S MAGNETIC FIELD

Geographic North = magnetic "South"

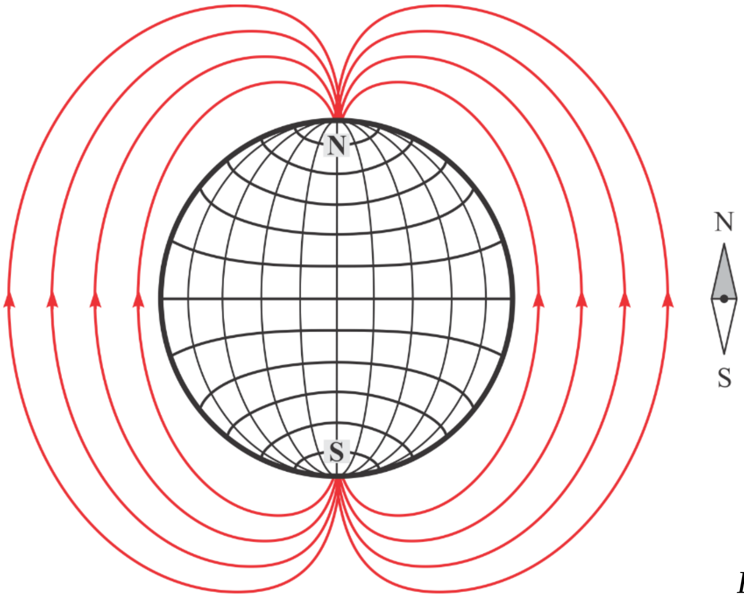


Figure 58: Magnetic poles

The pole of the magnetic needle which is oriented towards the "geographical north pole" of the Earth, has been named the "North" Pole of the magnetic needle.

The pole of the magnetic needle which is oriented towards the "geographic south pole" of the Earth has been called the "south" pole of the magnetic needle.

Cosmic rays, particles emitted by the sun, arrive on Earth in the form of charged particles (electrons, protons, etc.) of high energy.

Near the Earth's surface, these particles are subject to the influence of the Earth's magnetic field and they modify their trajectory (Fig. 3).

Some of them moving towards the earth's magnetic poles will move almost along earth's magnetic induction lines, draping around them Charged particles heading towards earth near the equatorial plane are oriented almost perpendicular to the earth's magnetic poles. magnetic flux lines and turn around. Only the fastest ones (R ~ v) can reach the Earth's surface.

As a result, the intensity of cosmic rays reaching Earth near the equator is lower at higher latitudes. This explains the luminosity of the upper atmosphere caused by the emission of charged particles from the Sun which are observed in particular in the polar regions (polar auroras).

The Earth's magnetic field is a real breastplate that protects humanity against damage from cosmic radiation,

The magnetic field is due to the formation of **the so-called radiation belt discovered in 1959 by Van Allen** based on data obtained using artificial satellites.

These belts are the zones of accumulation of cosmic particles due to the magnetic field which is what is called a **magnetic trap.**

Van Allen's first belt is at heights included

Between 500-4000 km,

the second Van Allen belt is at the heights included

between 6000 to 60000 kilometers.

Spaceflight is offshoots of the radiation belts.

AURORA –

History

The Polar Aurora is an optical phenomenon that consists of a glow observed in the intense night sky in areas proximal to the polar regions due to the impact of the solar wind with the Earth's magnetic field.

When first seen in latitudes of the northern hemisphere the phenomenon is known as the **NORTHERN LIGHTS** , a term originally used by Galileo, referring to the Roman goddess of dawn, Aurora, and the titan who represented the winds, Boreas.

It normally occurs in intervals from September to October and from March to April.

At southern hemisphere latitudes, the phenomenon is called **THE AURORA SOUTHERN** after James Cook, a direct reference to its occurrence in the south.

The phenomenon is not exclusively terrestrial, occurring on other planets in the solar system, such as Jupiter, Saturn, Mars and Venus. However, the phenomenon is of natural origin, although it can be reproduced artificially by nuclear explosions or in the laboratory.

The Northern Lights have been scientifically studied since the 17th century.

In 1621, the French astronomer Pierre Gassendi observed the phenomenon described in the south of France.

In the same year 1621, the Italian astronomer Galileo Galilei began to study the phenomenon as part of a study of the movements of stars in the sky. His study covered the European continent he observed the phenomenon in Northern Europe, hence the name Northern Lights.

In the 18th century, the English navigator James Cook noted the presence of the phenomenon observed by Galileo in the Indian Ocean too, baptizing it Southern Aurora.

Since then, it has become clear that the effect is not only specific to the northern hemisphere of the earth, which is why the name aurora polaris has been given.

At the same time, British astronomer Edmond Halley launched the hypothesis that the earth's magnetic field is linked to the phenomenon of the aurora borealis.

In 1741, Hiorter and Anders Celsius were the first to record evidence of magnetic control recorded when observing auroras.

The Polar Aurora is an optical phenomenon that consists of a glow observed in the intense night sky in areas proximal to the polar regions due to the impact of the solar wind with the Earth's magnetic field.

It normally occurs in intervals from September to October and from March to April.

AURORA MECHANISM

Figure 59: Aurora recorded south 22:50 (local time) at Lakes Entrance, Victoria, Australia

The Aurora generally appears as a diffuse glow and as an extended curtain in horizontal space.

Sometimes in the spring it can change shape permanently.

Each curtain is made up of a series of parallel rays aligned in the direction of the magnetic field lines, suggesting that our planet's phenomenon is aligned with the earth's magnetic field. Also, the variability of some factors can cause lines of different shades of color to form.

TERRESTRIAL AURORA

The Earth's Polar Aurora is caused by the collision of charged particles (electrons) for example in the magnetosphere, with atoms in the upper layers of the Earth's atmosphere, at altitudes above 80 km.

These particles have an electrical energy of 1 to 15 keV and their collision with the gas atoms in the atmosphere causes the latter to be excited. With each collision part of the energy of the particle is transmitted to the atom in the process of ionization, dissociation and excitation of the particles.

Figure 60: Aurora recorded south 22:50 (local time) at Lakes Entrance, Victoria, Australia

During ionization, electrons break off from atoms, which become charged with energy and cause the ionization effect in other atoms, like a domino. The excitation results in the emission causes unstable states to the atom, as they emit light at specific frequencies, when they stabilize. If the process of oxygen stabilization takes up to a second, nitrogen stabilizes and emits light instantly.

The Earth's magnetosphere is a region of space dominated by the magnetic field.

It is considered an obstacle in the path of the solar wind, causing it to disperse in the return direction. Its width is about 190,000 km, and during the nights a long magnetic line extends over even greater distances.

The energy source of the auroras is given by the solar winds which circulate on the Earth. The magnetosphere as well as the solar winds can conduct electricity.

It is known that if two electric conductors connected to an electric circuit are placed in a magnetic field, and one of them moves on the other, the circuit is generated by an electric current. Generators and dynamos use this principle, but conventional conductors can be replaced by plasma or other fluids.

In this context, the solar wind and the magnetosphere are fluids that conduct electricity in relative motion, being able to produce electricity, which produces a light effect

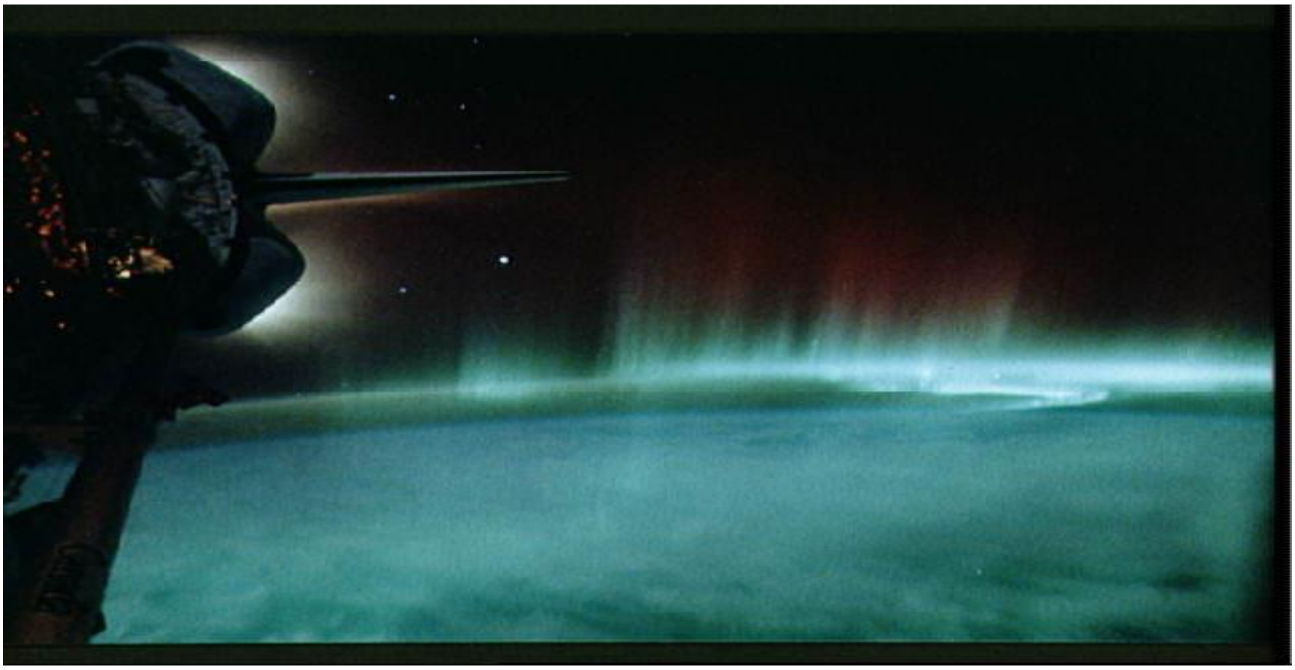


Figure 61: The aurora borealis seen from the International Space Station

THE FORCE ACTING IN A MAGNETIC FIELD
ON A CONDUCTOR CARRYING AN ELECTRIC CURRENT

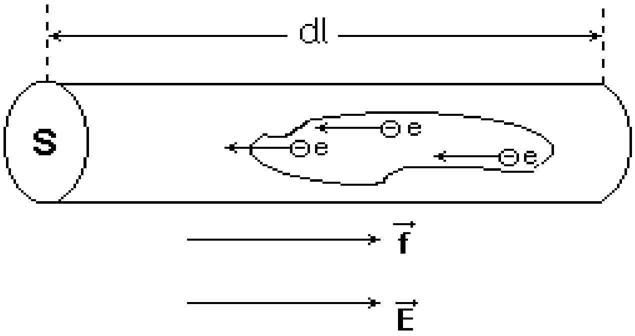


Figure: 62: The force acting in a magnetic field on a conductor through which an electric current passes

Consider a uniform induction magnetic field B, an element of length dl of a metallic conductor through which a current I flows (Fig. 4).

Since on a free electron, which forms the metallic conduction current, acts a Lorentz force from the magnetic field,

It follows that the conductive element will be subjected to a force, because the electrons cannot leave the metallic network constituted by positive ions.

If S is the cross-sectional area of the conductor, and N is the number of electron bundles per unit volume of the conductor, the force acting on the dl is $dF = N.f.S.dl$

where f is given by $f = e.v.B.\sin\theta$ (3)

SO: $dF = N.e.v.S.dl.B.\sin\theta$

SO $I = j.S = N.e.v.S$

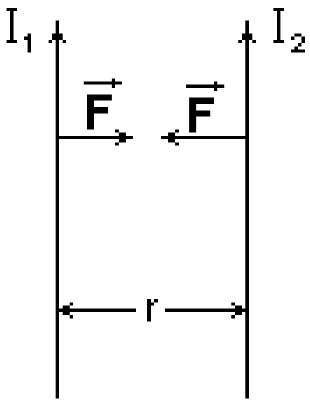
Choosing the vector dl in the direction of the current (ev ≥0).

For a straight conductor we have the length relation l $d\vec{F} = Id\vec{l}x\vec{B}$ (4)

The force F given by (4) is therefore the force acting on a conductor through which the current I flows in the magnetic field B and is called Laplace's force or electromotive force.

When the main thread considered is not straight (4), by generalization, we have: $\vec{F} = I\int_C (d\vec{l}x\vec{B})$

RECIPROCAL ACTION BETWEEN TWO CONDUCTORS THROUGH WHICH AN ELECTRIC CURRENT FLOWS. MAGNETIC FIELD VECTOR



Picture: 63: Reciprocal action between two conductors through which an electric current passes

The experiment shows that the interactions between the conductors traversed by the current produce forces called electrodynamic forces.

Considering two straight conductors, practically of infinite length and parallel to each other (fig. 5), through which the currents pass, the force acting on part of the length of one of the two cores is given by $F = \frac{\mu . I_1 I_2}{2.\pi . r}$

where r is the distance between the conductors,

And μis a factor that depends on the nature of the environment.

When the currents in the two conductors have the same direction, the electromotive force is attraction, and when the currents have opposite directions, the force is rejection.

The fact that an electrical conductor carrying current is subjected to the action of a force when it is close to another conductor also traversed by the current, suggests that, when a current passes through a conductor ,the space around the conductor displays a magnetic field.

Therefore the movement of electric charges creates a magnetic field.

As the electrodynamic force (θ) depends on the nature of the environment in which the two conductors are located, it follows that the value of the magnetic induction must depend on the nature of the environment.

MAGNETIC INTERACTION OF ELECTRIC CURRENTS

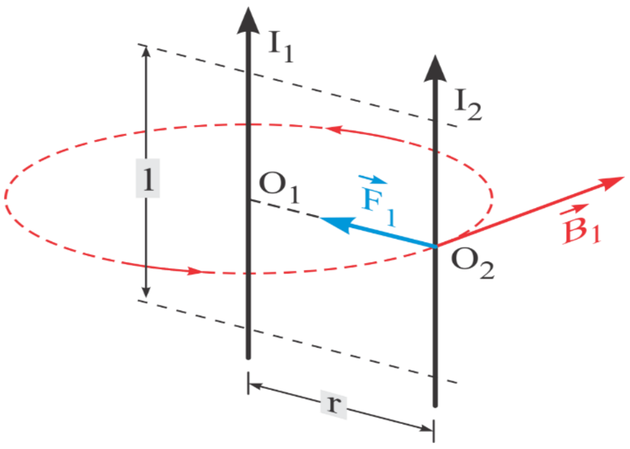


Figure: 64: Magnetic interaction of electric currents

$$F_1 = B_1 \cdot I_2 \cdot l$$

$$B_1 = \frac{\mu_0 \cdot \mu_r \cdot I_1}{2 \cdot \pi \cdot r}$$

$$F_1 = \frac{\mu_0 \cdot \mu_r \cdot I_1 \cdot I_2 \cdot l}{2 \cdot \pi \cdot r}$$

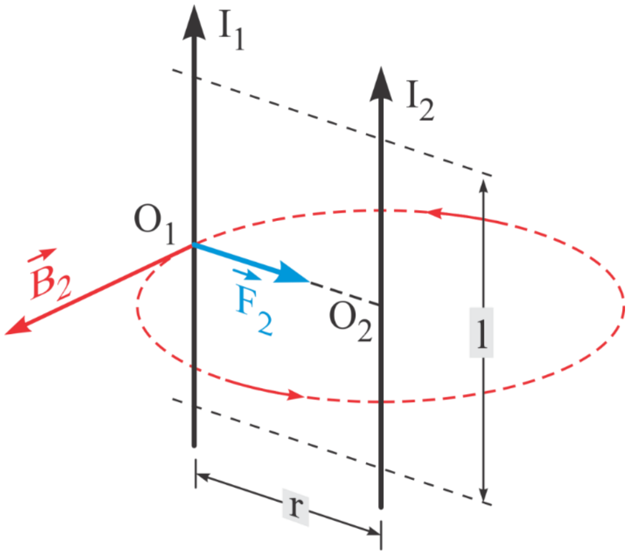


Figure: 65: Magnetic interaction of electric currents

$$F_2 = B_2 \cdot I_1 \cdot l$$

$$B_2 = \frac{\mu_0 \cdot \mu_r \cdot I_2}{2 \cdot \pi \cdot r}$$

$$F_2 = \frac{\mu_0 \cdot \mu_r \cdot I_2 \cdot I_1 \cdot l}{2 \cdot \pi \cdot r}$$

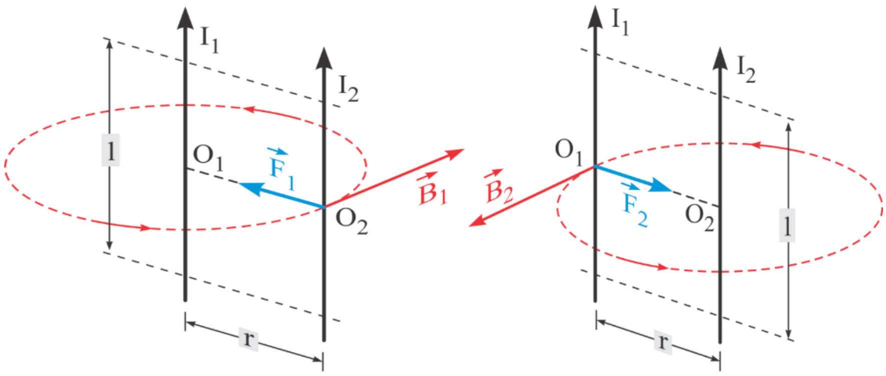


Figure: 66: Magnetic interaction of electric currents

$$F_1 = F_2 = \frac{\mu_0 \cdot \mu_r \cdot I_1 \cdot I_2 \cdot l}{2 \cdot \pi \cdot r}$$

Definition of the unit of measurement "Ampere"

An ampere is the intensity of the constant electric current flowing through each of two straight, parallel, very long conductors, of negligible circular section, placed under vacuum at a distance of 1 meter, if on each element conductors of 1 meter exerts a force

$2 \cdot 10^{-7N}$.

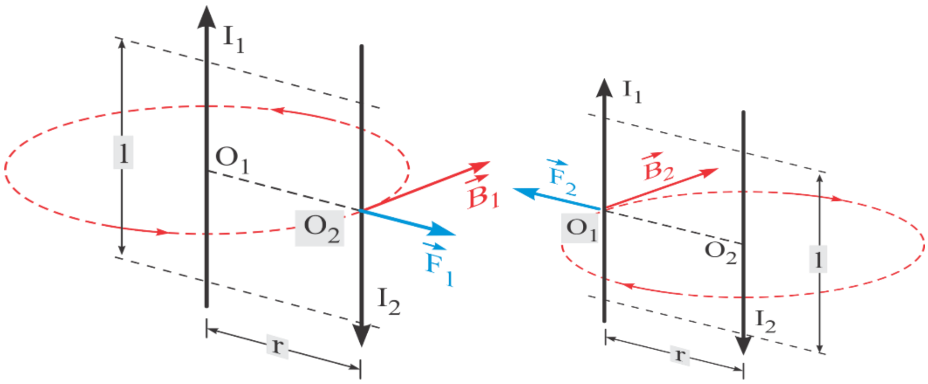


Figure: 67: Magnetic interaction of electric currents

If the currents I1 and I2 are parallel opposite directions, then between the conductors there is a rejection force: $F_1 = F_2 = \frac{\mu_0 \cdot \mu_r \cdot I_1 \cdot I_2 \cdot l}{2 \cdot \pi \cdot r}$

MAGNETIC FLUX IN RELATION TO A SURFACE

For a description and characterization of magnetic phenomena it is useful to define the magnitude of " **magnetic flux** " with respect to a surface.

Qualitatively: the denser the set of intersecting magnetic field lines on a surface, the greater the flux of the magnetic field through the surface.

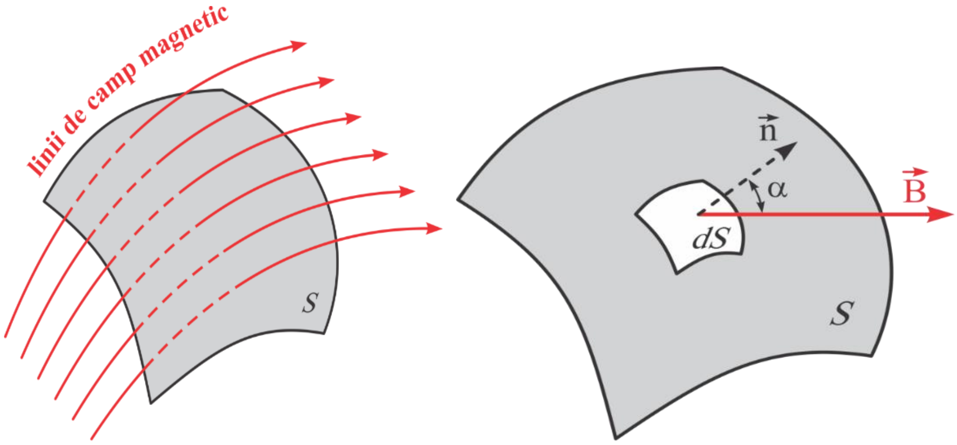


Figure 68: Magnetic flux relative to a surface

In the general case, for an infinitesimal surface (dS) infinitesimal flux (dF) is:

$$d\Phi = \vec{B} \cdot \vec{n} \cdot dS = B \cdot \cos\alpha \cdot dS$$

For the whole surface (S):

$$\Phi = \int_{(S)} \vec{B} \cdot \vec{n} \cdot dS = \int_{(S)} B \cdot \cos\alpha \cdot dS$$

Magnetic flux relative to a surface

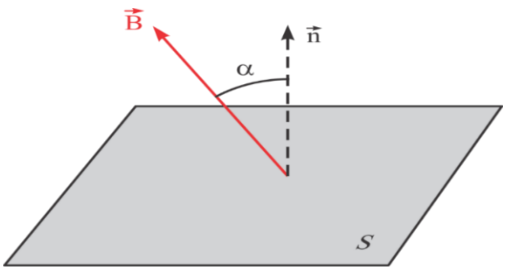


Figure 69: Magnetic flux relative to a surface

If the surface (S) is flat and the magnetic field is homogeneous everywhere, then: $\Phi = B \cdot S \cdot \cos\alpha$

We see that the magnetic flux is a scalar quantity.

The Unit of measurement in SI is Weber (Wb): $Wb = T \cdot m^2$

The magnetic flux of magnetic induction generated by a current through the surface of a solenoid by magnetic solenoid coils

$$\Phi = N \cdot B \cdot S = N \cdot \mu_0 \cdot \mu_r \cdot \frac{N \cdot I}{l} \cdot S$$

$$\Phi = \mu_0 \cdot \mu_r \cdot \frac{N^2 \cdot I}{l} \cdot S = L \cdot I$$

Or

N = number of turns

S = area of the solenoid section (m2)

l = magnet length (m)

L = coil inductance (Henry, H)

$$L = \mu_0 \cdot \mu_r \cdot \frac{N^2 \cdot S}{l}$$

Magnetic field created by the wired conductor traversed by an electric current

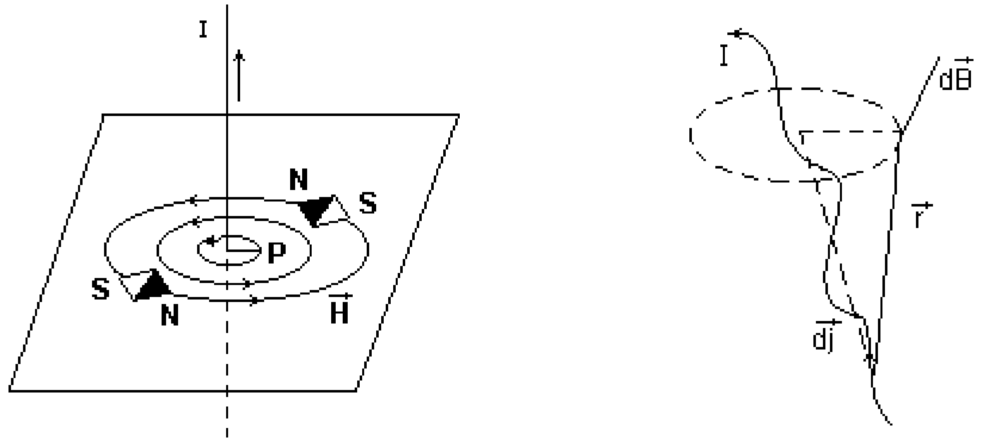


Figure 70: Magnetic field created by the wired conductor traversed by an electric current

In 1820, Biot and Savart found that a point P (Figure 6) located at a distance r from a straight wire of practically infinite length traversed by a current I, there is a magnetic field

$$H = \frac{I}{2\pi r}$$

Magnetic field created by the wired conductor traversed by an electric current

Laplace generalized this relationship and showed that a magnetic field created by a current flowing through a conductor of any shape can be expressed by the positive vector (super) sum of the element fields created by the conductor parts.

For the magnetic field created by a conductive element of length dl (Figure 7), respectively, of a wire of length L,

Laplace found the formulas:

Biot-Savart-Laplace Law

$$d\overrightarrow{H} = \frac{Id\vec{l}}{4\pi}\frac{x\vec{r}}{r^2}$$

$$\overrightarrow{H} = \frac{I}{4\pi}\int\frac{d\vec{l}}{r^3}\frac{x\vec{r}}{}$$

where dl is the element vector of length whose direction coincides

for the current I, and r is the vector which connects the element of the current with the point where H or dH is determined.

SUBSTANCE IN THE MAGNETIC FIELD

If a conductor traversed by an electric current is first placed in a vacuum and in a certain medium, it is observed that in both cases, the magnetic fields around the conductor are not identical. This is explained by the fact that any substance has magnetic properties, that is to say magnetized (magnetically polarized) under the action of a magnetic field.
One can establish a parallelism between the magnetizing substances and their contribution to the magnetic field, on the one hand, and the polarization of the dielectrics and their contribution to the electric field, on the other hand.
But also it is necessary to underline the essential difference due to the absence of the free magnetic loads. to express the action of a magnetically polarized magnetic body with a magnetic charge distribution is used the representation given by Ampère based on the equivalence of closed elementary currents and magnetic dipoles which considers magnetism as a phenomenon produced by the displacement of electrical loads.

MAGNETIC DIPOLE MOMENT – MAGNETIC MOMENT

Assuming a circular conductor of small diameter, driven by a constant current I, the orientation of the contour in space can be characterized by the positive direction of the normal (as determined by the gimlet rule) in the plane (figure 8).
This contour behaves like a small magnet and is called <u>a magnetic dipole</u> .
The direction of the normal N is at the same time the north and south direction of the field produced by the circular current
In a uniform magnetic field on the magnetic dipole acts a force of positive normal direction n focusing direction parallel to the field. Experimentally it has been found that F is proportional to the current IS of the shape and the contour, but does not depend on the shape of the contour.
On this basis we have defined **for the dipole magnetic moment the relation m:** $\vec{m} = I\vec{S} = IS\vec{n}$
The moment of the couple of forces F is then: $\vec{C} = \vec{m} x \vec{B_0}$
if the dipole is a parcel, it is obvious that due to the fact that the forces of the uniform field are no longer equal, the couple of forces will be doubled by the acceleration of the center of mass of the dipole.
We can show that this force has the expression: $\vec{f} = grad(\vec{m}\vec{B_0})$
therefore, a dipole magnetic moment of m in an induction magnetic field has potential energy

$$U_{mag} = -\vec{m}\vec{B}_0$$

MAGNETIC VECTOR

When the substance is placed in an external magnetic field, the magnetic moments of the molecules are oriented, and as a result, the substance becomes a magnetic moment and creates a magnetic field which is superimposed on the original field.

The resulting field is: $\vec{B} = \vec{B_0} + \vec{B_n}$

The magnetizing substance is characterized by the magnetizing vector, the magnitude of which is the magnetic moment of unit volume: $\vec{M} = \lim_{\Delta v \to 0} \frac{\Delta \vec{m}}{\Delta V} = \frac{d\vec{m}}{dV}$

or a **magnetic polarization vector** $\vec{\Im} = \mu_0 \vec{M}$

which is the analog of the magnetism of the electric polarization P.

The relationship between B, H and M can be studied on the basis of reasoning analogous to those used in electrostatics to deduce the ratios between D, E and P, except that instead of the electric dipoles and the theorem of Gauss , in magnetism one uses the magnetic dipoles of the amperian currents and the theorem of the magnetic circuit.

The result of such a study is represented by the relationship :

$$\vec{B} = \mu_0 \vec{H} + \vec{\Im} = \mu_0 \vec{H} + \mu_0 \vec{M} = \mu \vec{H}$$

magnetic fields not too intense s we have the relation **:** $\vec{\Im} = \mu_0 \chi \vec{H}$ (18)

Orχ is called s **magnetic susceptivity**

results : $\mu = \mu_0 . \mu_r$ **and** _ $\mu_r = 1 + \chi$ **(19)**

Often , instead of the magnetic susceptivity of the volume unit, we use the kilomolar susceptivity or the specific susceptivity defined by the relations :

$\chi_{kmol} = \chi . V_{kmol}$ (20)

$\chi_s = \frac{\chi}{\rho}$ (21)

The values of magnetic susceptivity are important in chemistry because their type of structure indicates the chemical composition of substances. In different industrial processes methods based on magnetic susceptivity are applied.

CLASSIFICATION OF MAGNETIC SUBSTANCES

According to the sense and value of susceptivity, substances can be classified as follows:

1. **Diamagnetic substances** with $\chi < 0$ and have smaller absolute values (10^{-8}-10^{-7} m^3/kmol) and the vector $\Im$ has the opposite direction to H for mercury, water and bismuth.
2. **Paramagnetic substances with** $\chi > 0$ and have smaller absolute values (10^{-6} m^3/kmol) , and the vector $\Im$ is in the same direction with H for: Na, K, Al, Rb, Mg, Mn, Cs, gaseous oxygen and liquid oxygen
3. **Ferromagnetic substances** with $\chi > 0$ and have the greatest absolute value (10^3 m^3/kmol)
4. **Ferrimagnetic substances** (ferrites), special antiferromagnetic substances, where only a part of the elementary magnetic moments is oriented in the opposite field and therefore, ferrites are close to the magnetic permeability of ferromagnetic substances.

APPLICATIONS OF FERROMAGNETIC FLUIDS IN DRUG TRANSPORT IN THE BODY

One of the prerequisites for the successful application of chemotherapeutic agents for the treatment of localised diseases is the development of efficient means of transporting the drug to the target site in an organism.

In the mid-1970s, a new concept of targeted drug delivery was introduced, based on the use of external magnetic systems and biocompatible ferromagnetic particles as drug carriers.

Experiments carried out in the 1980s in numerous biomedical research centres and clinics clearly indicate that most of the magnetic carrier systems investigated - both chemotherapeutic.

Agents containing microspheres and ferrofluidic compositions - can be concentrated at predetermined sites using a sufficiently strong magnetic field.

At the same time, all these drug delivery systems have certain physical, physicochemical and biochemical characteristics, very often controversial:

- Particles in the magnetic fluid stabilized by biocompatible substances must have appropriate shapes and sizes (approximately a few □m) to pass through the capillary systems of organs and tissues without posing the threat of vessel embolism.

-Compositions containing both ferrofluids and chemotherapeutic agents must have sufficiently high magnetisation.

- Magnetically guided carrier systems must be capable of transporting the required quantities of pharmacologically active compounds and must be an efficient mechanism for delivering the drug from the carrier to the target site.

- All components of the drug carrier system must be non-toxic, biodegradable and removable from the reticuloendothelial system

Research in this area has been carried out in the following directions:

- in oncology
- in the treatment of heart and blood diseases and
- in the treatment of hollow organ diseases , and also
- in the field of cell separation and the creation of biospecific magnetic absorbers.

There are three types of magnetic particle suspensions,whose interaction with magnetic fields can be used in medicine:

- magnetic fluids (0.01-0.1 particles μm),
- unstable suspensions of larger ferroparticles (1-10 μm) and
- magnetic microspheres (complex constructions of 0.1-10 μm).particles containing dispersed magnetic materials and drugs).

Magnetic colloidal solutions (magnetic fluids or ferrofluids) are stable suspensions of ultradispersed particles of magnetic materials with dimensions 0.01-0.1 μm, which are subjected to thermal molecular motion to prevent their sedimentation in gravitational and magnetic fields.
Each particle is a single-domain region with a constant magnetic moment (away from the Curie point). To prevent their aggregation, the particles must be coated with a surface active substance.
Because of the mechanism of viscous friction the magnetic fluid droplets can move as a whole fluid body in a non-uniform magnetic field although it acts magnetic forces only on the suspended magnetic particles. *[E.K. Ruuge and A.N. Rusetski , Magnetic fluids as drug carriers: Targeted transport of drugs by a magnetic field, Journal of Magnetism and Magnetic Materials 122 (1993) 335-339]*
This is very important for medical purposes because we can simply dissolve pharmacologically active (non-magnetic!) substances in this fluid and carry, hold, capture or locate it in a desirable way in parts of blood vessels or hollow organs with the help of a non-uniform external magnetic field.
In our previous studies, the conditions required to maintain or capture a ferrofluid droplet in water, solution and blood streams have been investigated in model and "in vivo" systems [11-13].
We concluded that these conditions are highly dependent on ferrofluid magnetization and viscosity, flow velocity and magnetic field strength gradient.
For example, to make it possible to magnetically capture the ferrofluid-drug composition with magnetization J = 1-10 G from the blood flow in an occluded vessel, a magnetic field gradient | | ∇ H|=0,3-1,0 kOe/cm is required, i.e. the magnetostatic specific volume force f= I(J ∇)HI must be greater than 300 dyn/cm2 at physiological blood flow velocities in unoccluded vessels.
A possible application of ferrofluids is in the treatment of hollow organ diseases.
An interesting approach has been tested on patients with different types of fistulae. The fistula channel was closed with a drug-carrying ferrofluid composition that was injected into the channel and held with a magnet with a special ring shape.
The second type of slurry is a well-dispersed system containing magnetic multi-domain particles of 1-10 μm, ten times larger than the particles in magnetic fluids.
In this case, the energy of the dipole-dipole interactions is greater than the thermal fluctuation energy, leading to the creation of a rigid spatial structure of magnetic particles in the presence of a sufficiently strong magnetic field.
This type of magnetic suspension is mainly used for thrombus formation in desired regions of the body for selective occlusion of blood vessels feeding organs or tissues damaged by tumor to induce necrosis of tumor cells.

Another application of such suspensions is for targeted hyperthermic necrosis of tumor tissues using selective absorption of high-frequency electromagnetic radiation energy by these well-dispersed magnetic particles.

The third type of magnetic suspension is the magnetic microsphere. Microspheres are complex systems comprising a special matrix (albumin or polysaccharide) or container (liposomes or red blood cells) carrying a magnetic material and a drug

The saturation magnetic moment of such microspheres is usually in the range 10 ~ 2-1 (I L) Gcm ~. From our theoretical estimates and experimental results a magnetic field gradient of 1-20 koe is required to hold such microspheres on the wall of a blood vessel under normal conditionsblood flow in a desired region of the body.

Ferrofluid-containing red blood cells are closest to the body's native components and appear promising as potential drug carrier systems.

An erythrocyte can be viewed as a biocompatible container that can be loaded with drug and a magnetic compound. For example, aspirin-loaded red cells have been used for local prevention of thrombosis in animal arteries

In this paper we try to show the main dependencies of the magnetic retention process of ferrofluid apposition on the wall of a tube (blood vessel model) in the current of a non-magnetic fluid medium. We also studied "in vivo" the transport process and holding a ferrofluid droplet in a rabbit stomach.

5. ELECTROMAGNETISM

LAW OF INDUCTION ELECTROMAGNETIC

The phenomenon of electromagnetic induction was discovered by Faraday in 1831.

This phenomenon consists of the following: In any closed circuit, when the magnetic induction flux varies through the limited area of the circuit, there is an electric current. This current is called induced current.

The phenomenon of induction is confirmed by the following experiments:

If we approach the solenoid A of an electromagnet, in the solenoid an electric current is produced as indicated by a galvanometer G. It disappears if we stop moving the solenoid. If we quickly remove the magnet, we again see the appearance of a current in the coil (but of opposite voltage). The same effect is observed if instead of the magnet is used a coil traversed by a current (diagram b), because this is equivalent to a permanent magnet.

Approaching two solenoids, one of which has a galvanometer and the other is powered by a battery and has a switch k,when closing or opening the switch, in the first coil appears an induction current of very short duration.

When passing a constant current through coil II, nothing is observed. (The coils are fixed) (figure c).

In the two experiments above, there is a variation of the magnetic field in the vicinity of the solenoid. (With the galvanometer). In the second experiment this variation occurs suddenly from the value B = 0 (k = open) to the value B = B max (k off)

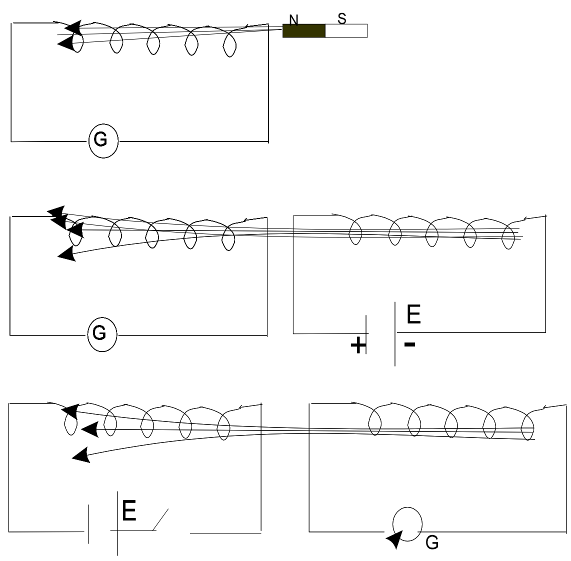


Figure 71: Induction electromagnetic

The variation of the value of the magnetic field leads to the variation of the magnetic induction flux according to the zone delimited by the circuit.

It is this variation of the flux of magnetic induction which triggers an electromotive induction force in the circuit with a galvanometer.

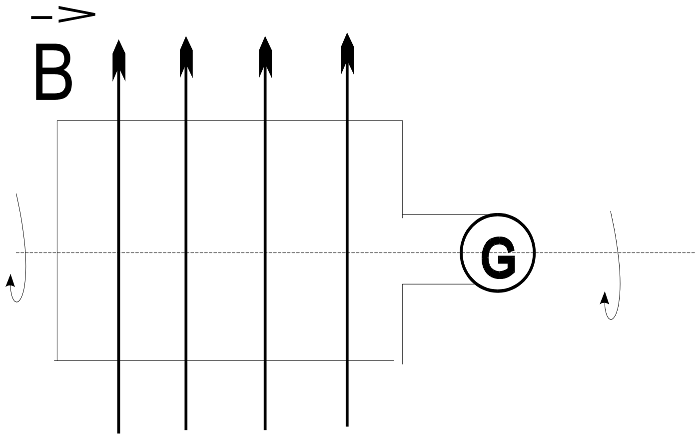


Figure 72: Induction electromagnetic

To verify this assertion, we rotates a fully enclosed conductive frame in a uniform magnetic field; in this case, the induction value of the magnetic field remains constant in the region occupied by the circuit and varies, only the flux through the surface contour because in the circuit:

f = BScosα

α has always varied.

But **if we move in translation a conductor enclosed in a uniform magnetic field, the flux of the magnetic induction remains constant and we observe the absence of current.**

Mr. Faraday made the following experiment of this type which confirmed the following laws of electromagnetic induction

LAW I: An induction current occurs in a closed circuit each time it passes through the circuit.

Lenz formulated the second law of electromagnetic induction by specifying the direction of the induced current.

LAW II: - Lenz's law: The induced current has the sense by which the induced magnetic flux can oppose the variation of the inductive magnetic flux. The induced current has the direction which can oppose the cause which produces it .

Magnetic flux can be produced by magnets or by currents so we can talk about induction magnet and the induction of currents.

From the formula of the magnetic flux which crosses a surface S whose normal makes an angle with the direction of the uniform field of induction B.

$$f = B.S.\cos\alpha = m.H.S.\cos\alpha$$

$$f = f(m, H, S, \alpha)$$

Each of these four factors causes the variation f => the appearance of an induced current (in a circuit placed in the magnetic field, respectively).

The appearance of the induction current in a closed contour is determined by the appearance in the electrical circuit of a force, under the influence of an induction magnetic flux var.

How can this electromotive force be calculated?

During the short crossing of the induced (born) current in the frame-shaped circuit results in the appearance of an electric current.

dW = FI dt

F = induced electromotive force (to be calculated)

I = current intensity at time t

It follows that the electromotive force must appear in the name of another energy. It is the energy that is expended to move the frame in the ABCD of magnetic field.

ELECTROMAGNETIC INDUCTION

The electromagnetic induction phenomenon consists in the appearance of an electromotive voltage in a circuit crossed by a time-varying magnetic flux.

The magnetic flux in a circuit can vary over time because . . .

(1). .: magnetic induction varies over time;

(2). . . the conductive surface varies over time;

(3). . . the angle between the magnetic induction vector and the normal to the surface bounded by the conductor varies with time

(1) electromotive voltage induced by time variation of magnetic induction $e = -S\dfrac{\Delta B}{\Delta t}$

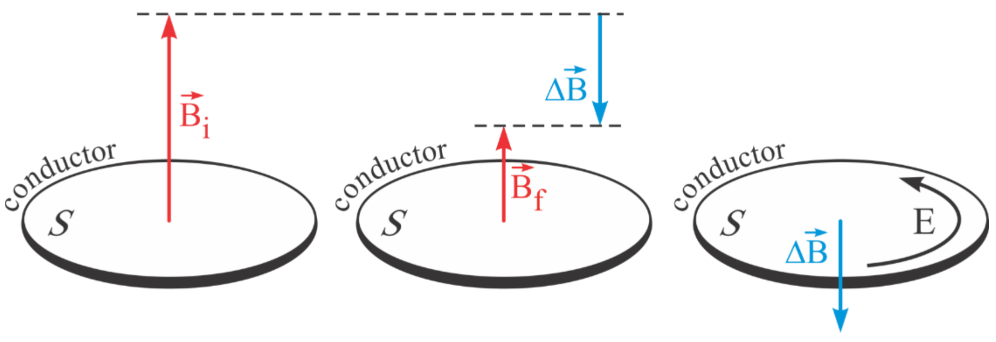


Figure 73: Electromotive voltage induced by time variation of magnetic induction

2. Electromotive voltage induced by the time variation of the surface of the conductor.

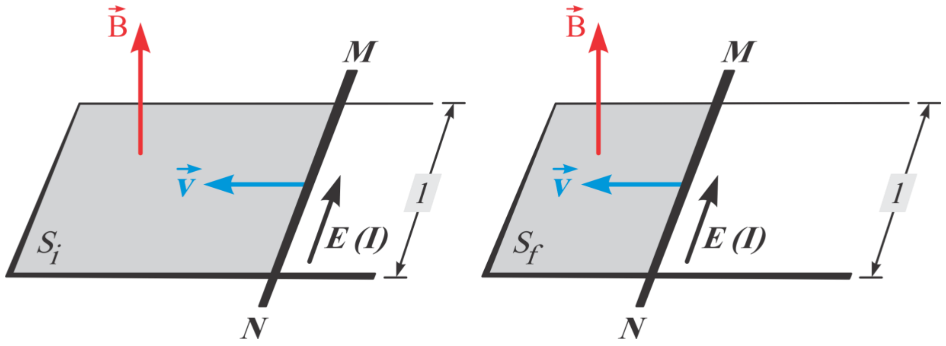


Figure 74: Electromotive voltage induced by the time variation of the surface of the conductor

$$e = -B\frac{\Delta S}{\Delta t}$$

$$\Delta S = v \cdot \Delta t \cdot l$$

$$e = -B\frac{v \cdot \Delta t \cdot l}{\Delta t} \text{ And } e = -B \cdot v \cdot l$$

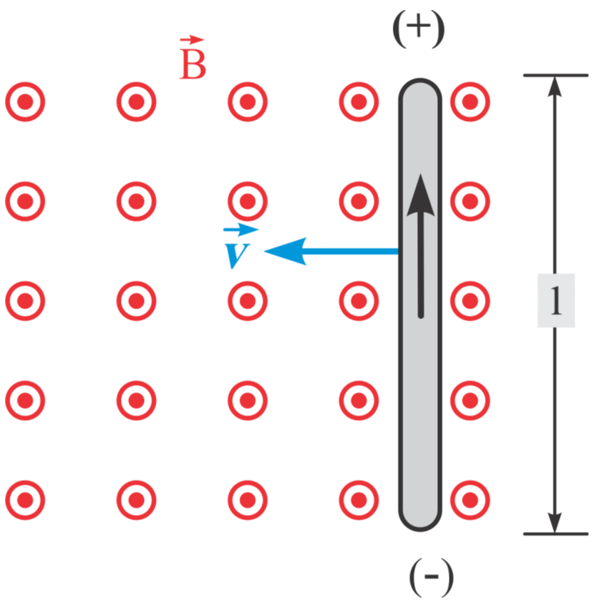


Figure 75: The direction of the electromotive voltage of the current

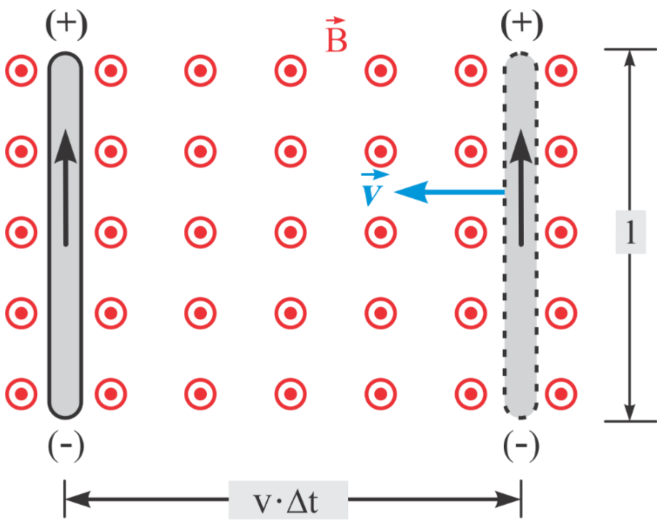
The direction of electromotive voltage

(of current):

Right hand rule:

- Vector B between the palm;
- Big toe: the direction of the speed of movement;
- The other fingers: the direction of the electromotive voltage (current)

$e = -B\frac{\Delta S}{\Delta t}$ And $\Delta S = v \cdot \Delta t \cdot l$



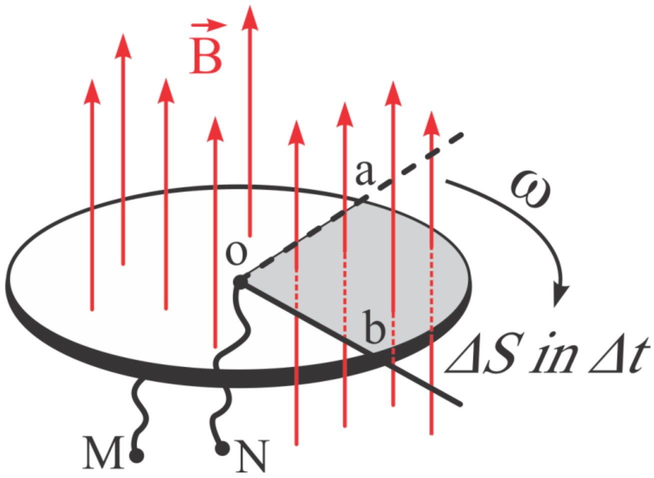


Figure 76: The direction of the electromotive voltage of the current

The relationship can be generalized :

The electromotive force between the ends of a conductor is directly proportional to the area "swept" by the conductor per unit time (i.e. the flux of the uniform magnetic field through the area "swept" by the conductor per unit time) and the speed of the driver.

$$e = -B \cdot \frac{\Delta S}{\Delta t} = -B \cdot R^2 \cdot \frac{\omega}{2}$$

(3) electromotive voltage induced by the variation over time of the angle between the magnetic induction vector and the normal to the surface bounded by the conductor.

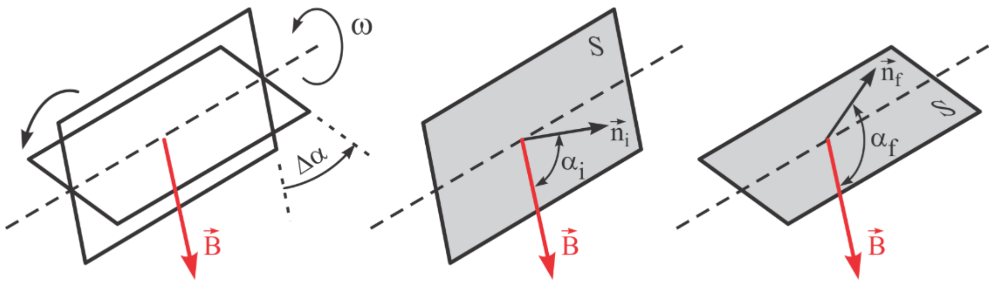


Figure 77: The direction of the electromotive voltage of the current

$$e = -\frac{\Delta\Phi}{\Delta t} = -B \cdot S \cdot \frac{\Delta \cos\alpha}{\Delta t} = -B \cdot S \cdot \frac{\Delta \cos\alpha}{\Delta\alpha} \cdot \frac{\Delta\alpha}{\Delta t}$$

$$e = -B \cdot S \cdot \frac{\Delta \cos\omega \cdot t}{\Delta(\omega \cdot t)} \cdot \frac{\Delta\alpha}{\Delta t} = -B \cdot S \cdot (-\sin\omega \cdot t) \cdot \omega$$

$$e = -B \cdot S \cdot \omega \cdot (-\sin\omega \cdot t) = e_{max} \cdot \sin\omega \cdot t$$

MAGNETIC FIELD VECTOR

Depending on the nature of the magnetic polarization phenomena, the relation can also be written for the magnetic field: $\vec{B} = \mu\vec{H}$

Introducing the vector H called magnetic field intensity and the known size of the permeability (absolute magnetic), which characterizes the magnetic properties of the environment.

In void (7) we write: $\vec{B} = \mu_0\vec{H}$

μ_0 = 4. π.10 $^{-7}$ (Henry/m) is the permeability of vacuum.

In practice, we use a dimensionless value equal to the ratio of the permeability of the medium considered and that of the vacuum: $\mu_r = \frac{\mu}{\mu_0}$

Called the relative permeability of this environment.

ELECTROMAGNETIC INDUCTION

When the force F moves the lateral ab of the frame in the time interval dt, its point displacement travels the distance dl in the direction in the direction of the force so that:

$d W = Fdl \rightarrow dW = F dt = F dl$

One can calculate the work dW' expended by the magnetic field to move the induced current.

The magnetic field is assumed to be uniform and perpendicular to the plane of the drawing. On the mobile part of the current I = ab will act an electromagnetic force (Laplace)

$F' = BIL \sin\alpha$

As $\sin \alpha = 1 \Rightarrow F' = BI l$

but d.dl = dS - surface described by cond in motion => $dW' = BIS = I. d\phi$.

because $B dS = d\phi$ a small variation of the magnetic flux crossing the plane of the interval dt abcd is obtained.

The mechanical work d W ' can be calculated differently knowing that during the displacement of the frame, the electromagnetic force F also displaces its point of application by dl

$d W = F' dl \cos\alpha$

As the movement dl is in the opposite direction

of the force F ' will be equal to $180^{0} \Rightarrow d W' = - F' dl$

Because F' = F (action = reaction) =>

$dW' = -F'.dl = - \Sigma I.dt$

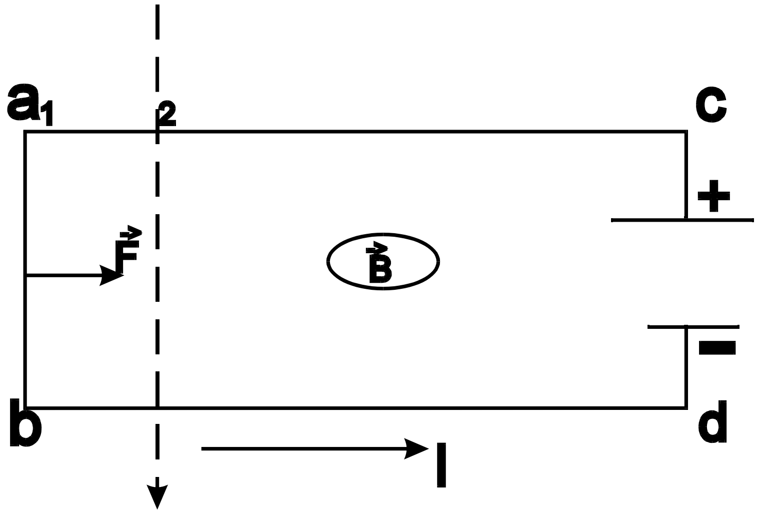


Figure 78: The direction of the electromotive voltage of the current

LAW OF ELECTROMAGNETIC INDUCTION

$$e = -\frac{d\phi}{dt}$$

fundamental formula of induced electromagnetic induction = induced electromotive voltage in a circuit

The electromotive force of induction is equal and opposite to the rate of change of the magnetic flux.

If we use $\phi = \int B dS \cos\alpha = \int \vec{B}.d\vec{S}$

The electromagnetic induction formula becomes:

$$\Sigma = \frac{-d\phi}{dt} = -\frac{d}{dt}\int \vec{B} d\vec{S} = -\int_S \vec{B} d\vec{S}$$

The electromotive force in a closed circuit

the movement of the electric field vector along the circuit

$$e = \oint \vec{E} d\vec{l}$$

THE LAW OF ELECTROMAGNETIC INDUCTION written in vectorial form is:

$$\oint \vec{E} d\vec{l} = \int_S \left(\nabla x \vec{E} \right) d\vec{S} \Rightarrow \nabla x \vec{E} = -\vec{B}$$

MAGNETIC CIRCUIT LAW OR AMPERE'S LAW

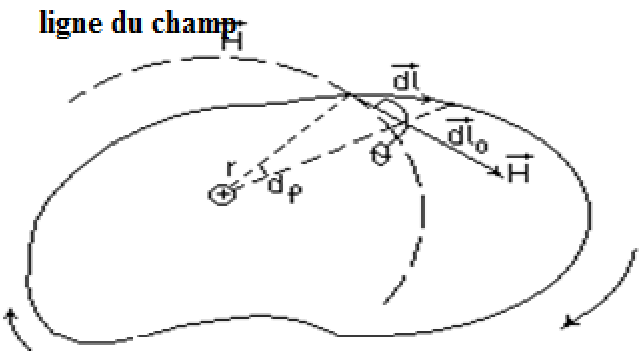


Figure 79: The direction of travel or for the current and the lines of the magnetic field

One can introduce **the notion of magnetomotive voltage** , as the motion of the magnetic field vector along a closed curve: $U_{mm} = \oint_c \vec{H}d\vec{l}$

Consider a homogeneous medium (= constant)

a contour C of a plane shape, surrounding an infinite straight conductor, traversed by a current I (figure 1). **The magnetic field lines are concentric circles, in the plane of the drawing** .

If you have chosen the conventional way, the direction of current flow in the clockwise direction in C, that is to say the same direction as the magnetic field lines of Fig. 1 we observe that:

$$\vec{H}d\vec{l} = Hdl\cos\theta = Hdl_0 = Hrd\varphi \qquad (1)$$

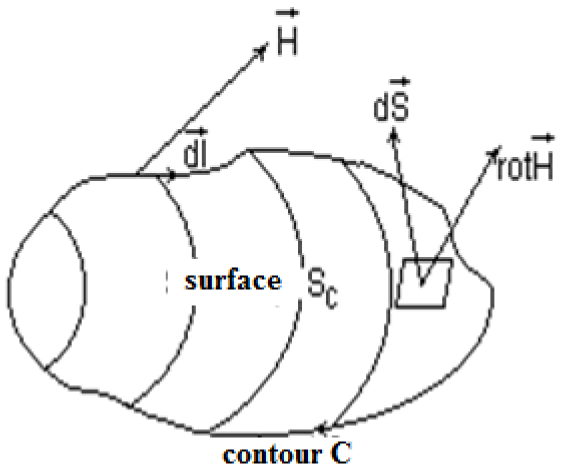
Where we take into account the fact that it is of an infinitesimal size.

By expressing the circulation of the vector H on the contour C we obtain:

$$\oint_C \vec{H}d\vec{l} = \oint_C Hrd\varphi = \frac{I}{2\pi}\oint_C d\varphi = I \qquad (2)$$

Or for **the magnetic induction vector B**

$$\oint_C \vec{B}d\vec{l} = \mu I \qquad (3)$$



MAGNETIC CIRCUIT LAW OR AMPERE'S LAW

The circulation of the magnetic induction vector along a closed curve around a conductor traversed by a current is proportional to the intensity of the current in question.

When the curve C surrounds several conductors through which currents flow, then the movement of H is equal to the algebraic sum of the currents:

$$\oint_C \vec{H} d\vec{l} = \sum_{k=1}^{n} \pm I_k = \theta \qquad (4)$$

The magnitude is called solenation and is measured in amperes.

The magnetic field created by stationary currents (I = constant) is static (does not depend on time) and is therefore called

4.2.**MAGNETOSTATIC FIELD.**

Contrary to the circulation of the electrostatic field vector E, which is null, the circulation of H does not cancel out, except in the case where the contour C does not contain conductors traversed by electric currents

If **the current I is expressed** as:

$$I = \int\int_S \vec{j}\vec{n} dS = \iint_S \vec{j} d\vec{S} \qquad (5)$$

$$I = \iint_S \vec{j} d\vec{S} \qquad (6)$$

Then from (10), we get: $\oint_C \vec{H} d\vec{l} = \iint_S \vec{j} d\vec{S}$

Figure 80: The direction of travel or for the current and the lines of the intensity of the magnetic field

If we apply Stokes' theorem to the first term of this relation, it follows (Figure 2):

$$\oint_C \vec{H}d\vec{l} = \iint_S rot\vec{H}d\vec{S} = \iint_S \vec{j}d\vec{S} \qquad (8)$$

where S is a surface based on the perimeter C.

From (8) is obtained $rot\vec{H} = \nabla x\vec{H} = \vec{j}$ (9)

or vector B, $rot\vec{B} = \nabla x\vec{B} = \mu\vec{j}$ (10)

Relations (9) or (10) express the differential form of Ampère's law and highlight the character field of magnetic rotation: the electric current density therefore the displacement of the electric charge creates vortices, that is i.e. closed field lines, with the rotor of B-H-OR different from 0.

Ampère's law on the circulation of the vector H a **in the study of the magnetic field** H has the same importance as **Gauss's law in the study of the electrostatic field.**

In particular, like Gauss's law for calculating E-field distributions for certain charges, then Ampère's law determines the intensity of the magnetic field created by currents, without using the Biot-Savart-Laplace law, which greatly simplifies the calculations.

FLUX LAW OF MAGNETIC INDUCTION

If in a magnetic field we draw curves which have as tangent at each point, the vector of the magnetic induction B we obtain lines of magnetic induction. Unlike the lines of induction of the electrostatic field which begin and end on charges and are therefore open lines, the lines of the magnetic flux produced by the currents are closed curves, i.e. no point of these lines can diverge and therefore :

$$\mathrm{div}\,\vec{B} = 0 \qquad (11)$$

This relation is always true even for dynamic magnetic fields (not only in magnetostatics).

As for the electric field, we can define the size called magnetic induction flux (magnetostatic flux), denoted.Φ

On a reasoning analogous to that described in the previous paragraph for the magnetic flux through a surface S is obtained the relation: $\Phi = \iint_S \vec{B}d\vec{S}$

(12)

According to the Green-Ostrogorski theory the magnetic flux through a closed surface S is zero:

$$\Phi = \oiint_S \vec{B}d\vec{S} = \iiint_V \mathrm{div}\vec{B}dV = 0$$

LAW OF FLUX OF ELECTRIC INDUCTION . GAUSS LAW

GAUSS LAW IN INTEGRAL FORM

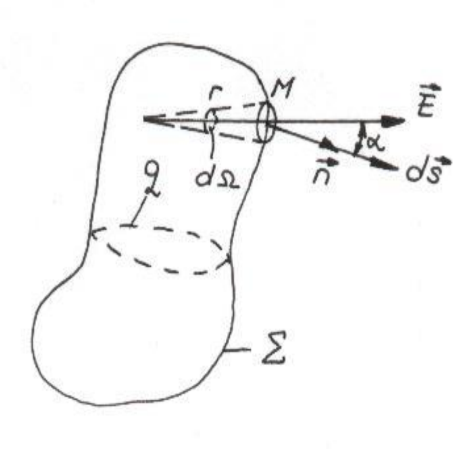


Figure 81: Gauss's law

Consider a closed surface Σ of arbitrary shape, located in an electric field and a point-like electric charge any located on the inner surface Σ. Calculate the flux of the electric field strength generated by the electric charge q on the closed surface Σ. We consider an arbitrary point M on the surface Σand a primary surface dS located on the area around the point M.

In point M: $$E = \frac{1}{4\,\pi\,\varepsilon_o} . \frac{q}{r^2}$$

The flux through the surface is:

$$d\Phi = e.dS.\cos\alpha = \frac{q}{4.\pi.\varepsilon} . \frac{dS}{r^2}\cos\alpha$$

$$d\Omega = \frac{dS}{r^2}\cos\alpha$$

dS is the surface element

where dΩ is the solid angle under which we see the surface dS of the place where the electric charge q is located

Gauss's law in integral form

The total flux through the surface Σwill be $$\Phi = \oint_{\Sigma} E.dS.\cos\alpha = \frac{q}{4.\pi.\varepsilon_o}\oint_{\Sigma} d\Omega$$

Or

$$\oint_{\Sigma} d\Omega = 4.\pi$$

is the solid angle under which the closed surface sees from where the load q is placed.

From an internal point, but any surface is taken as the solid angle 4π under which sees a sphere in the center.

GAUSS'S LAW FOR THE FLUX is written: $\oint_{\Sigma} \vec{E}.d\vec{S}. = \dfrac{q}{\varepsilon_o}$

The flow of the electric field through a closed surface is proportional to the charge which is inside the surfaceΣ

This law is a fundamental law that reflects the causal relationship between the general electric charge (which is the cause) and the electric field (the effect)

The law refers to electric charges and still allows the determination in principle according to the distribution of electric charges.

In accordance with the law of flux: if the electric charges are distributed outside the closed surface Σand inside this surface there is no charge, the flux through the surface Σis zero.

We consider a set of charges in their domain, **a closed space Σinside which the maximum charge is positive.**

In this case, **the law of flux** is written as:

$$. \oint_{\Sigma} \vec{E}.d\vec{S} = \frac{q}{\varepsilon_o} > 0$$

Thus the flux determined by lines coming out of the surface is greater than that determined by flux lines entering the zone. Thus, the number of lines of force emerging from the surface is greater than the number of lines of force entering the area.

In conclusion, we can say that there are points inside the surface which are the sources of the lines of force.

If inside the surface Σthere are negative charges we can write

the law of electric flow as:

$$\oint_{\Sigma} \vec{E}.d\vec{S} = \frac{q}{\varepsilon_o} < 0$$

Therefore, the flux of lines entering the surface is greater than the number of lines leaving the surface. Inside the box the field lines end.

The negative charges are sensors of the field lines.

Electrical loads are usually the sources of power lines.

LAW OF FLOW IN DIFERENTIAL FORM

The relationship: $\oint_{\Sigma} \vec{E}.d\vec{S} = \frac{q}{\varepsilon_o}$

Establishes the relationship between the density of electric charges and the electric field at a point. The volume density of these charges ρ(x, y, z) depends on the following position according to the relation:

$$dq = \rho(x,y,z)\ dV$$

According to the law of flux we have:

$$\oint_{\Sigma} \vec{E}.d\,\vec{S}. = \frac{q}{\varepsilon_o}$$

Or

$$q = \int_V \rho(x,y,z)\ d\ V$$

it is the total charge of the volume V.

If a(x,y,z) is a point vector function, using the relation

$$\oint_{\Sigma} \vec{a}(x,y,z)\ d\vec{S} = \int_V div\ \vec{a}(x,y,z)\ dV$$

Applying Gauss's law for the electric field strength E and we write

$$\oint_{\Sigma} \vec{E} \cdot d\vec{S} = \int div\vec{E} \cdot dV$$

$$\int_V div\vec{E}\ dV = \int_V \frac{\rho}{\varepsilon_o} dV = \frac{q}{\varepsilon_o} = \frac{1}{\varepsilon_0}\left(\int_V \rho(x,y,z) dV\right)$$

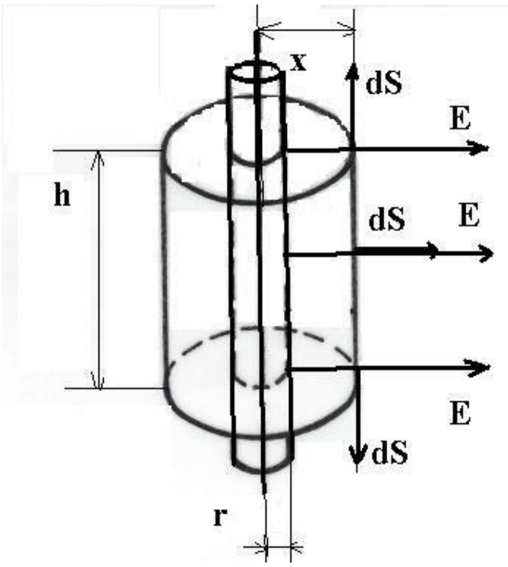
So Gauss's law for electric flux in the differential form reads:

$$div\vec{E} = \frac{\rho}{\varepsilon_o}$$

or we can write it:

$$\frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z} = \nabla \cdot \vec{E} = \frac{\rho(x,y,z)}{\varepsilon_o}$$

CALCULATION OF ELECTRIC FIELD INTENSITY USING GAUSS'S LAW FOR SURFACE CHARGE DISTRIBUTION σ



To determine the electric field strength for a circular conductor of radius R with the surface charge density σ , infinitely long , according to the distance from the axis of the cylinder.

In case x > r

$$\oint_{\Sigma} \vec{E}d\vec{S} = \frac{q}{\varepsilon_0}$$

And

Figure 82: Gauss's law for surface charge distributionσ

$$\oint_{\Sigma} \vec{E}d\vec{S} = \int_{\Sigma lateral} \vec{E}d\vec{S} + \int_{\Sigma baza1} \vec{E}d\vec{S} + \int_{\Sigma baza2} \vec{E}d\vec{S}$$

But on the surfaces of the bases the vector E is perpendicular to dS and

$$\oint_{\Sigma lateral} \vec{E}d\vec{S} = E.\Sigma_{laterala} = E.2\pi.x.h = \frac{q}{\varepsilon_o}$$

But the study cylinder has a surface distribution of the load

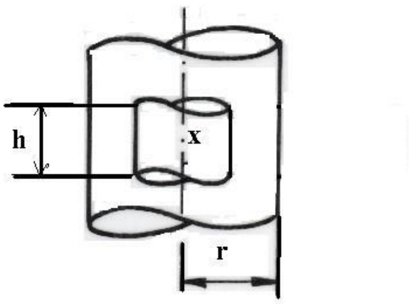
$$\sigma = \frac{dq}{dS}$$

ou

$$\sigma = \frac{q}{S_{laterala}} = \frac{q}{2\pi rh}$$

SO: $q = 2\pi\ r\ h\ \ \sigma$

From Gauss's law written above we obtain the expression of the electric field for a surface distribution of the charge when the charge is placed outside the studied area: $E = \frac{\sigma\, r}{\varepsilon_o x}$

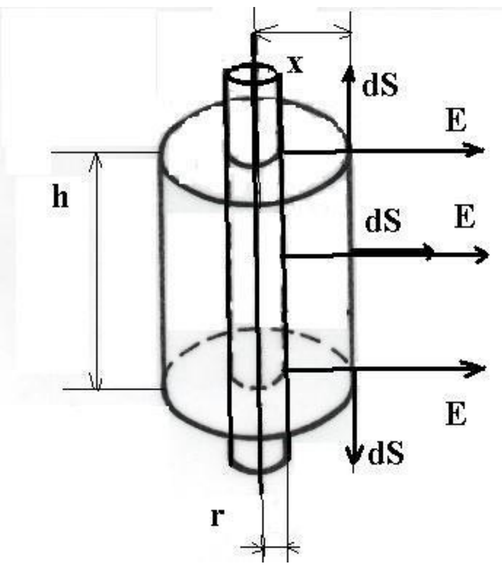


- **In the case: x<r ,**
- **When Gauss's law E=0 applies**

Because the electric charge is distributed in the exterior of the studied cylinder (because the charge is zero inside).

Figure 83: Gauss's law for surface charge distributionσ

CALCULATION OF ELECTRIC FIELD INTENSITY USING GAUSS'S LAW FOR LINEAR CHARGE DISTRIBUTION λ



Consider a filiform, straight, infinitely long conductor with a uniformly distributed electric charge with linear density λ. Calculate the electric field strength as a function of the distance x from the axis of the conductor

By applying Gauss's law: $\oint_{\Sigma} \vec{E}\, d\vec{S} = \frac{q}{\varepsilon_0}$

Figure 84: Gauss's law for linear λcharge distribution

The surface is arbitrarily chosen based on symmetry.

Here we have cylindrical symmetry.

The calculation of electric field strength to a linear distribution $\lambda$of electric charge.

$$\oint_{\sum totale} \vec{E} d\vec{S} = \int_{\sum lat} \vec{E} d\vec{S} + 2 \int_{\sum base} \vec{E} d\vec{S} = E_2 =$$

$$= \int_{\sum lat} EdScos0 + 2\int_{\sum lat} EdScos90^0 = \int_{\sum lat} EdS$$

So: $E = \dfrac{\lambda}{2\pi\varepsilon_0 x}$ or $\lambda = \dfrac{q}{h} \Rightarrow q = \lambda h$

MAXWELL'S EQUATIONS FOR THE ELECTROMAGNETIC FIELD

The integral form of Maxwell's equations for the electromagnetic field is useful for solving such kinds of problems that require full symmetry such as spherical, cylindrical, and one-dimensional rectangular symmetry.

1. LAW OF INDUC TION E LECTROMAGNETIC _

$$\int_{\Gamma}^{0} \vec{E} \cdot d\vec{r} = -\frac{d}{dt} \int_{S\Gamma} \vec{B} \cdot d\vec{S}$$

2 . MAGNETIC CIRCUIT LOI

$$\int_{\Gamma}^{0} \vec{H} \cdot d\vec{r} = -\int_{S}^{0} \vec{J} \cdot d\vec{S} + \frac{d}{dt} \cdot \int_{S}^{0} \vec{D} d\vec{S}$$

3. L AW OF FLUX OF MAGNETIC INDUCTION

$$\int_{\Sigma}^{0} \vec{B} d\vec{S} = 0$$

4. L AW OF FLOW OF ELECTRIC INDUCTION

$$\int_{S}^{0} \vec{D} d\vec{S} = \rho$$

The differential form for Maxwell's equations for the electromagnetic field is obtained from their integral form using:

STROKES $\int_{\Gamma}^{0} \vec{A}d\vec{S} = \int_{S\Gamma}^{0} \left(rot\vec{A}\right)d\vec{S}$ **THEOREM :**

GAUSS $\int_{\Sigma}^{0} \vec{A}d\vec{S} = \int_{V\Sigma} \left(div\vec{A}\right)dV$ **THEOREM :**

OTHER LAWS

- **LAW OF CONSERVATION OF CHARGE:**

  $$div\vec{J} + \frac{\partial \rho}{\partial t} = 0 \quad \text{sau} \quad \nabla.\vec{J} + \frac{\partial \rho}{\partial t} = 0$$

- **TEMPORARY POLARIZATION LAW** $\vec{D} = \varepsilon.\vec{E}$
- TEMPORARY MAGNETIZATION LAW: $\vec{H} = \frac{\vec{B}}{\mu}$
- The link between electromagnetic and mechanical phenomena is made by Lorentz force $\vec{F} = q\left(\vec{E} + \vec{v}x\vec{B}\right)$

THE LAW OF ELECTROMAGNETIC INDUCTION OR FARADAY'S LAW :

$$\oint_{\Gamma} \vec{E}.d\vec{r} = -\frac{d}{dt} \int_{S\Gamma} \vec{B}.d\vec{S}$$

says that **: the instantaneous emf along a closed curve Γ is equal to the instantaneous rate of decreasing magnetic flux Φ m passing through any open curved surface S bounded by the curve Γ.**

MAGNETIC CIRCUIT LAW OR AMPERE'S LAW:

by analogy with Maxwell's first equation, it was considered necessary in the general dynamic case to add the temporal variation of D.

Thus, we have: $\oint_{\Gamma} \vec{H}.d\vec{r} = -\oint_{S} \vec{J}.d\vec{S} + \frac{d}{dt} \oint_{S} \vec{D}.d\vec{S}$

And we can say that: the **instantaneous electromotive voltage, along a closed curve Γ is equal to the sum of the instantaneous intensities of conduction of the electric current and the**

displacement (radio) passing through an open zone limited by the curve Γ in the same conditions as the law of electromagnetic induction.

The intensity of the electric current I is expressed as a function of the current density through the relationship: $I = \int_S \vec{J}.d\vec{S}$

And from the physical point of view it can happen in various ways.

FLOW LAW OF MAGNETIC INDUCTION

OR GAUSS'S LAW FOR THE MAGNETIC FIELD

$$\oint_\Sigma \vec{B}.d\vec{S} = 0$$

This relation expresses: the **instantaneous magnetic flux passing through any surface Σ is equal to zero.**

This means that if we move from a point that is inside the magnetic field region and continue along the direction of the field vector, we can return to the starting point.

- If we start from a different point through which we did not pass the first time and still we follow the direction of the field vector, we can return again to the starting point without having to cross the first road. Note that it is a vector normal to the surface of Σ and directed outward.

FLOW LAW OF ELECTRIC INDUCTION or Gauss's law for the electric field:

$$\oint_S \vec{D}.d\vec{S} = \rho$$

This relation indicates that: the instantaneous flow of the electric induction which passes by a closed surface Σ is equal to the total electric charge inside the surface Σ .

If the electric charge $q > 0$, the flux will be D outside the surface Σ,

and if $q < 0$, it will be of D inside the surface Σ.

6. SOUND, ULTRASOUND, INFRASOUND

CLASSIFICATION OF WAVES

Definition: The set of oscillations of a material point in an elastic domain is called an elastic wave.

a. **LONGITUDINAL WAVES:** are the waves for which the momentary speed is parallel with the direction of wave propagation in the point where they are. When a longitudinal wave propagates pressure vibrations are created.

b. **TRANSVERSE WAVES** are waves for which the speed at a given instant is perpendicular to the direction of propagation.

PARTIAL DIFFERENTIAL EQUATIONS OF WAVES

PARTIAL DIFFERENTIAL EQUATIONS OF LONGITUDINAL ELASTIC WAVES

$$\frac{1}{c^2}\cdot\frac{\partial^2 u}{\partial t2}=\frac{\partial^2 u}{\partial x^2}$$

Wave equation for propagation in space

$$\frac{\partial^2 u}{dx^2}+\frac{\partial^2 u}{dy^2}+\frac{\partial^2 u}{dz^2}=\frac{1}{c^2}\cdot\frac{\partial^2 u}{\partial t^2}$$

C – wave propagation speed

$$c=\frac{1}{\sqrt{\varepsilon_0\mu_0}}=2{,}997924\cdot10^8\,\frac{m}{s}$$

Solution for wave equation

Wave time equation $\omega^2+\frac{1}{T}\frac{d^2T}{dt^2}=0$

Temporal solution $T=C_1e^{i\omega t}+C_2e^{-i\omega t}$

Spatial wave equation $\frac{1}{X}\frac{d^2X}{dx^2}+k^2X=0$

Spatial Solution $X=D_1e^{ikx}+D_2e^{-ikx}$

General solution for the wave equation

$$u(x,t)=e^{\pm i(\omega(\pm kx)}$$

CLASSIFICATION OF ELECTROMAGNETIC WAVES

1. **Radio wave** $1m < \lambda$
2. **Microwave** $1m > \lambda > 1mm$
3. **IR infrared radiation** $1mm > \lambda > 760nm$
4. **visible radiation** $760nm > \lambda > 400nm$
5. **Ultraviolet radiation: UV:** $400nm > \lambda > 1nm$
6. **X-radiation (Röngen)** $10^{-3}nm > \lambda > 10nm$
7. **Centimeter wave:** $\lambda \in (0.01;0,1)m$
8. **Millimeter wave:** $\lambda \in (0.01;0,001)m$
9. **Cancellation γ:** $\lambda < 0.1nm$

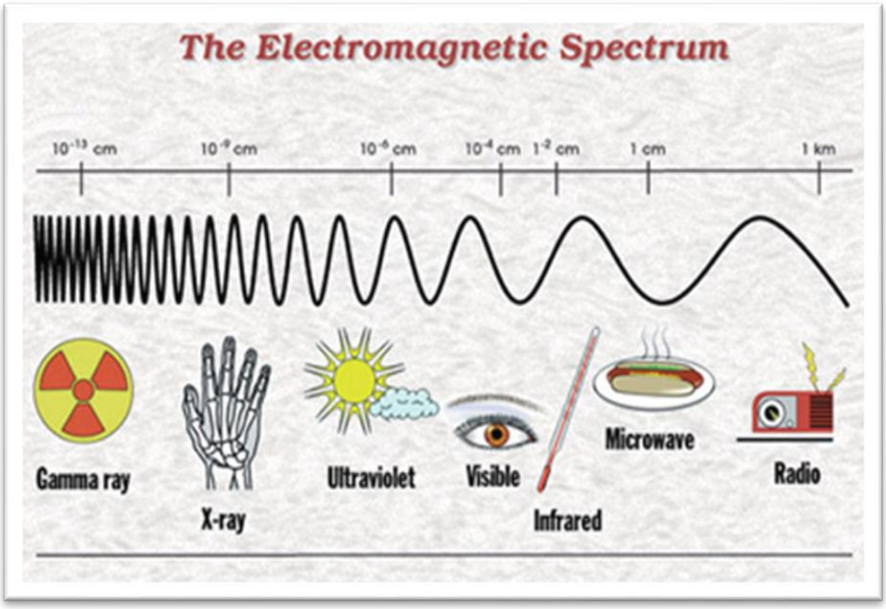


Figure 85: The spectrum of electromagnetic waves

- **Characteristics of electromagnetic waves**
  - Mirametric waves 3-30KHz or 100-10Km
  - or 10-1km LF
  - MF 300Khz-3MHz or 1km-100m
  - HF 3-30MHz or 100-10m
  - Metric waves 30-300MHz or 10-1m
  - UHF 300MHz or 1-0.1m
  - Centimeter waves 3-30GHz or 0.1-0.01m
  - Millimeter wave 30-300GHz or 0.01-0.001m
  - Decimillimetre waves 300-3000GHz or 0.001-0.0001m

- **Characteristics of the long-medium-short and ultra-short wave ranges**
  - Longwave 148.5-283.5KHz or 2020-1058m
  - Medium wave 526.5-1606.5KHz or 569.8-186.7m
  - Shortwave 3.9-26.1MHz or 75-11m
  - ultrashort waves
    - OIRT 66-73MHZ or 4.54-4.11m
    - CCIR 87.5-108MHz or 3.42-2.77m

CHARACTERISTICS OF ELECTROMAGNETIC WAVES

Frequency domain	wave title	apps
3-30kHz or 100-10km	MIRIAMETRIC WAVES	10 - 150 kHz – radio communications, radio navigation; 3-30kH – inductive heating;
30-300kHz or 10-1km	WAVES KILOMETRICS (LONG WAVES)	151-281 kHz - longwave broadcasting 30-300 kHz - inductive heating;
300kHz -3MHz Or 1km-100m	WAVES HYCTOMETRICS (MEDIUM WAVES)	285-405 kHz - Radionavigation; 405-520 kHz – Radiocommunication; 520-1602 kHz – Medium wave broadcasting; 1602-8000 kHz - radio communication;
3-30MHz Or 10010m	WAVES DECAMETRICS (WAVES SHORT)	3-3.9 MHz – radio communication; 3.9 -26.1 MHz – radio communication and broadcasting on short waves (in the subranges) 26.1-30 MHz – radio communication 13.56MHz; 27.12 MHz – heating with high frequencies;
30-300MHz Or 10-1m	WAVES METRICS (ultraSHORT WAVES very high frequency)	41-68 MHz – television band I 66-73 MHz sau 87.5 -108 MHz - ultra short wave broadcasting (UUS-MF – band II) 162-216 MHz – television – band III; 30-300 MHz - radio communication (in free slots); 40.68 MHz - heating with high frequencies
300-MHz-3GHz Or 1-0.1m	HF WAVE (ultra-high frequency)	470-960 MHz –TV (Banda IV) 2.5 GHz – 2.69 GHz – satellite broadcasting 2.375 GHz - heating with high frequencies
3-30GHz Or 0.1-0.01m	CENTRIMETRIC WAVE (ultra-high frequency)	11.7-12.5 GHz – radio - satellite broadcasting 3-30 GHz - radio communication, radar; 22.125 GHz - heating with high frequencies
30-300GHz Or 0.01-0.001m	MILLIMETRIC WAVE (ultra-high frequency)	41-43 GHz - radio - satellite broadcast 30-300 GHz - radio communication, radar;
300-3000GHz Or 0.001-0.0001m	DECIMILLIMETER WAVE	

LONG - MEDIUM - SHORT AND ULTRA-SHORT WAVE RANGES

Frequency domain	wave title	apps
LONG WAVE	148.5-283.5kHz Or 2020-1058m	The waves are strongly absorbed by the ionosphere allowing propagation in a summer day of the order of 1900 km and more slightly higher during the night and in winter. The transmission does not show specific fluctuations for ionospheric propagation, but is strongly affected by atmospheric noise.
MEDIUM WAVE	526.5-1606.5kHz Or 569.8-186.7m	The waves are absorbed by the ionosphere during the day (maximum propagation: a few hundred km). During the night, the absorption disappears and the waves can propagate several thousand kilometers (of ionospheric reflection). The continuous variation of the ionospheric characteristics determines the random fluctuations of the intensity of the reception (fading) more pronounced in the case of distant stations. Fading occurs near broadcast stations at night (60 to 200 km away from the frequency transmitter) due to sky wave overlap on the field wave.
SHORT WAVE	3.9-26.1MHz Or 75-11m Subrange:	Direct waves propagate within a radius of a few tens of km and ionospheric reflection to several thousands of kilometers (strongly depends on the weather and the frequency transmission work adopted). Thus optimal reception is obtained on the small sub-range (13-30 m) and in the evening and at night on the large sub-range (30-50 m). The fading is more pronounced than on the medium waves
ULTRA SHORT WAVE	ORT: 66-73MHz Or 4.54-4.11m CCIR: 87.5-108MHz Or 3.42-2.77m	Waves propagate within line of sight depending on height and antenna positions (up to a maximum of 200-300 km)

ELECTROMAGNETIC WAVE IN VACUUM

Electromagnetic field: all electric and magnetic fields that oscillate and generate another.

Electromagnetic wave: it is an electromagnetic field which propagates

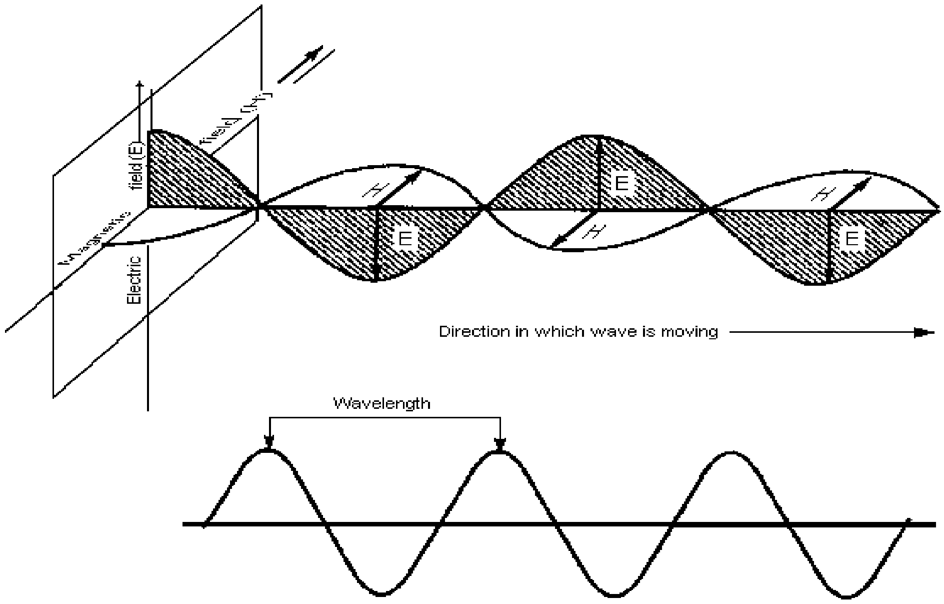


Figure 86: Electromagnetic waves in vacuum

1. Phase velocity (c) - universal constant does not depend on wave characteristics
2. Electromagnetic wave- vector wave E and H are vectors
3. The wave is the effect of transverse waves
4. E and H are mutually perpendicular
5. E and H oscillate in phase and the amplitude values are proportional
6. Poynting vector

SOUNDS

Sounds are mechanical oscillations capable of impressing the organ of hearing: the ear (receiver). Sound waves are longitudinal mechanical waves that travel through solids, liquids and gases.

For the waves to be perceived by the ear, it is necessary that:

- ❑ The waves are produced by a sound source
- ❑ There is an elastic medium of propagation between the source and the sound receiver.
- ❑ The oscillation frequency is contained within a frequency range
- ❑ The intensity of the sound waves is sufficient to produce an auditory sensation
- ❑ The duration of the signal is greater than a minimum time interval (approx. 0.05 s) to be picked up by the auditory organ

The perception of sounds by ear

1 - sound (sound wave)

2 - eardrum

3 - cochlea

4 - cellular auditory reception

5 - frequency spectrum of sound recording

6 - nerve

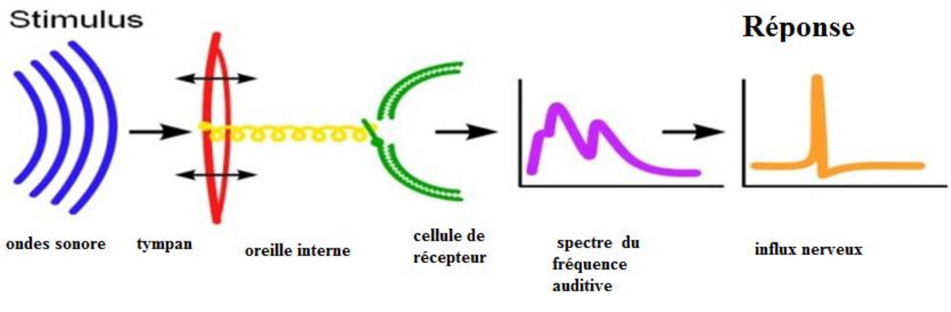


Figure 87: The perception of sounds by ear

PRODUCTION OF SOUNDS

SOUNDS are produced in vibrating strings (violin, human vocal cords), vibrating air columns (organ, clarinet), vibrating plates and membranes (xylophone, speaker, drum).

All these vibrating elements alternately compress the surrounding air when moving forward and rarefy it when moving backward.

The air transmits these disturbances from the source to the outside in the form of a wave.

After touching the ear, these waves produce the sensation of sound.

Waves that are approximately periodic or consist of a small number of approximately periodic components give rise to a pleasant sensation (if the intensity is not too high) - for example musical sounds.

The sound whose wave is not periodic is heard as noise.

NOISE can be perceived as a superposition of periodic waves having a very large number of components

Halliday D., Resnick R., Fizica vol.I., EDP, Bucuresti, 1975, p.528

PRODUCTION OF ULTRASOUNDS

The high frequencies corresponding to ULTRASOUND can be produced by the elastic vibrations of the quartz crystal induced at resonance by an applied alternating electric field

THE PIEZOELECTRIC EFFECT) [1] .

Thus, sounds with frequencies up to 600 MHz can be produced.

The corresponding wavelength in air is approximately 5.10-5 cm = 500.10-9m = 500 nm, comparable to the wavelength of light waves.

Brothers Pierre Curie and Jacques Curie demonstrated for the first time the direct piezoelectric effect in 1880. They combined the knowledge of pyroelectricity and crystal structures and they predicted pyroelectricity and demonstrated the effect using crystals of tourmaline, quartz, topaz, cane sugar and Rochelle salt (sodium tartrate tetrahydrate).

Quartz and Rochelle salt exhibited the highest piezoelectricity.

WEBER & FECHNER'S LAW

The variation of the intensity of the sensation is proportional to the logarithm of the ratio of the intensities of excitation.

$$\Delta S = S_2 - S_1 = k \ln \frac{I_2}{I_1}$$

- ❑ Frequency of mechanical waves capable of impressing the human ear is between 16 and 20,000 Hz.
- ❑ Vibrations with a frequency above 20,000 Hz are called **ultrasound** .

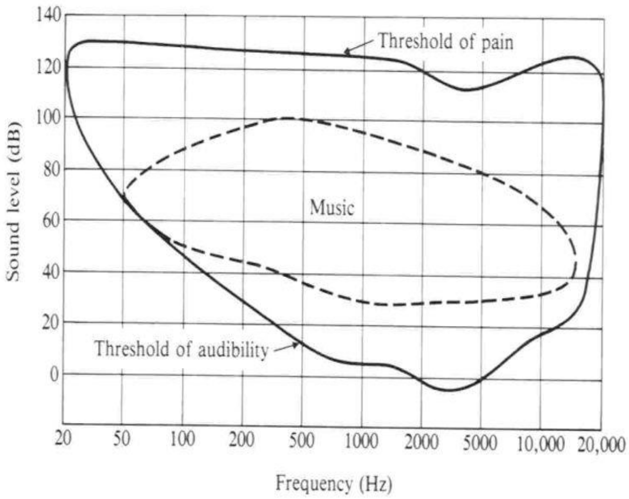


Figure 88: The perception of sounds by ear

SOUND INTENSITY

The sound intensity level (SIL) or sound intensity is the level (a logarithmic quantity) of sound intensity relative to a reference value.

L_I is indicated, expressed in dB, and defined by

$$L_I = \frac{1}{2}\ln\left(\frac{I}{I_0}\right) Np = \log_{10}\left(\frac{I}{I_0}\right) B = 10\log_{10}\left(\frac{I}{I_0}\right) dB$$

The standard unit of sound intensity is the decibel dB = 1/10. B

Bel is equal to the ratio between the applied force or energy and a reference force or energy.

As a reference, the power required for 1000Hz of pure tone to be barely heard is often used in auditory activity, and this power is approx. 10^{-16} W/cm^2,

So $$N_{dB} = 10\log_{10}\left(\frac{P}{P_0}\right) dB$$

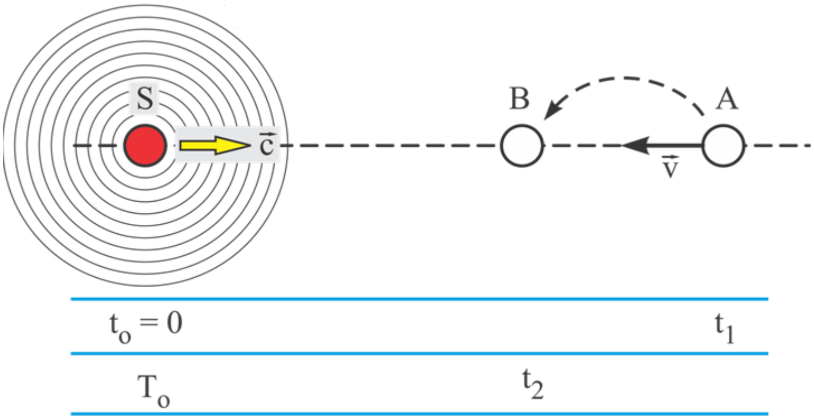
Where P is the applied power and P0= 10^{-16} W/cm^2

THE DOPPLER EFFECT

Case 1. The source is at rest relative to the environment.

The observer approaches the source with velocity "v" relative to the environment.

The propagation speed in the medium of the wave emitted by the source is "c"



$$T = T_o + \frac{SB}{c} - \frac{SA}{c} = T_o - \frac{SA - SB}{c} = T_o - \frac{AB}{c}$$

$$but \ \ldots \ AB = v \cdot T \quad so \quad T = T_o - \frac{v}{c} \cdot T$$

$t_1 = \frac{SA}{c}$ and $t_2 = T_o + \frac{SB}{c}$, $T = t_2 - t_1$

So

$$T = T_o - \frac{v}{c} \cdot T \quad \Rightarrow \quad T_o = T \cdot \left(1 + \frac{v}{c}\right)$$

$$and\ because\ f_o = \frac{1}{T_o} \quad si \quad f = \frac{1}{t} \quad \Rightarrow \quad f = f_o \cdot \left(1 + \frac{v}{c}\right)$$

because $\lambda_o = \frac{c}{f_o}$

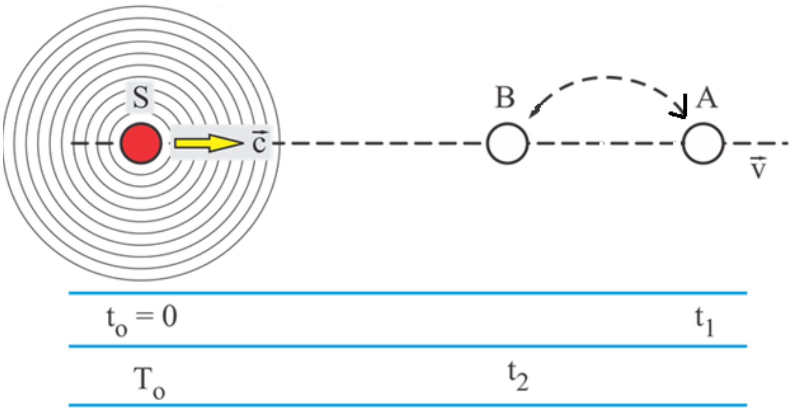
and during t2 – t1 (in which the observer traveled the distance AB) the second wave crossed the distance SB with speed "c" compared to the environment, so

$$SB = c \cdot T \;\; si \;\; AB = v \cdot T \quad ; \quad insa \;\; SA = SB + AB = (c + v) \cdot T$$

Case 2 : If the source is at rest with respect to the environment and the observer moves away from the source with speed "v" with respect to the environment, then, from a similar reasoning, it follows:

$$T = T_o + \frac{v}{c} \cdot T$$

$$\Rightarrow \; T_o = T \cdot \left(1 - \frac{v}{c}\right) \; si \; deoarece \;\; f_o = \frac{1}{T_o} \;\; si \;\; f = \frac{1}{t} \;\; \Rightarrow \;\; f = f_o \cdot \left(1 - \frac{v}{c}\right)$$



OBSERVATION: It can be shown that the period and frequency of the wave perceived by the observer differ from those emitted by the source, but the wavelength perceived by the observer is equal to the wavelength emitted by the source **($\lambda = \lambda_0$).**

Really $$\lambda_o = \frac{c}{f_o}$$

and during t2 – t1 (in which the observer traveled the distance AB) the second wave crossed the distance SB with speed "c" compared to the environment, so

$$SB = c \cdot T \;\; and \;\; AB = v \cdot T \quad ; \quad but \;\; SA = SB + AB = (c + v) \cdot T$$

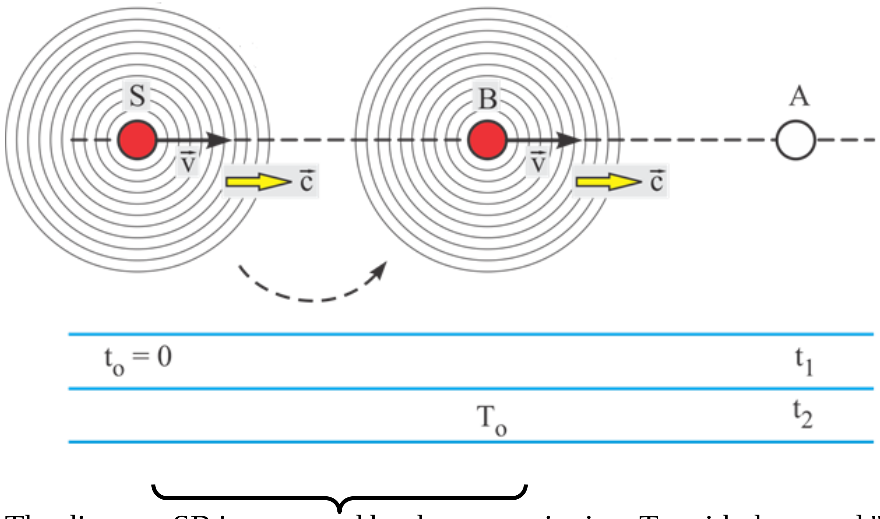
From the observer's point of view, the phenomenon unfolds as if he were standing still and the wave was propagating with speed c' = c + v.

In this case

$$\lambda=\frac{c'}{f}\ ;\ \lambda=\frac{c+v}{f_o\cdot\left(1+\frac{v}{c}\right)}=\frac{c\cdot\left(1+\frac{v}{c}\right)}{f_o\cdot\left(1+\frac{v}{c}\right)}=\frac{c}{f_o}=\lambda_o$$

Case 3 The observer is at rest with respect to the environment.

The source approaches the observer with speed "v".



The distance SB is traversed by the source in time To with the speed "v" compared to the environment

$$SB=v\cdot T_o$$

and $t_1=\frac{SA}{c}$; $t_2=T_o+\frac{BA}{c}$

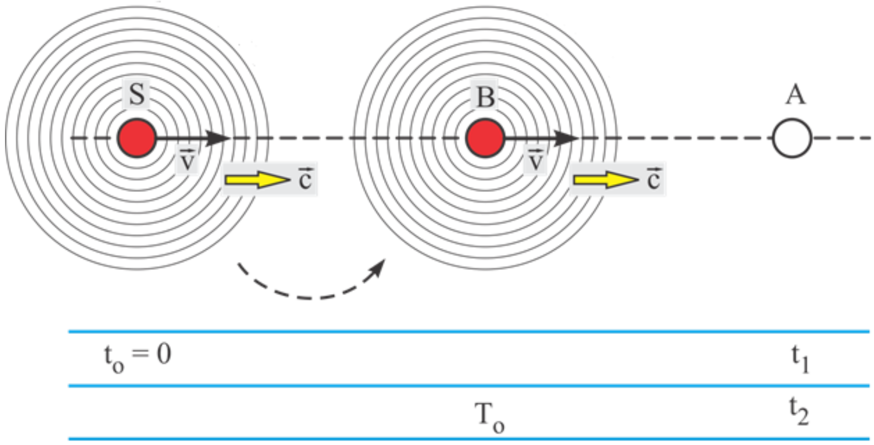
The period of the waves received by the observer (T):

$$T=t_2-t_1=T_o+\frac{BA}{c}-\frac{SA}{c}=T_o-\frac{SA-BA}{c}$$

$$T=T_o-\frac{SB}{c}=T_o-\frac{v}{c}\cdot T_o$$

$$T=T_o\cdot\left(1-\frac{v}{c}\right)$$

Case 4. If the observer is at rest with respect to the environment and the source moves away from the



observer with speed "v", then

$$T = T_o \cdot \left(1 + \frac{v}{c}\right) \; ; \quad f = \frac{f_o}{1 + \frac{v}{c}}$$

Because $f_o = \dfrac{1}{T_o}$ *and* $f = \dfrac{1}{T}$ so

$$f = \frac{f_o}{1 - \frac{v}{c}}$$

If the observer is at rest with respect to the environment and the source moves with the speed "v" of the observer, then the wavelength (l) sensed by the observer differs from that of the wave emitted by the source (λo): $\lambda = \lambda_o \cdot \left(1 \mp \frac{v}{c}\right)$

The sign (-) refers to the case when the source approaches the observer, and the sign (+) refers to the case when the source moves away from the observer.

STRIPS THROUGH THE HUMAN EAR AND THAT OF SEVERAL ANIMAL SPECIES

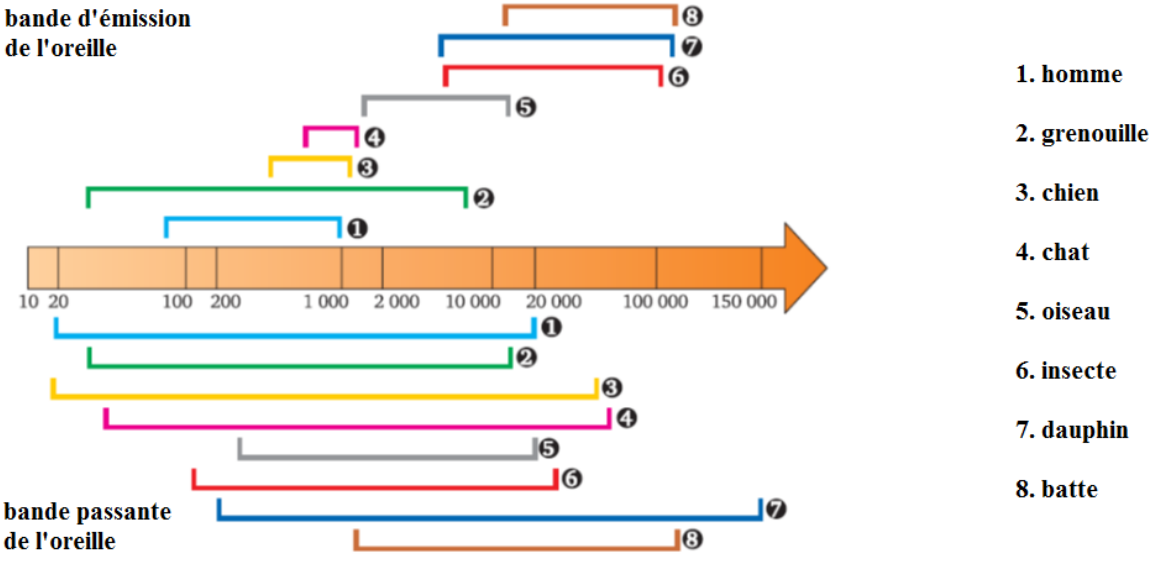


Figure 89: The perception of sounds in the ear bands crossing the human ear and that of several animal species

ULTRASONIC WAVE

Among some sound vibrations that go beyond the limits of audibility of the human ear, of great interest in practical terms, have ultrasound, sounds whose frequency is higher than 20,000 Hz.

Ultrasound is obtained by certain crystals called piezoelectric (piezocrystals) exhibiting the electrostrictive phenomenon, either contraction or expansion under the action of an electric field. The most widely used is quartz, from which a plate (blade) is cut with a particular orientation towards the crystallographic axes of the quartz (piezoquartz). The thickness of the plate is that which vibrates in resonance with the applied alternating electric field (through a capacitor).

Thus, the plate thickness is given by: C = 5.5 km/s:

The same blade is used to receive ultrasound, due to its opposite effect. When it is in resonance under the action of the ultrasonic wave, the blade polarizes alternately, that is to say on its sides appear alternating electrical charges.

One can also use the phenomenon of magnetostriction: The variation of AC dimensions which crosses the windings of a coil.

Ultrasound is strongly absorbed in gas and poorly absorbed in liquid and solid. Their intensity can reach values up to 10 atm.

Since the intensity is proportional to the square of the amplitude and the squares of the frequency, the vibration amplitudes of the particles are high.

The orientation of bats, for example, is based on the fact that they emit short ultrasonic signals with frequencies between 30 to 60 kHz. Flying bats emit on average approx. 30 signals per second. Some of them are perceived by the large ears of bats in the form of echo signals after a period of time depending on whether the obstacle is closer or further away (the closer the obstacle the more time is short) . When the bat approaches an obstacle it emits more and more signals up to 60 signals per second, for example, for the obstacle located at 1 meter distance. This allows the bat to accurately grasp the position of obstacles.

The practical use of ultrasound is related to its short wavelength. So, for example, ultrasound can be delivered and propagate like rays of light in packets, unlike ordinary sounds which scatter in all directions. Thus, it is found experimentally that if the wavelength of the emission is lower than the linear dimensions of the source wave it propagates in a straight line as a beam. Also, due to the short wavelength, the phenomenon of diffraction (around obstacles) occurs only for very small obstacles, since usual waves avoid almost any obstacle in their path.

Ultrasound undergoes reflection and refraction at the surface separating two different media, just like light waves. Using this phenomenon special concave mirrors or lenses have been constructed to focus in an ultrasound beam.

An interesting phenomenon that occurs in the propagation of ultrasound in the fluid, is the **PHENOMENON OF CAVITATION** which is the appearance of bubbles that rise to the surface and burst.

This is explained by the fact that the very rapid expansions and compressions in the liquid lead to strong tensions in certain zones which cause the liquid molecules to "break". This produces bubbles containing vapors and gases dissolved in the liquid. Small bubbles merge into large bubbles begin to vibrate and then break up giving rise to very high local pressures which manifest as hydraulic shocks in very small volumes. Damage to turbine blades and ship propellers is caused by cavitation produced by machine-generated ultrasonic vibrations.

Before discussing some of the practical applications of ultrasound, let's see how it is produced. Here we take the example of the piezoelectric generator. The piezoelectric effect: if the crystal is subjected to deformation by traction or compression in different directions, electrical charges appear on its sides, equal and of opposite sign and which changes the role depending on whether the compression by tension, and vice versa. There is also the inverse piezoelectric effect or electrostriction, on which the generation of ultrasound is based, which consists in the successive expansion and compression of the crystal under the action of an alternating electric field.

Ultrasound can be produced using the magnetostrictive effect which consists in the deformation of ferromagnetic bodies (iron, nickel, cobalt) under the action of a magnetic field. By inserting a bar of such material (Ni) in a magnetic field parallel to the length (produces, for example, a coil in which the bar is inserted), it is shorter. When the magnetic field varies periodically (current flowing through the coil is periodically) bar shorts periodically.

Through high frequency and high energy carried by ultrasound, ultrasound produces a series of physical and chemical effects among which: the destruction of labile equilibrium states; heating medium; the formation of dispersed systems (emulsions and suspensions) and the destruction of these systems (coagulation); influence electrochemical potential and passivity of metals; buckling of photographic plates; increase the rate of chemical reactions; furnaces less stable substances (e.g. nitrogen iodide), etc.

The properties of ultrasound allow its use in a wide variety of practical applications.

Sound waves produce heat and the redistribution of substance in living cells which leads to their therapeutic use (the heating of certain tissues and deep massage) and to preserve food (through the use of frequency appropriate and intensity ultrasound to destroy microorganisms).

Another application of ultrasound is related to measuring the depth of the sea. The process is essentially the same as when using conventional sound, however having the advantage of directed beams. It is also possible to produce very short signals, which increases the precision of the measurement of the time interval between the production of the direct signal and the recording of the reflected signal.

Ultrasounds are used in various processes such as washing, cleaning, drying or welding as well as for the transformation of parts.

Another field that uses ultrasound technology very much is the medical field. For example scanning a woman's pregnancy, using ultrasound or to break up kidney stones, surgery is no longer necessary there.

ELECTROMAGNETIC FIELD USED IN BIOPHYSICS. INTRODUCTION

Oriented movement is generally random movement in space, taking into account objects in the environment, the presence of other human beings, spatial landmarks, cardinal points, etc. Random motion is motion with preferential directions. It is related to finding favorable conditions of life, avoiding unfavorable conditions, finding nourishment, etc. In determining a leading role the oriented movement played by physical factors in the environment or the physical properties of the environment and objects (animals have evolved, these chemical properties are detected by the sense organs of the smell, taste, etc.).

Orientation subordinates varied manifestations, at all levels of phylogenetic development, from unicellular to multicellular plant and animal kingdoms. Physiologists distinguish between very near and far orientation and direct orientation (as in tropism) and indirect orientation (which assumes memory).

The movements of unicellular plants and mobile animals is called tactism (photo-thermal, galvano-chemotaxis etc.). The tactisms are positive when their movement is at the source of excitation (for example, algae have a positive phototactism when they seek light), and negative when the movement is in the opposite direction. The direction of the tacticism can depend on the intensity of excitation. Navicula radipsa shows a positive tactism intensity of 20-30 and a negative tactism intensity between 100 and 10,000.

Tropisms are oriented movements where the direction of movement of bodies is determined by the physical or chemical agent of the environment (geotropism, phototropism, chemotropism etc.).

ELECTROMAGNETIC FIELD USED IN GUIDING BIOPHYSICS. INTRODUCTION

Orientation includes specific events such as:

- explore the nearby environment;
- detect environmental objects or beings that have a special value for the animal (housing, food, enemy, sexual partner);
- ability to find useful spatial cues in recognition and recovery family space (hive nest etc.), location, back to nest (Anglo-Saxon), etc.;
- maintaining it in an appropriate manner during aquatic or terrestrial migration, flight (birds travelling), etc.

These events require the existence of sense organs appropriate to the way of life and the way of moving, which proves a "sense of space". In the case of vertebrates, the sense of space is given by the presence of the semicircular canals of the inner ear. It is often closely linked to a "sense of time" a real biological clock. This inner clock (clock) shows its presence in this value of excitation(signal) environmental factor which varies from hour to hour and sometimes d From moment to moment, in this case, you could speak of a biological calendar. The "Compass" as biological animals automatically performs a correction of the hourly data indicated by the sources of natural light. Similar to the navigator which determines the geographical coordinates according to the position of the sun and the stars.

The Haming has been explained by two types of hypotheses. Some authors (F. Petter) must admit that the animal by a methodical search, selects from the environment auditory, visual or olfactory landmarks which can indicate the general direction of their habitat. Rodent species that excel in their sense of direction have exceptional hearing abilities, thanks to the hypertrophy of the bony cavity of the middle ear (tympanic bulla). Other authors argue that the animal has a "sixth sense" of orientation, through which habitat is found almost without probing by rapid, straight motion. The hypothesis is based on observations made on the different species. E. Indenlaub found, working on small rodents, that individuals placed in a cage with radial symmetry, having differently oriented exits preferentially choose the direction of the nest (at least if the nest is located at a distance of less than 3km). In newts also the return to the nest is constant at 38-58% of the experiments of arbitrary removal of specimens (Twitty, Grant Anderson) at a distance of 2.5-4 km. Like the bat, rodent eyes do not seem to interfere essentially in homing.

GUIDANCE BY SOUND

Hearing is the result of mechanical vibrational stimulation of a certain frequency, intensity and pitch, called sound. The frequency of mechanical waves capable of impressing the human ear is between 16 and 20,000 Hz. These limits depend on the age, the person, etc. Vibrations outside these limits can be detected by other senses and not by the ear.

At frequencies lower than noise, vibrations of greater amplitude than sound are perceived by tactile contact. Vibrations with frequencies above 20,000 Hz (ultrasound) are perceived by the different nerve endings in the tissues only when their energy is so great that it produces local heating or cell damage.

All vertebrates have the homologous hearing system to that of humans, but the frequency at which they respond is different from the frequency at which the human ear responds. Thus, insects sensitive to vibrations or to very high frequency have particular receptors, the operating mechanism of which is different from the functioning of the human ear. Some plants, such as Paramecium, also respond in some way to vibrational energy (low and moderate energies) as exciting.

The simple sound or pitch, such as that given by the vibration of the tuning fork, exerts an acoustic pressure p, periodically oscillating and can be represented by $p = p_0 .\sin 2. \pi. \upsilon.t$

where P0 is the maximum amplitude of the pressure or sound pressure, a sound of frequency ν (ν being the reciprocal of the period T), and t-time calculated from an instant t0 that the origin and which measures the pressure p.

The sounds produced by musical instruments, the vocal organ of humans or animals are compound. In such a sound we distinguish the fundamental tone, with the lowest frequency and the harmonic frequency which is an integer multiple of the fundamental frequency (for example 2ν, 3ν, ..., nν). Each sound can be decomposed (mathematically, ent) according to Fourier series into a fundamental sound and its higher harmonics.

In the measurements and calculations, the effective sound pressure Pef is generally considered, which has the following value: $p_{ef} = \frac{p_0}{\sqrt{2}} \approx 0,0707p_0$

The unit is bar or microbars.

By analogy with electrical impedance, we can speak of sound impedance as a physical quantity that characterizes the resistance that the environment opposes to the passage of sound waves;

It is measured in ohms and mechanical Ωmec. AT.

The impedance of the eardrum (which depends on the frequency from 700 to 800 Hz) is minimal and amounts to ~ 10 Ωmec, therefore very close to that of air (T. Tröger, 1936). In other words, the

eardrum provides conductivity without reflecting sound and without any sound absorption or attenuation.
Sound energy (compared to surface and time) gives sound intensity. The ear is sensitive to certain intensities, located between the lower auditory threshold Im and the upper auditory threshold IM. The minimum intensity of sound that can be perceived by the ear is called the lower hearing threshold. The maximum intensity of the sound after which gives the sensation of pain is called upper or painful hearing threshold.
The hearing threshold is below a minimum "optimal" frequency of 2000 Hz, and IM is maximum near the same frequency.

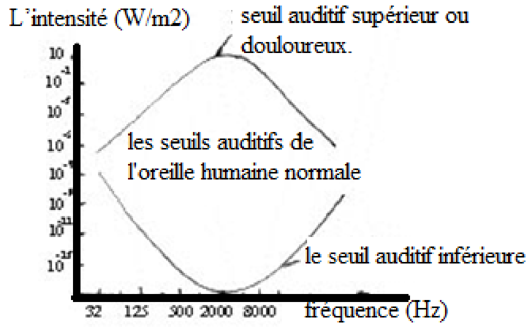


Figure 90: hearing thresholds of the normal human ear

The curves indicating the hearing frequency thresholds are called hearing curves (hearing).
The area between these curves represents the audibility range.
The ratio is very high for the human ear.
Defined above, the sound range therefore has the value of

$$\frac{I_M}{I_m} = \frac{\left(2\cdot 10^3\right)^2 / 43}{\left(2\cdot 10^{-4}\right)^2 / 43} = \frac{10^6}{10^{-8}} = 10^{14}$$

In the process of hearing, it is not the real absolute intensity of the sound that is of interest, but its relative value or sound level, i.e. the intensity of the sound I, in relation to the threshold lower auditory. The sound level Ns of the sound is defined by the decimal logarithm of this ratio, ie.

$$N_s = \log \frac{I}{I_m}$$

As I is (as shown in acoustics) proportional to p ^{2}

$$N_s = \log \frac{p^2}{p_m^2}$$

The value of this ratio is expressed in units called Bell with submultiple decibels. In decibels, its value is $N_s = 10 \log \frac{p^2}{p_m^2} \mathrm{dB} = 20 \log \frac{p}{p_m} \mathrm{dB}$

The lower hearing threshold increases with age, but also when the ear is exposed to noise for a long time (blacksmiths, boilermakers etc.).
The energy corresponding to common sounds is very small. When 2000 people speak continuously for 0.5 hours, the energy of the voices is enough to boil a cup of tea.

EAR AUDIO SYSTEM

The organ which perceives sound vibrations and transforms them into nervous excitation which produces auditory sensations is the ear.

It forms, together with part of the nervous system, the auditory analyzer, which makes it possible to distinguish the intensity, pitch and timbre of a sound, the direction from which the sound comes, the distance from the sound source , etc.

A brief overview of the human ear, with its three main parts, the outer, middle and inner ear is-depicted in the figure drawing

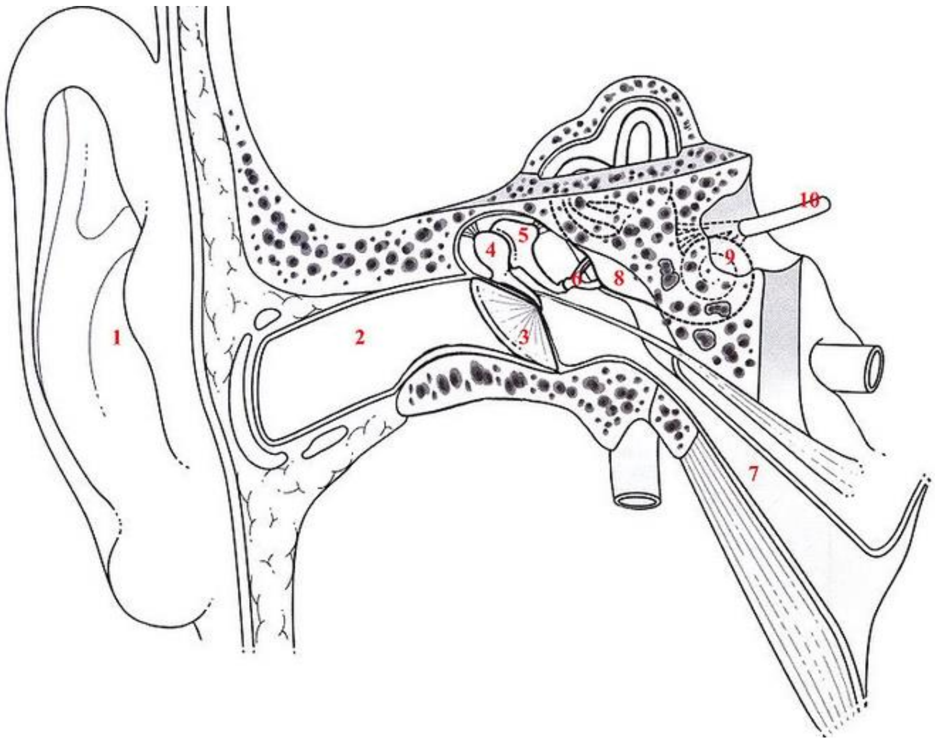


Figure 91: The normal human ear

Diagram of the ear:

1) Pavilion

2) External auditory canal

3) Eardrum

4) Hammer

5) Anvil

6) Stirrup

7) Eustachian tube

8) Inner ear

9) Cochlea

10) Auditory nerve

EAR AUDIO SYSTEM

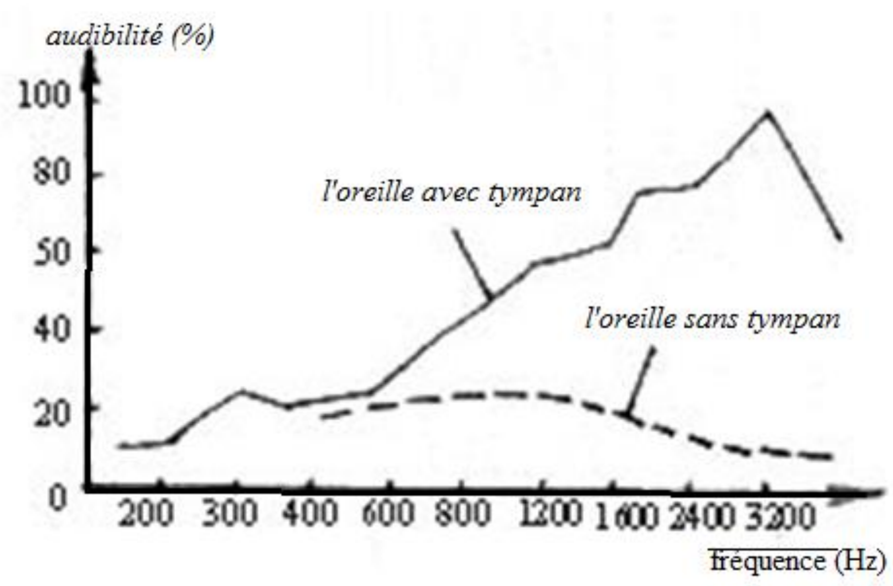


Figure 92: Diagram of audibility of the ear with and without eardrum depending on frequency

The outer and middle ear contain air and are designed to conduct sound waves from the inner ear whose channels contain fluids: perilymph and endolymph.

Although the inner ear's organ of Corti is linked to a cranial nerve, only the cochlear portion of the inner ear is associated with hearing.

Sound waves in the air are trapped in the pinna, which directs them to the external auditory canal.

In the external auditory canal which serves as a closed acoustic tube with the eardrum connecting one of the ends, the sound pressure is maximum for the eardrum, where the speed of sound is low. For the open side of the tube (outside the ear) the pressure is minimum and the velocity maximum.

The movements of sound waves striking the eardrum have been studied particularly at low frequencies, and the results have been extended by and for higher frequencies. At a frequency of 1 kHz, the speed of the particles is 0.1 and the displacement is 0.1, less than the radius of an atom (surprising assertion).

The three (oxy) ossicles of the middle ear: hammer, anvil, stirrup, on which sound energy falls, are designed as levers with unequal arms and act as mechanical transformers.

They amplify the sound pressure of vibrations transmitted through the air to the eardrum. Another role is to decrease (at high intensity) their sound energy entering the inner ear. This is done by the

tension that varies in the muscles and the tendons that bind them. This is an example of "automatic control" the middle ear seeks to maintain a certain level of sound waves entering the inner ear.
The sound pressure p, transmitted by the eardrum increases at the oval window. Considering that the surface of the eardrum in contact with the hammer is 0.55 cm2, the force exerted on the hammer is. But the magnitude of the force, in the absence of friction is.
The scale pressure on the 0.032 cm2 area of the oval window is

$$p_{t_0} = \frac{F_s}{0{,}032} = \frac{1{,}3 \cdot 0{,}55 p_t}{0{,}032} \approx 22 p_t$$

Thus, the theoretical amplification pressure from the eardrum to the oval window is 22 times. The measurements made by Békésy show that the real gain is 17 times, which corresponds to a gain of 25 dB sound pressure.
It can be said that the middle ear carries sound energy from the gaseous environment into the liquid environment of the inner ear, amplifies the pressure and protects the inner ear from excessive sound pressure.
The Eustachian tube, which connects the middle ear to the pharynx, makes both sides of the eardrum to maintain approximately the same air pressure environment, protecting it from distortion that could destroy. The amplification of the sound pressure produced by the outer ear on the average is greater than 35 dB.
From the middle ear, sound waves pass into the inner ear, the central part of which is the bony labyrinth, carved into the rock of the temporal bone. The last part of the labyrinth is formed by the cachlea or the meteor whose spiral shaft (columella) stands out from the spiral blades, ending before the tip of the columella with a free edge.
The space between this free edge and the tip of the columella tip is called Helicotrema and serves to balance the pressure differences on the two sides of the cochlea. Inside the bony labyrinth is the membranous labyrinth, which includes several cavities.
The perilymph fills the space between the bone and the membranous labyrinth, and the endolymph is in the membranous labyrinth. The cochlear duct, which occupies part of the ramp labyrinth, has the shape of a triangle in section, one of its sides is the basilar membrane.
Sensory cells are found in the organ of Corti Gasec, located on the upper surface of the basilar membrane. Here are the ends of the auditory nerve fibers. The cochlea can be considered a biophysical system in which sound waves are converted into nerve impulses.

THE AUDITORY SYSTEM transmits information to the central nervous system regarding air pressure variations.

THE TRANSMISSION MECHANISM consists of:

1. Internal ear and middle ear

2. the cochlea

3. The auditory nerve and the pathways to the various central nervous structures

- **The first stage** is a mechanical impedance equalization device that transmits pressure variations from the air to the cochlear fluid with very little energy loss.
- **The second stage** is the seat of nervous tissue excitation, a process that depends on an external source of energy. Energy for nerve conduction is provided by the body's metabolism.

SOUND RECEPTION

The main applications of these transformations are grouped into two theories:

RESONATOR THEORY AND TELEPHONE THEORY.

In the **RESONATOR THEORY** (developed by Helmholtz in 1863), the basilar membrane, made up of 24,000 elastic fibers, is considered to be a system of acoustic resonators, each fiber being independently a resonator. The basilar membrane is narrower at the base of the cochlea and wider near the helicotrema. Therefore, the length of the transverse elastic fibers increases from the helicotreme base in a ratio of approx. These fibers can be compared to the large metal chains of a piano. At the top of the cochlea can be located resonators for lower sounds, and at its base - resonators for higher sounds. Each sound entering the ear, with its own frequency, vibrates a single resonator on the vibrating fiber which gives the same sound, and each fiber (resonator) on the basilar membrane excites a nerve fiber. The pitch of the sound is detected by the vibrating fiber and the sound pressure by the amplitude of the fiber.

In support of this theory is the fact that by injuring the membrane of the basilar ear of animals (dogs, cats, guinea pigs) in certain parts , the ear is deaf to sounds located in a certain range. The closer the organ of Corti is injured near the base, the more the sound frequency cannot be "heard". Experiments done on mice and reported that for different octaves the resonators do not occupy equal areas on the basilar membrane. The lower five octaves occupy less area than the higher four octaves, and the speech frequencies the longest part.

Békésy G. has subjected the theory of experimental resonance to experimental and multilateral critical examination. If basilar membrane fibers were comparable to the taut coards of a piano, their resonant frequency should correspond to the formula (acoustic set); where l is the length of the string, P - tension (force) stretching, ρ - mass unit length. When the sound frequencies perceived by the ear (16 to 20,000 Hz) vary by approximately 103 times, it would have to vary times. But Békésy's measurements show that the basilar membrane can withstand the postulated tensions of the high-pitched resonators.

According to the TELEPHONE THEORY the cochlea acts as a microphone which transmits the signal along the nerve fiber, the shape of which is the same as the sound wave entering the ear. According to a variation of this theory, the nerve fibers located near the windows are stimulated by soft sounds, while intense (high) sounds activate the entire cochlea.

Thanks to electronic tools in the ear, three types of electrical potential can be registered: the cohear microphonic potential, the action potentials of the VIII th cranial nerve (auditory nerve) and the resting potential DC (direct current).

The cohlear microphonic potential, not exceeding values like 100 mV, has its origin in the cochlea. It decreases exponentially along the auditory nerve and the surrounding tissues of the cochlea: it has no refractory period and can be produced by sound with a frequency of more than 16,000 Hz, reproducing the sound waveform applied to the cochlea. Békésy argues that the potential energy of this microphone is not given entirely by the mechanical energy of the sound which causes it, but by the metabolic energy reserve measured by the resting potential. The latter is very high: 50 mV in the fluid of the cohlean canal and 5 mV in the organ of Corti.

According to telephone theory, the conversion of acoustic energy into electrical energy could be carried out in the following sequence: sound pressure → microphone potential → nerve impulses . The telephone theory is contradicted by the fact that a single fiber cannot conduct more than 1,000 pulses per second. This means that the nerve fibers could lead to ring with a frequency of up to hundreds of hertz (at a rate as low as 1 Hz several hundred pulses are needed). However, a group of fibers acting simultaneously can lead to a high frequency vibration.

According to the HYDRODYNAMIC THEORY of Békésy, in addition to the known longitudinal acoustic waves, also occur in the cochlea hydrodynamic waves similar to the waves observed at the surface of the water-oil or water interface. Their speed is not constant but varies according to the frequency. In the cochlea there are areas where the crowding of these waves is maximum. The most important action of the cochlea would be to transform these maximum hydrodynamic waves into nerve impulses. The transformation is mediated by the "microphone" potential born in the membrane.

SOUND constitutes from a physiological point of view the sensation produced on the auditory organ by the material vibrations of bodies and transmitted by way of acoustic waves.

The human ear is sensitive to air vibrations with frequencies between 20 Hz and 20 kHz, with a maximum hearing sensitivity around 3500 Hz.

This range depends greatly on the amplitude of the vibration and the age and health of the individual.

Below the amplitude of 20 µPa the vibrations can no longer be perceived.

With age, the range of sensitivity decreases, especially high frequencies cannot be heard.

SOUND CHARACTERISTICS

Pitch or frequency is the sound's characteristic of being deeper, graver or sharper (sharp or thin).

The intensity or loudness of sound is determined by the amount of energy the sound wave carries. It is objectified in the amplitude of the wave and is measured in **decibels.**

Timbre – between sounds of the same intensity and pitch and the emission of different instruments there is a qualitative difference called the timbre of the sound**.**

Thus, for a person to perceive the pitch of a sound well, his ear must receive sound waves for at least 1/100 of a second. Through practice, this limit can be lowered as well as the differential threshold for discrimination of sounds can be educated.

0 db	➜	**silence**
10 db	➜	**rustling of leaves**
30 db	➜	**whisper**
40 db	➜	**a quiet room**
60 db	➜	**speaking**
80 db	➜	**music played loud**
110 db	➜	**pneumatic hammer**
120 db	➜	**the plane taking off**

APLICATIONS IN PHARMACEUTICAL FIELD

HEARING PROSTHESIS.

Hearing prostheses are electronic devices that are an aid in the perception of language and the acquisition of verbal communication. These prostheses cannot correct the deficiency, but they can replace or minimize its effects.

Hearing prostheses differ in design, size, type, amplification mode, ease of wearing or volume control. All prostheses have common components:

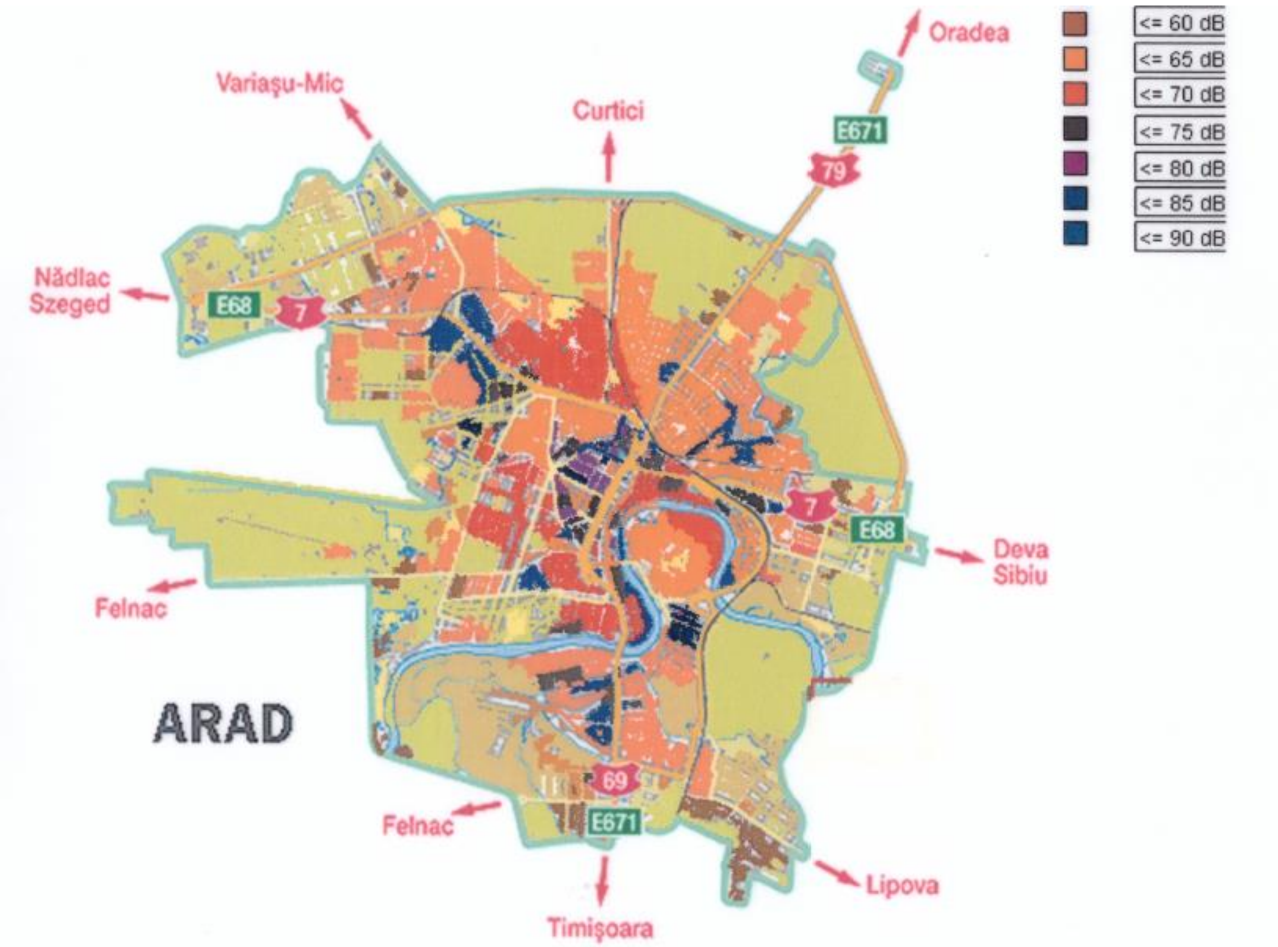
- microphone that collects sounds from the environment;
- amplifier for the size of the intensity of sounds;
- receiver through which amplified sounds are transmitted to the ear;
- batteries to support the entire system with

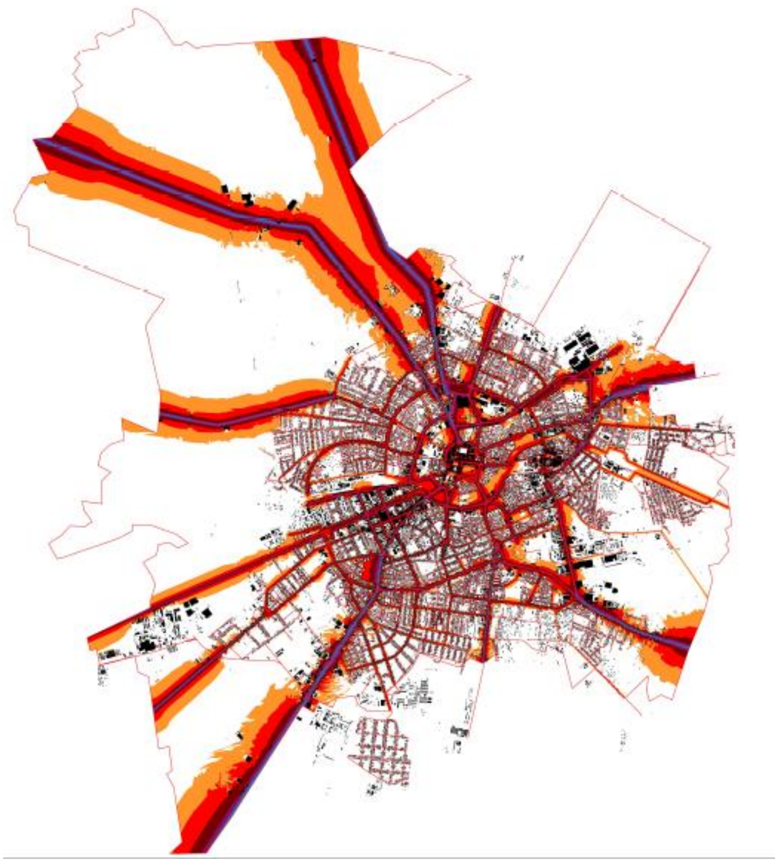

hearing prostheses in the ear canal (these are the smallest types of prostheses and offer aesthetic advantages);



behind-the-ear/postaural hearing prostheses (the components of the hearing aid are contained by a device placed behind the ear and connected to the ear).

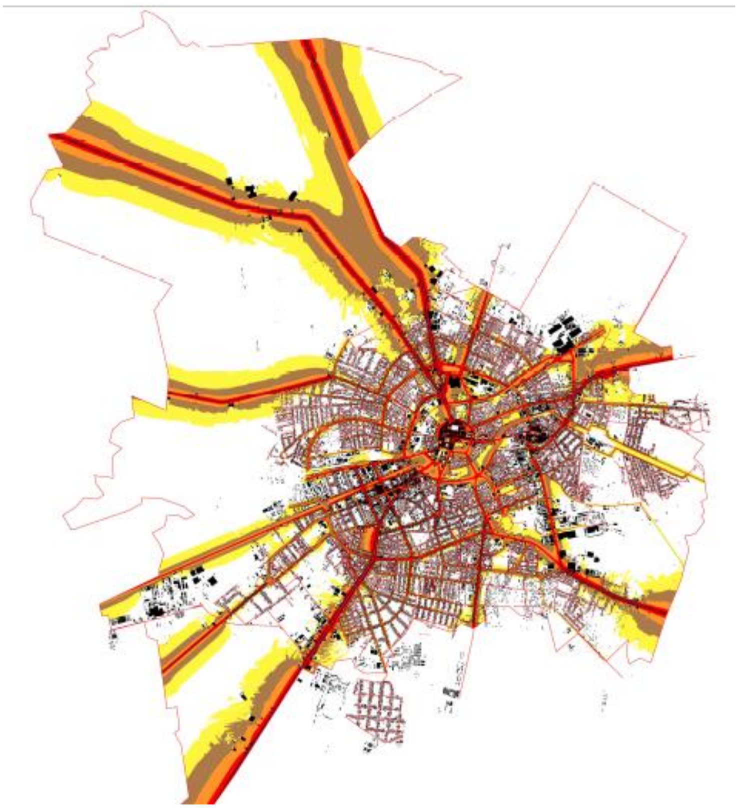
APPLICATIONS OF SOUNDS: NOISE MAPS





Timisoara during the day

Yellow	<=	50.0 dB(A)
Brown	<=	55.0 dB(A)
Orange	<=	60.0 dB(A)
Red	<=	65.0 dB(A)
Dark red	<=	70.0 dB(A)
Purple	>	70.0 dB(A)

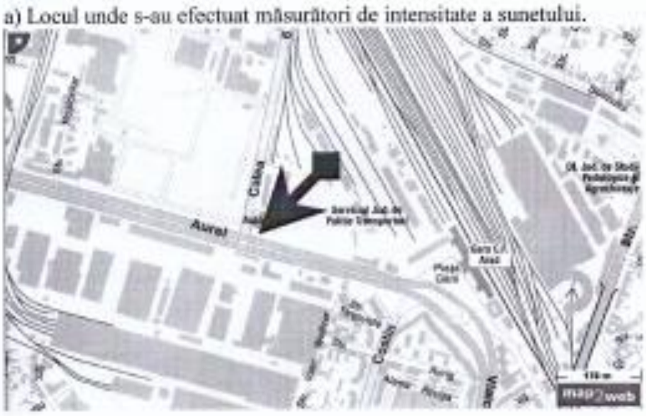


Timisoara during the nigth

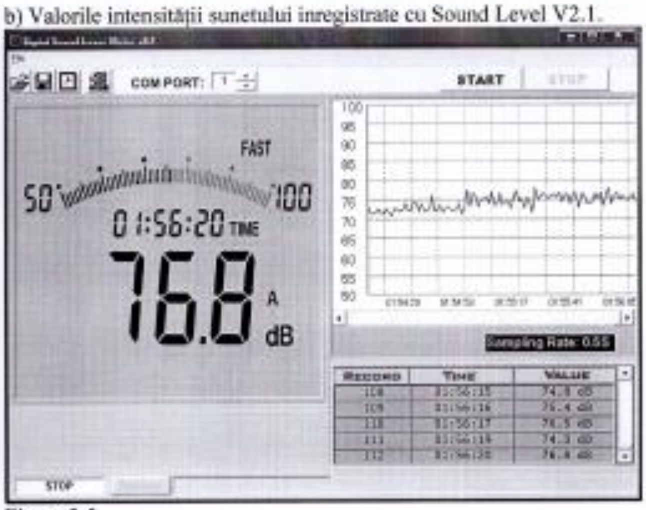
INSTRUMENTS USED FOR SOUND MEASURING: Digital Sound Level Meter MS6701 conected to a Note- book an be use to measure the sound intensity after a easuring of 2 minutes

• AUTOGARĂ

a) Locul unde s-au efectuat măsurători de intensitate a sunetului.



b) Valorile intensității sunetului inregistrate cu Sound Level V2.1.



Figuar 3.5

ULTRASOUNDS

The human ear - frequency spectrum (audio frequency) between 16 (20) -20,000 Hz, exceeding this limit, unapproachable for the human auditory sensor

>20 KHz = ultrasound

for technical-scientific reasons, for the precise delimitation of the accessible frequency spectrum, ULS 20 - 3000 KHz

ULS is classified - 3 categories:

- low frequency ultrasound - 20-100 KHz
- medium frequency ultrasound - 100-300 KHz
- high frequency ultrasound - 300-3000 KHz

production of ULS

- mechanical, thermal, magnetic, piezoelectric

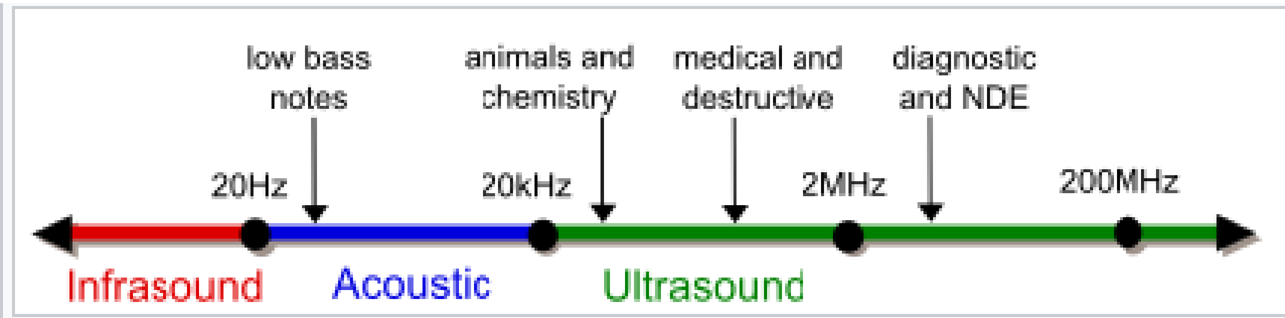
Ultrasound production:

Elastic bodies, following an excitation, perform oscillatory movements that are transmitted to the surrounding environment = sources of oscillation/ "transducers" (transducers)

Electroacoustic transmitters - the transformation of electrical energy into oscillatory energy, with the help of transducers based on the phenomenon of: piezoelectricity, electrostriction, magnetostriction

- produce ULS - values up to 100 MHz - emission of ultrasonic energy, either continuously or in pulses

Propertiesn of ultrasounds



PHYSICAL PROPERTIES

- Propagation / Spread
- Absorption
- Reflection

BIOPHYSICAL PROPERTIES:

Thermal phenomena are absorption – reflection : increase Heat Q (□ T by increasing temperature T with 3-4^{0}C) – produce hyperemia + hyperlymphemia and so metabolism is increased.

Mechanical phenomena (fundamental component)

at the application site, vibration amplitude = 100 x diameter ø of the molecule , by micromassage determine the inrasing of te cell membrane permeability

THE METHOD OF PRODUCING ULTRASOUND

The high frequencies corresponding to ULTRASOUND can be produced by the elastic vibrations of the quartz crystal induced to resonance by an applied alternating electric field (PIEZOELECTRIC EFFECT) [1]

[Halliday D., Resnick R., Fizica vol.I., EDP, Bucuresti, 1975, p.528]

Thus, sounds with frequencies up to 600 MHz can be produced.

The corresponding wavelength in air is approximately 5.10^{-5} cm = 500.10^{-9} m = 500 nm, comparable to the wavelength of light waves.

The first demonstration of the direct piezoelectric effect was made in 1880 by the brothers Pierre Curie and Jacques Curie

They combined their knowledge of pyroelectricity with an understanding of crystal structures leading to pyroelectricity predicting crystal behavior and demonstrated the effect using crystals of tourmaline, quartz, topaz, cane sugar and Rochelle salt (sodium tartrate tetrahydrate).

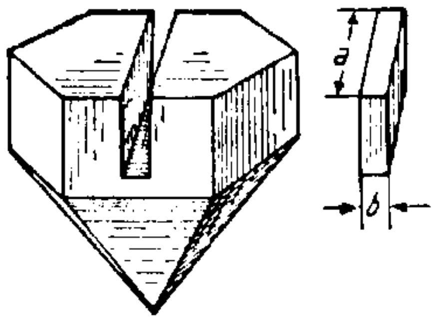
Quartz and Rochelle salt exhibited the highest piezoelectricity.

The direct piezoelectric effect and its inverse are the primary means used in biomedical ultrasonography regarding the conversion of acoustic energy into electrical energy and vice versa.

Piezoelectricity has numerous bioengineering applications ranging from ultrasound imaging and therapeutics, to piezoelectric and microelectromechanical surgery, as well as to biomedical implants.

Due to its fundamental importance for the proper functioning of ultrasonic systems, most doctors must understand the general effect, the history of its development and, for this reason, an appreciation of its limitations and advantages in the generation and detection of ultrasound is required.

This article describes the historical development associated with its use in relation to most medical ultrasound applications and is intended to serve as an introduction to non-expert readers.



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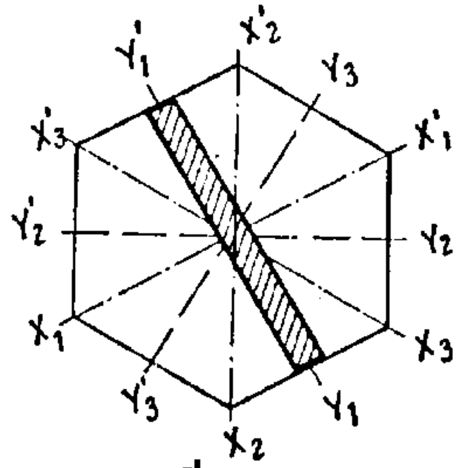


d

The quartz blade is cut along a direction perpendicular to an X axis ("X" cut) and subjected to a compression along the corresponding Y axis, its faces (perpendicular to X) different electrification, one positive and the other negative.

Reversing the mechanical effort (stretching) also reverses the polarity of the electrical charges on the faces the phenomenon of piezoelectricity - reversible: putting the plate to an electric voltage, it contracts / elongates, depending on the polarity of the voltage.

The piezoelectric properties depend on the dimensions of the blade, the cutting angle and the mode of excitation.

The factor that most influences the frequency of a quartz oscillator - the variation of parameters with temperature.

APLICATIONS OF ULTRASOUNDS IN MEDICINE

The average speed of propagation of ultrasonic waves in

- air = 330 m/sec,
- biological tissues = 1500 m/s

Biological effects of ultrasonic vibrations - for therapy 800-1200 KHz - optimal frequency = 800 KHz

Irradiated tissues - sufficient energy, considering that the absorption of emitted energy is a function of frequency

The vibration energy, generated by an ultrasonic source, is transmitted to the surrounding environment - vibratory movement

Tissues of living systems - behavior similar to that of liquids - propagation of ultrasonic vibrations takes place in the form of longitudinal waves, except - bones (transverse waves, of negligible energy) the ultrasound resistance of air with a negligible value in relation to that of living tissues,

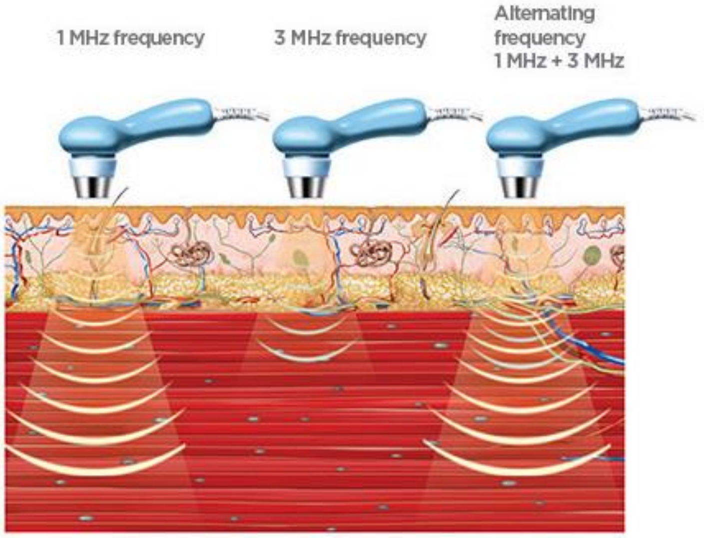
ULS produces ~100% sound wave reflection at the air-tissue interface

In medical practice - it is not possible to introduce ultrasonic energy from the air into the body - the elimination of the air interposed between the ultrasonic transducer (solid) and the skin - layer of cream / special gel

The presence of an air layer, with a thickness of 1 µm, cancels the transmission of ultrasonic radiation in the biological tissue

Very high frequencies, absorption in tissues - high, increased intensities, efficiency only in superficial tissues

Low frequencies - the depth effect is increased



http://callyourdoc.net/ultrasound-therapy

ULS - WORKING TECHNIQUE

ULS - "underwater" irradiation (water) - valves of different sizes, with water heated to a temperature of 36-37°C, because below or above this threshold, ultrasound changes its intensity (positive or negative), altering the effects

The ultrasonic emitter - distance of 2-3 cm from the skin (via a special support), the radiating surface of the emitting capsule should be kept parallel to the surface of the skin and the beam of ultrasonic waves should propagate perpendicular to the tissue - increased depth effect

ULS METHODS OF APPLICATION:

- **continuous mode** - ultrasonic energy continuously, throughout the treatment
- **pulse regime** - ULS in the form of "trains" (burst); Rhythmicity at a frequency of 50 or 100 Hz, the thermal (caloric) effect on the tissue is reduced
- **modulated mode** - continuous variation of the amplitude of ultrasonic waves (MA), with "envelopes" of various shapes (triangular, exponential, rectangular, trapezoidal), auxiliary device called "excitation generator", which is connected to the ultrasound device by means of a cable specialized

ULTRASONOPHORESIS

ULTRASONOPHORESIS represent thepenetration of some pharmaceutical substances into the irradiated body

drugs that can be introduced into tissues by means of ultrasound:

- hydrocortisone,
- local anesthetics (procaine 2%);
- analgesics

Ultrasonophoresis is a therapeutic method that presents important therapeutic successes in various diseases such as: inflammatory rheumatic diseases (not exacerbation of inflammation), degenerative rheumatic diseases (coxarthrosis), tendinitis, traumatic and orthopedic diseases, scapulo-humeral periarthritis dislocations and contusions and sprains

Ultrasound has the ability to favor the passage of the medicine through the skin and to help its action in the deep tissues.

As more ultrasonophoresis sessions are performed, the dose of medicine that penetrates the deep tissues increases (effect desired by the therapist).

Ultrasound cannot be applied directly to certain regions such as the hand, elbow or ankle, due to the irregular relief of these segments. Thus, a container with water will be prepared in which you will hold your hand, for example, after which the ultrasound emitter will be inserted, which has a more special construction and which is kept at a distance of 2-3 cm from the region to be treated. The method just described is indirect ultrasound therapy.

Important, complex phenomenon = cavitation, representing a concentration of acoustic energy on very small volumes

Cavitation = strong traction forces act on a liquid, its rupture occurs, by creating microscopic voids, followed by the restoration of the liquid, by closing the voids

The local breaking of the liquid - overcoming the cohesive forces - requires very high (mechanical) stresses

Transient cavitation, at the moment of the bursting of gas bubbles (which contain water vapor, the temperature of which reaches 2000°C) => shock wave of the order of tens of thousands of atmospheres, which destroys cells and macromolecular structures

The increase in pressure and temperature following the "implosion" of the cavitation bubble - time interval of 0.01-0.1 µsec

functional parameters of the device:

-start switch (optically signaled)

- the "working mode" switch (continuous, impulse, modulated)
- regulator of the emitted power;

"timer" (clock for the duration of the session)

- measuring instrument as an indicator of applied energy (W/cm2)

in overdose determine the rupture of the cell membrane (so the contraindications: on growth cartilage, on facial regions due to retinopathy and post-traumatic cataracts, in laminectomized patients due to the production of spinal cord injuries).

The cavitation effect = the breaking of the extracellular H2O molecule during the compression wave and the restoration of the valences during the decompression wave with a f= fULS □ □ redox reactions, □ the diffusion process, the pH shift towards alkaline, ionic changes, the release of substances with pharmacodynamic action, the transformation of colloids from a gel state to a solid state, changes in the ratio of protein fractions

ultrasound dose = the amount of energy absorbed in a unit of time, by a unit of volume of the irradiated object

The physico-chemical effects of ULS in continuous mode and in pulses:

Domain I (0.1-0.4 W/cm2) – low intensity – with insignificant, reversible changes

Domain II (0.5-0.6 W/cm2) – medium intensity - maximum physico-chemical action (domain of medium therapeutic intensities)

Domain III (0.8 W/cm2 and above) – high intensity – stable and irreversible changes in the experimental environment

Biological Effects of ULS:

Analgesic effect: due to the mechanical + thermal effect and at doses of 0.05-0.5 W/cm2 it has action especially on the nerve root - lymph nodes - muscles

Myorelaxant effect: through the mechanical effect = micromassage; indicated in algic muscle contraction (primary) = myopathies and in antalgic (secondary) = discopathy. Contraindicated in analgesic muscle contraction = central motor neuron syndrome.

Metabolic effect: due to the cavitation effect at doses of 0.5-1 W/cm2 - increase in cellular permeability and the possibility of applying ULS . ULS in combination with ionizable drugs is used in ultrasonophoresis

Resorptive and fibrinolytic effect: at doses = 1-2 and 3 (less used recently) W/cm2

ULS Instrument AS01

https://terapievertebrala.ro/ro/fizioterapie/aparat-ultrasunet-ak01.html

Functions

Ultrasounds have an effect on the human body and are related to natural therapy, which has a history of 50 years.

For the obvious effects of use, this technology is known to be one of the best performing technologies.

Ultrasound machine treatment is a high-tech product with three effects of ultrasound, it has mature technology, reliable effects, and does not cause trauma, radiation and adverse effects, etc.

High frequency mechanical effects

Ultrasonic vibration can cause the cells to move, thus having massage and pain-relieving effects.

It accelerates metabolism, improves blood and lymph circulation, improves tissue nutrition, changes the degree of protein synthesis, increases regeneration, etc.

Creates cytoplasmic flow, oscillation, rotation and friction of cytoplasmic granules. It can stimulate the propagation process of the semipermeable membrane of cells, causing the degree of propagation and changes in membrane permeability.

Thermal effects:

It intensifies the number of open blood capillaries, intensifies blood circulation, strengthens metabolism.

It intensifies the tension of muscle tissues and connective tension, relieves cramps.

It improves the partial nutrition of tissues, increases the activity of enzymes. Promotes the establishment of collateral circulation.

It is good for absorbing congestion.

Penetration effects

Improving membrane penetration, bacteria accumulate faster in the medicinal environment.

Mast cell degranulation, increased intracellular calcium levels, increased vascular permeability, development of blood vessels and collagen elasticity, etc.

The ultrasonic machine can create enzyme inactivation in oxidase and dehydrogenase and promote the invertase effect.
The ultrasound machine can affect blood flow, angiogenesis, collagen dissolution and scar maturation applications of ultrasound
Ultrasounds are produced by mechanical oscillations with high frequencies, over 20 kHz.
Like sound, ultrasound propagates linearly (being partially absorbed by the medium), reflects and refracts.
Reflection is the basis of the echo, important in the biological and technical applications of ultrasound.
Ultrasonic waves can be localized with acoustic mirrors or lenses (with energy concentration up to 5 kW/cm2).
In organic media, some longitudinal ultrasonic waves (compression waves) are converted into transverse waves. In a viscous medium such as protoplasm, these waves are very quickly attenuated.
The transformation of ultrasonic energy into other forms of energy can be done in a very small volume of tissue, because the wavelength is very small (on the order of microns, for example); the volume required for such a transformation is much smaller than that required for the transformation of radio waves
At the border between tissues of different densities and hardnesses, the absorption of ultrasonic energy is very high.
The transformation of ultrasound energy into heat is used in therapeutics, and the transformation into heat occurs inside the tissues, which removes some of the frequent shortcomings caused by external heating.
High-intensity ultrasound destroys cells suspended in water (or other liquids). Their energy is intensively absorbed, without producing heating effects.
The destruction of isolated cells in suspension is mainly due to the so-called cavitation phenomenon. The compressions and expansions at a certain point become so strong that the suspension medium (water) "breaks" at that point. Bubbles or small gas cavities are formed, which are filled with liquid vapors, first expand a lot and quickly, then return to an extremely small volume and burst (implusion). Their breaking causes hydraulic shocks (hundreds or thousands of atmospheres) in the liquid. At the same time, electrical discharges similar to microscopic lightning occur in the bubbles, which cause chemical transformations. Phenomena of mechanical resonance of the cells are also added.
We mention that ultrasound can produce chemical reactions and disturb the colloidal balance.
At low energies (up to 1-2 W/cm^2), they produce biopositive effects: acceleration of seed germination, reactivation of defense forces and stimulation of the nervous and endocrine systems. Below 0.5 W/cm^2 there is no net influence of the propagation medium.

Ultrasonic waves produce echoes when they hit an obstacle. The devices with which these echoes are received are called sonars.

BEAUTY TREATMENT WITH ULTRASOUND

MEDIO SONO is a device used in the medical and cosmetic field; The 1 MHz and 3 MHz ultrasound probes have two different sizes (1 cm^2 and 5 cm^2). The duration of the therapy and the intensity are adjustable.

The ultrasound device is a complex device that can be used both in the field of cosmetics and in the medical field. It is a state-of-the-art device that has "miraculous" properties, thus helping to solve several ailments.
Used in body remodeling centers, the device can practically "disperse" fat cells, which give the unsightly appearance of orange peel - the fight against cellulite.
At the intradermal level, ultrasound acts by melting the fat cell conglomerates, dissolving them, thus allowing with the help of other techniques (massage, vacuum) to produce a total body remodeling without any discomfort on the part of the patient.
As a sensation, at the integumentary level, a slight heating of the place being worked is felt.
To "destroy" cellulite, the device is used with special creams with caffeine, grapes, or thermosudation creams. Results are obtained after a minimum of 12 sessions, being indicated even after this session to continue with at least one session per week, for maintenance.
This device is also used in the medical field, in several fields:

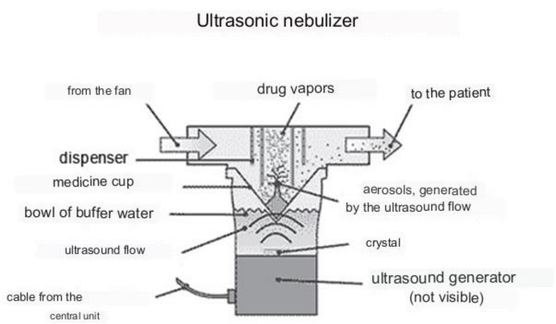
dermatological, vascular, orthopedic and even gynecological. Small skin conditions, dislocations, sprains, stretching of ligaments, broken vessels, etc. can be treated. Appropriate medical solutions will be used for different ailments. The sessions are customized according to the condition, working at different intensities.

All patients who used this device were satisfied with the results

ULTRASONIC NEBULIZER

Aerosol devices or ultrasonic nebulizers are silent medical equipment that transforms medication from liquid into microscopic particles with the help of ultrasound.

The most important advantage of the ultrasonic nebulizer is that it is a silent aerosol device. Aerosol particles, created by an ultrasonic nebulizer, can be in the 3.5-5 micron range, generally with fairly consistent particle generation.



[http://www.feo.ro/ce-este-un-nebulizator-cu-ultrasunete-.html]

ULTRASONIC NEBULIZER UN300A

The NEBTIME UN300A ultrasonic aerosol machine has the most efficient technology, being very silent

http://www.nbmedical.ro/ro/Dispozitive-medicale/Aparate-aerosoli/NEBTIME/Aparat-aerosoli-profesional-cu-ultrasunete-NEBTIME-UN300A-p76c59c61.html

Description:
Recommended for professional or personal use
The NEBTIME UN300A ultrasonic aerosol machine transforms medicines from liquid form into aerosols in an efficient and silent manner.
During the process of transforming the liquid into vapor, frequency is used instead of heating techniques.
The frequency is transformed into mechanical vibrations with the help of a piezo-ceramic crystal.
With the help of these vibrations, the liquid is effectively and quickly transformed into vapors. The vapors thus generated can be easily administered to patients.

ULTRASONIC EMULSIFICATION

The application of ultrasound and agitation individually or in combination to improve the emulsification of turmeric oil in skimmed milk was investigated.
The effect of different operating parameters such as addition of surfactant, sodium dodecyl sulfate (SDS), at different concentrations, amount of oil phase, applied power, sonication time and duty cycle on droplet size was investigated.
Emulsion stability was analyzed in terms of the fraction of emulsion that remains stable over a period of 28 days. The optimized set of major emulsification process variables was used at higher emulsion volumes. The effectiveness of the treatment approach was analyzed based on oil droplet size, energy density, and time required to form a stable emulsion.
It was successfully demonstrated that ultrasound-assisted emulsification in the presence of SDS could be used to prepare stable emulsions of turmeric oil in milk, also providing insights into the role of SDS in increasing the stability of emulsions and ultrasound in obtaining smaller droplet sizes .

ULTRASOUND IN ORIENTATION

Ultrasounds are produced by mechanical oscillations with frequencies above 20 kHz. Like sound, ultrasound propagates linearly (partly absorbed by the environment) is reflected and refracted. Reflection is the basis of the very important echo in biological and technical applications of ultrasound. Ultrasound waves can be localized by mirrors or acoustic lenses (with energy concentration up to 5kW/cm^2).

In organic media, some longitudinal ultrasonic waves (compression waves) are converted into transverse waves. In a viscous medium such as protoplasm, these waves are quickly attenuated. The transformation of ultrasound energy into other forms of energy can be carried out in a very small volume of tissue, because the wavelength is very low (micron, for example); the required amount of such transformation is much lower than that required to convert radio waves.

For example, 10 ^{6} Hz of the ultrasound wavelength λ us is only 1.5 mm (calculated by the formula; · cm s-1 for ultrasonic єm s-1 for radio waves), when the λ em of electromagnetic waves is 300 m. At the same frequency (1 MHz) the diameter of the ultrasound beam of 0.25 mm would correspond to a beam of electromagnetic waves with a diameter of 50 m. The movements acquired by the oscillating particles of the environment under the influence of ultrasound are small (10 $^{-6}$ cm), the speeds also (єm s-1), while the accelerations are very large (up to 105 -106g).

At the border between tissues of different densities and hardnesses the absorption of ultrasonic energy is very high. The transformation of ultrasound energy into heat is used in therapeutic treatment and heat transformation occurs in the tissues, which eliminates some common disadvantages caused by external heating.

High intensity ultrasound produces damage to cells suspended in water (or other liquid). Their energy is strongly absorbed without heating effect.

The destruction of single cells in suspension is largely due to the so-called cavitation phenomenon. Compressions and expansions at some point become so strong that the suspending medium (water) "breaks" at that point. Small bubbles or gas cavities, which are filled with liquid-vapour, first expand very rapidly and return to a very small volume and explode (implusion). Their explosion causes hydraulic shocks in the liquid (hundreds or thousands of atmospheres). At the same time, bubbles are produced by microscopic electrical discharge like lightning, resulting in chemical changes. Add the mechanical resonance phenomena of the cell.

Note that ultrasound can produce chemical reactions and disturb the colloidal balance.

At low energy (up to 2.1 W / cm2) biopositive effects: acceleration of seed germination, reactivation of defense forces and stimulation of the nervous and endocrine system. At less than 0.5 W/cm2 no net influence of the propagation environment occurs.
Ultrasonic waves produce echoes when they encounter an obstacle. The device for capturing these echoes is called sonar.
Sound and ultrasound echolocation are effective for the orientation of movements in relation to objects.
It is well known that bats move equally well at night and during the day, with their eyes open or closed. The part of their brain adapted to vision is much smaller than that reserved for hearing. If you cover the ears of the bat it loses its sense of direction, cannot hunt and comes up against obstacles, can no longer defend itself against enemies. Since 1918, DR Griffin and GW Pierce have shown that bats have a kind of sonar that detects pulses of ultrasonic echoes emitted from themselves.
Echolocation is also found in some birds, which use both sound and ultrasound, and in some mammals (for which sight and touch are not very useful). For mammals, it is found in bats (Chiroptera) in certain cetaceans (Tursiops truncatus) and (perhaps) pinnipeds. These devices are not equally developed at all bats. Thus, in microchiroptera, echolocation is widespread, while in megachiroptera (the vampire), which have well-developed eyes, hearing and smell, it is exceptional. Therefore, it has been speculated that echolocation is an adaptation to track mobile and small prey, in other words, an adaptation to insect diet. However, many carnivorous species (some vampire, for example, or Noctylia, which locates fish from water by ultrasound) use echolocation.
According to Brosset, echolocation **was an adaptation to a cave habitat** . Adopting a nocturnal lifestyle, the bats would later use their faculties to orient themselves in the dark to hunt.
According to Möhres, ultrasound guidance allows rapid movements in a dark or cloudy (opaque) medium, which is a major selective advantage. This explains why the order Chiroptera contains a large proportion of all mammalian species (10%).
Ultrasounds occur in the throat for microchiroptera or in the tongue for megachiroptera.
The larynx is characterized by a particular structure: it is the voluminous bone (without cartilage) which has swellings of various shapes and a huge muscle.
The rinolofidels (horseshoe bats) have "guides" of waves on the nose, while in the vespertilionide (Myolis) ultrasound comes out through the mouth. Near the mouth of the bat one can have a pressure of 120 dB (175 dyn / cm2). Reception is done by ear. The outer ear is strongly developed, being equal – in some species – to the length of the body, and has a complicated structure.
The inner ear is characterized by the development of the first part of the cohlear canal and basal thickening. Auditory brain centers are extremely well developed (SL Polyak). There

accuracy of reception is similar to that of sight of other mammals, one can speak of "visual hearing" (Bildhoren). The resolving power of the bat is 0.05 mm at a distance of 10 m. receiver operates on one of two principles: a) estimating, with both ears, the difference in echo time it needs to reach them b) estimating the echo strength the along the sound wave (for this it is enough to have a single ear with a mobile pavilion, and sometimes the movement of the head) For a good resolution and for a fast flight it is necessary to evaluate the time (duration) with an accuracy of 1/30000 s).

Research has shown that if the bat flies higher, it emits relatively long (50 ms) and few (5 pulses per second) pulses. The closer the bat is to the ground, the more the pulse length (2 ms) decreases and the frequency in a second increases to 200.

It is interesting that the emission of ultrasound develops ontogenically (in Myotis) from the emission of audible sounds. Note also that some moths (Noctuidae, Geometridae, Pyralidae) which are the prey of bats perceive ultrasound through their body eardrum (KD Roeder and treat AE. 1960), they announced the approach of the enemy at a distance of 30 m. Dolphin ecolocators use very high frequencies (120 to 300 kHz) and tracking can be effective at 2-3 km (Manteufel, Naumov and Jacobi, 1965).

THE ELECTRIC FIELD IN ORIENTATION

Exact information about orientation in nature using electricity is currently only available on certain electric fish.

Galvanotactism of presence (galvanotaxis) does not yet demonstrate a value of electrical stimulation in the ordinary life of this organ. The electropisms of the plants studied showed fields of tens of kV / m, ultimately harmful results. These fields are not part of the normal living conditions of plants (earth's normal gradient is about 0.2 kV/m).

The electric shocks used to detect fish (orientation) are weak (potential difference of 0.3 to 2 V), short (milliseconds) and of constant frequency. They are found in Gymnotidae (except Gymnotus). HW (1958) studied in detail Gymnarchus species a freshwater fish from Africa which can reach 1 m in length; he is a carnivore, is able to detect and precisely locate his prey. The electric field created by this fish is similar to that of a dipole, because it has a negative tail with respect to the head.

The electric field is disturbed by conductive and insulating objects in the environment, which causes characteristic behavioral reactions.

The fish can be a potential gradient of at least 0.15 μ A/cm^2 in the body.

It is very sensitive to ordinary fish (sensitivity of the order of 10-100 μ A/cm^2). It is due to special receptors, the mormiromas, cutaneous sensory organs located especially in the head.

The epidermis is a poor electrical conductor, but mormiromasta communicate with the surface of the skin by means of a channel filled with an electrically conductive gel.

Thus, the current is directed and focused to the mentioned receptors. Gymnarchus can detect a glass rod 2 mm thick, which corresponds to a variation of the order of the intensity of the current. The receptors derive from the change in the sensory organs of the lateral lines. In clasmobranhi, ampullae of Lorenzini are electrosensitive, but they are also sensitive to temperature, water movement, osmotic concentration, etc. The Mormirid brain is well developed (weighs 2% of body weight), especially the cerebellum, which appears to be the tip of the central electrical analyzer. Electricity-receiving organs also have the Clarias fish which has no electrogenic organs. It is believed that this fish can detect currents emitted by prey or enemies or currents produced in the water by the movement of fish in the presence of a magnetic field.

Electric fish are active at night: darkness and water render them unnoticed by their enemies, and sight cannot serve them under these circumstances. The orientation of the electric field generated by themselves therefore confers a very selective advantage in the struggle for existence.

MAGNETIC FIELD IN ORIENTATION

FA Brown (1960-1963) showed that different animals (eg gastropod Nassarius) are influenced in their movement towards the magnetic field of the earth or in a domain of the same order of magnitude (~0.2 Oersted). This influence depends on the length of the day and the phases of the moon, which suggests the existence of an "internal clock".

Dugesia planaria orientation depends on orientation and magnetic field strength, time of day, season, and direction of light. And protozoan flagellum appears to have a "magnetic compass", which appears to serve as the earth's magnetic field for orientation (JD Palmer, 1962).

Research on the position taken by various flies (Sacophaga, Calliphora, Lucilia etc.) when placed on a flat wall surface has revealed that there are preferred directions: NS and EW. A magnetic field of 40 Oersted produces a transient excitation, followed by a preferred position parallel or perpendicular to the field lines (from magnetotaxis, G. Becker).

The hypothesis that birds use the earth's magnetic field in their orientation is not new. The first author who supported this idea seems to be Middendorff, 1855. Magnetic storms, for example, have been found to disturb the orientation of pigeons (Rochon-Duvigneaud, 1923). The magnetic hypothesis is contradicted by the negative experiments where the galvanization or the presence of the magnets did not disturb the orientation. The magnetic hypothesis has been rejected by authors such as E. Rabaud (1927). In 1963, L. Talkington suggested that "the comb", an organ sitting at the back of the bird's eye, plays a role in orientation. In the comb the lymph vessels constitute the conducting tubes where due to the movement birds in the earth's magnetic field -in their flight- would appear an electrical voltage able to determine the specific excitation of nerve endings.If the direction of flight is fixed the effect quickly compensated by the polarization of the conductor can only be noticed 'by changing direction (JM Barnothy) If a bird flew north at a speed of 100 m / s and should change direction with 1° / min we would obtain in the tissues of the bird a potential variation of only 0.35V μ/cm.min
(Which can be compensated by a current of the order of 10^{-19} A)

LIGHT IN ORIENTATION

Examples of direct orientation, not facilitated by direct light, are tacticisms and tropisms. Phototaxis (phototaxis) is seen in animals with light-sensitive eyes or skin.

There are two types of phototaxis (Kuhn, 1915):

1. **Tropotactism** , the direction of body motion is the effect resulting from right and left excitations of a bilaterally symmetrical body. At an asymmetrical illumination a rotation of the body occurs until the plane of symmetry coincides with the direction of the light radiation. Also, the animal moves in a straight line in the light or in the opposite direction. A snail with one eye removed follows a spiral path.
2. **Teletactism** consists in the fact that the animal fixes the target, then moves towards it. This reaction involves an evolved optical device to designate the direction of light radiation. The path to the target is straight even if the animal has only one eye.

The dorsal light reflex is when the animal points its back to the direction of the light, which helps maintain balance while swimming or resting on a support (Buddenbrock 1913).

Light is used as a compass ("Compass" movement) by certain lower animals.

The arthropods describe irregular trajectories in the dark (search movements), but only a weak radiation of light is enough for the movement to be oriented. The animal can move on a trajectory which forms angles of any value with the direction of the radiation which only serves as a guide. This movement differs significantly from tactics. Research has shown that the position of the Sun is an important criterion for the orientation of many insects.

Visual perception and recognition of shapes and colors play a role in targeting higher animals (higher arthropods, vertebrates).

The great importance of light for the life of animals is proved by the way it spreads.

It suffices to observe in everyday life that light rays cross space in a straight line and follow the laws of reflection and refraction. "Light Radiation" has no analogue in the other sense organs. In order for these skills to be put at the service of living organisms, the eyes have developed throughout the animal kingdom, their construction reminiscent of that of cameras. In the simplest cases, they only serve to perceive the direction of illumination or sunlight, while in higher organisms they serve sight.

The biological importance of light is given by the ability for most objects to selectively absorb or reflect the light falling on them, allowing the body to distinguish and recognize things by their glow and color. color.

POLARIZED LIGHT IN ORIENTATIONS.

Polarized light is widely used by animals in orientation, as first shown in v. Frisch (1949).
Bees orient and locate the food source based on the sun in the sky, but orientation and location is possible when they see only part of the blue sky. When using a polarizing filter in the experiment, a modification of the direction of their characteristic dance is produced (dance by which they reciprocally signal the position of each source of food). When the plane of polarization is rotated more than 55°, the bees are disoriented. Autrum T. and R. Stumpf (1950) found that polarized light has a more intense effect on the induction of electrical potentials of the retina of bees than unpolarized light.
In Limulus, M. Waterman (1950) observed a modification of the potential actions of the photoreceptors during the rotation of the plane of polarization of light.
In the crustacean Eupagurus Bernhard it was revealed that the maximum distance at which an object is perceived depends on the location of the plane of polarization of light (Kerz, 1950), which shows that this animal eye has a polarized light analyzer. Menner FA (1951) draws attention to the usefulness of such an analyzer for animals looking at the boundary between water and air, which might be disoriented by the glare reflected off the interface, widely polarized light.Filters of this type have been found in some birds.
The polarization detection operation includes:
a) Separation of incident light into vectors perpendicular to each other and perpendicular to the direction of propagation of the beam;
b) deleting a vector;
c) the intensity of the estimate vector remained.
For physical tools, the analysis of polarization depends on the rotation of the analyzer around the direction of propagation of the beam of light. In biological systems found in arthropods, analysis depends on whether the radially arranged analysis system (either it is the rabdomerretinule cell complex or it is different surfaces of cornea and lens of the compound eye). Such an arrangement allows the simultaneous comparison of polarized light intensities in all azimuths; the comparison can be made between different omatides or between parts of the receiving system of a single ommatid.
We propose three different models to explain the orientation of polarized light
a) The Brewster-Fresnel model, in which one or more reflections or refractions serve to preferentially modify the intensity of polarized light parallel to the plane of incidence. This pattern seems to be made in Drosophila (HH Stephens, 1953) and Daphnia;
b) Dichroic filters seem to be made from the bee (J.Autrum 1950; Stockhammer, 1956);
c) in some cases, the intensity of the scattered or reflected light is greater in the direction perpendicular to the plane of polarization (a situation emphasized by Baylor and Smith, 1958).

7. LASERS AND THEIR APPLICATIONS

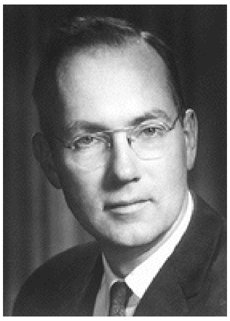
LASER CREATION

The word LASER comes from the initials of the full English name ***Light Amplification by Stimulated Emission of Radiation*** , the translation of which means **light amplification by stimulated emission of radiation.**

About the LASER effect we already know a lot. This branch of science has greatly expanded its creation (1955-1965) until today. Even if the theoretical foundations were more or less pre-established, the first who managed to materialize all the theories and hypotheses were two Russians and an American:

Nicolay Basov Gennadiyevich (Lebedev Institute of Physics for Akademija Nauk Moscow, USSR, born in 1922),

Alexander Mikhailovich Prokhorov Prokhorov (Lebedev Institute of Physics for Akademija Nauk Moscow, USSR, born in 1916) and



Charles H. Townes (Massachusetts Institute of Technology (MIT), Cambridge, MA, USA, born in 1915).

The three shared the Nobel Prize awarded in 1964 for "fundamental research in quantum electronics which led to the construction of oscillators and amplifiers based on the maser-laser principle".

THE PRINCIPLE OF LASER lies in the fact that atoms release energy in the form of photons when it undergoes the transition from a metastable level of excitation to the level of equilibrium. This transition is under the influence of a trigger emission and therefore the release of energy is called a stimulated or induced emission. Once the reaction has started, it propagates in a pyramidal form, so a photon emitted by a de-energized atom will begin to react on the other, which in turn will emit a photon and release the incident as well. We have two photons that will multiply exponentially. This produces an amplification of light radiation.

Radiation amplification using stimulated emission was performed first in the radio wave range in the UHF frequency range. It was called molecular generator or Maser, because a beam of ammonia molecules was used. It was built in 1954 at the same time by the USSR and Colombia. Later, the term laser was derived from the term maser resulting from the replacement of the letter M, with L-LIGHT. The appearance of the Maser meant the birth of a new technical discipline called quantum radio-physics and quantum electronics. The first laser was built by physicist T. Maiman in 1960 ruby laser. Beginning in 1961, various types of lasers, both solid state and gas, occupied an important place in optical laboratories. New environments are active and transform and improve laser technology. In the years 1962-1963 in the USSR and the USA semiconductor lasers were built simultaneously.

The block diagram of a laser includes the active medium, the mirrors of the optical resonator and an installation for pumping the active medium. As there are many types of construction of lasers, they are distinguished from each other by their appearance and by their size.

The variety of lasers is due to the types of active laser and pumping medium used. As an active environment, dielectric crystals, special glass, semiconductors, liquid solutions of dyes, gas mixtures are used. In dielectric crystal and glass lasers, optical pumping is used.

LASER PHYSICS

Radiation amplification using stimulated emission was performed first in the radio wave range in the UHF frequency range. It was called molecular generator or Maser, because a beam of ammonia molecules was used. It was built in 1954 at the same time by the USSR and Colombia. Later, the term laser was derived from the term maser resulting from the replacement of the letter M, with L-LIGHT. The appearance of the Maser meant the birth of a new technical discipline called quantum radio-physics and quantum electronics. The first laser was built by physicist T. Maiman in 1960 ruby laser. Beginning in 1961, various types of lasers, both solid state and gas, occupied an important place in optical laboratories. New environments are active and transform and improve laser technology. In the years 1962-1963 in the USSR and the USA semiconductor lasers were built simultaneously.

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The variety of lasers is due to the types of active laser and pumping medium used. As an active environment, dielectric crystals, special glass, semiconductors, liquid solutions of dyes, gas mixtures are used. In dielectric crystal and glass lasers, optical pumping is used.

A LASER (acronym for " ***Light Amplification by Stimulated Emission of Radiation*** **")** is a device that produces spatially and temporally coherent radiation based on the laser effect . Descending from the maser, the laser was first called optical maser.

A laser source combines an optical amplifier based on the laser effect with an optical cavity, also called a resonator, generally made up of two mirrors, of which at least one of the two is partially reflective, that is to say that a part of the light leaves the cavity and the other part is reinjected towards the interior of the laser cavity. With some long cavities, the laser light can be extremely directional. The geometric characteristics of this assembly require that the radiation emitted be of high spectral purity, that is to say temporally coherent. The radiation spectrum indeed contains a discrete set of very fine lines, at wavelengths defined by the cavity and the amplifying medium. The fineness of these lines is however limited by the stability of the cavity and by the spontaneous emission within the amplifier (quantum noise). Different techniques make it possible to obtain an emission around a single wavelength.

LASER OPERATING PRINCIPLE

1 - excitable medium 2 - pumping energy 3 - totally reflecting mirror 4 - semi-reflecting mirror5 - laser beam

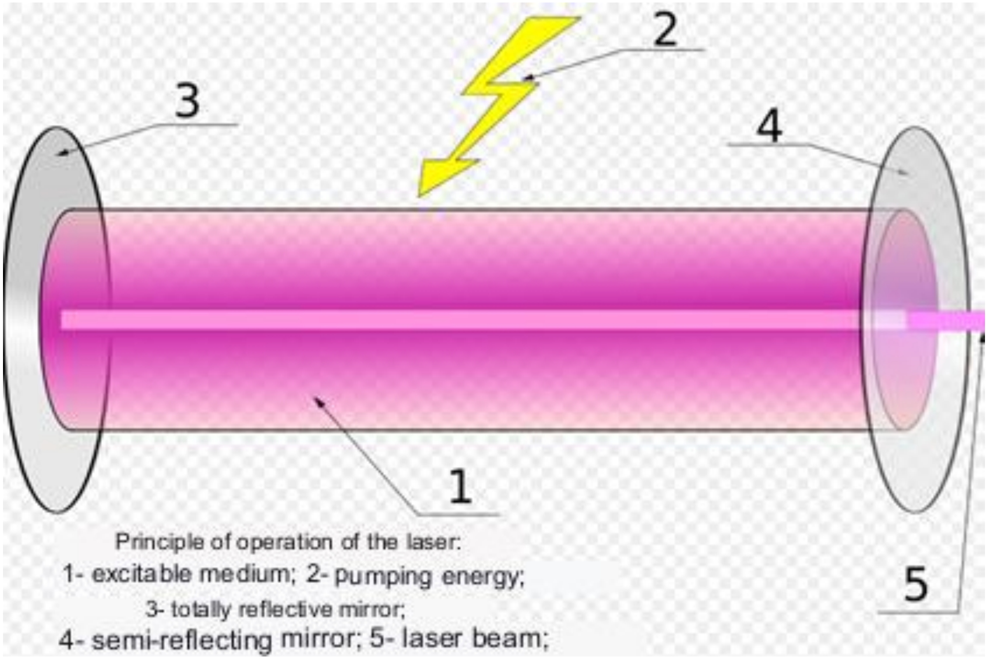


Figure 93: Laser operating principle

PHENOMENA INVOLVED (QUALITATIVE)

To understand how a laser works, it is necessary to introduce the concept of *quantification of matter* : the electrons are distributed over discrete energy levels (the "shells"). This hypothesis is *fundamental* and *not intuitive* : if we consider the image according to which the electrons can only be found on certain very precise orbitals around the atomic nucleus or nuclei.

In the following, we will consider an atom with only one electron (hydrogen), to simplify the discussion. This is likely to be on several levels. The knowledge of the level on which this electron is located defines the *state of the atom* . These states are numbered in increasing order of energy with an integer , which can take the values , , ... The state is therefore the state of lowest energy, corresponding to an electron on the nearest orbital of the core.

Let's come to the main processes of interaction between light and matter, namely absorption, stimulated emission and spontaneous emission.

Absorption — When illuminated by electromagnetic radiation (light), an atom can move from state to state, taking up the corresponding energy from the radiation. This process is *resonant* : the frequency of the radiation must be close to an *atomic Bohr frequency* for it to occur. The atomic Bohr frequencies are defined by , where are the energies of the states and . We can interpret this process as the absorption of a photon of the radiation (of energy) causing the atom to pass from the energy level to the energy level. The resonance condition then corresponds to the *conservation of energy*

THE PHENOMENON OF ABSORPTION

The energy photon moves the atom from its ground state 1 to the excited state 2.

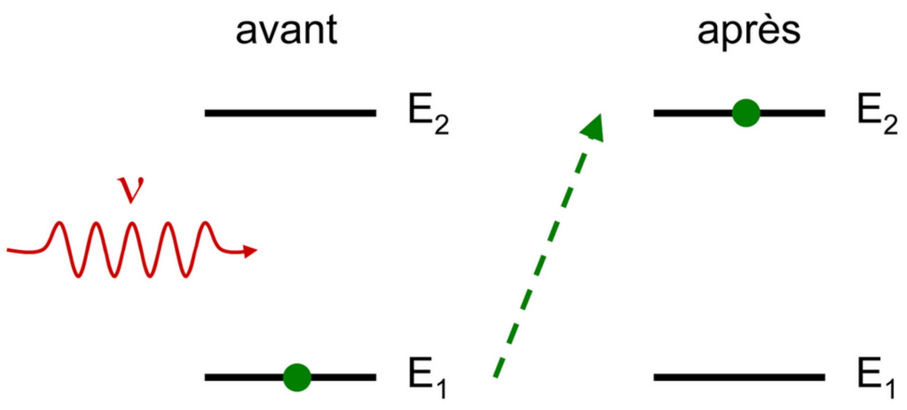


Figure 94: Laser operating principle

When it is illuminated by electromagnetic radiation (light), an atom can pass from an n state to an n'>n state, by taking the corresponding energy from the radiation. This process is *resonant* : the frequency of the radiation must be close to an *atomic Bohr frequency* for it to occur. The atomic Bohr frequencies are defined by , where are the energies of the states and . We can interpret this process as the absorption of a photon of the radiation (of energy) causing the atom to pass from the energy level to the energy level. The resonance condition then corresponds to the *conservation of energy* .

SPONTANEOUS EMISSION — This process is the mirror image of absorption: an atom in an excited state can de-excite to a state, even in the absence of radiation. The radiation is emitted in a random direction with a random phase, and its frequency is equal to the Bohr frequency.
We can interpret this process as the emission of a photon of energy in a random direction

THE PHENOMENON OF SPONTANEOUS EMISSION.
The de-excitation of the atom occurs spontaneously and is accompanied by the emission of a photon in a random direction

POPULATION INVERSION (QUALITATIVE)

Consider a two-level set of atoms. If a field is sent to a set of atoms in the “high” state, the privileged phenomenon will be stimulated emission and the field will be amplified. To make an optical amplifier, it is therefore necessary to find a way to excite the atoms towards the higher energy state. More generally, if some atoms are in the "low" ground state, photons can also be absorbed, which decreases the intensity of the field. There will only be amplification if more atoms are in the "high" state (likely to emit) than in the "low" state (likely to absorb): it is necessary to have a population inversion.
However, at thermodynamic equilibrium, the lowest state is always the most populated. At best, the populations oscillate between the two levels (Rabi oscillations). To maintain a population inversion, it is necessary to constantly provide an external energy supply to the atoms, to bring back to the higher state those which have returned to the ground state after the stimulated emission: this is the " **pumping** ". The external energy sources can be of different types, for example an electric generator, or another laser (optical pumping). The amplifier is therefore a set of atoms or molecules that are moved from a fundamental or weakly excited state to a more strongly excited state, by means of an external energy source (pumping). These atoms can then de-excite towards the state, by emitting photons with a frequency close to . Thus frequency radiation passing through this medium can be amplified by stimulated emission processes.

STIMULATED EMISSION OF LIGHT

The atoms and the molecules of the bodies are in a permanent movement their kinetic energy dissipated, distributed around certain mediums which depend only on the temperature.

Atoms and molecules can reside in different discrete states of energy, electronic, vibration, rotation, so that energy absorption or removal of these particles occurs only in a proper transition between two energy states quantified.

The distribution of atoms in these eigenstates of energy is also based on body temperature. This dependence means that, at a given temperature, the number of atoms in the low energy states is greater than those excited on the high energy levels.

An atom located in the highest energy state E2 can return to a lower level E1 either spontaneously, emitting an energy quanta = hv E2-E1, or as a result of interaction with a photon of frequency equal to the interval between the two levels. The former phenomenon is called spontaneous emission, while the latter is induced or stimulated emission, the emission is often called forced emission because the emission occurs under the influence of excitatory external irradiation.

LASERS OPERATING PRINCIPLE

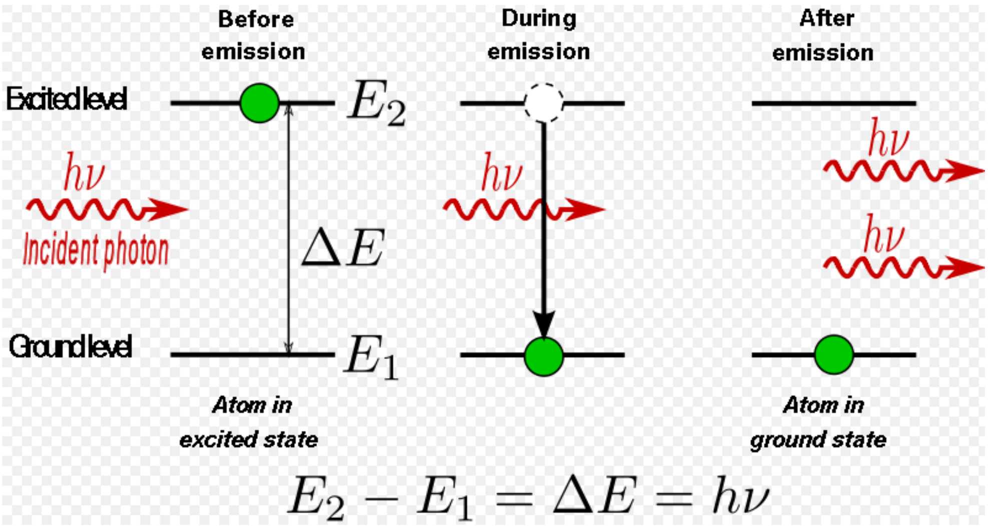


Figure 95: Laser operating principle

The phenomenon of stimulated emission was introduced by EINSTEIN in 1917, during the development of the theory of radiation, but it has been highlighted and used experimentally in the last thirty years.

In the case of induced emissions, in addition to the incident photon, another appears with the same power and in phase with the first. This, in turn, can cause another photon to appear when it encounters a new atom in E2. One could thus obtain an amplification of the incident radiation, if in the irradiated sample there were enough atoms in the upper state E2.

In reality, the phenomenon of amplification, is practically non-existent, because, at thermodynamic equilibrium, the high level E2 is much less populated than E1 and then the most frequent phenomenon at the irradiation of a substance will be the interaction of incident photons with many atoms in the E1 energy state. This interaction can lead to the excitation of the atom into the E1 energy state. The atom stays in the excited state for a limited time, called the average excited state lifetime, after which it returns to the lower energy state E1 either by energy transfer E2-E1 of the atoms neighbors, in the form of heat, or by the emission of a photon. This new photon may leave the irradiated body or may in turn be absorbed as a result of other excitation processes.

Under normal circumstances, from the irradiated body will come out per unit of time, a number of photons lower than the incident and therefore the incident radiation and will always be weakened as a result of its passage through the body in question.

It follows that any irradiated organ will deliver less power than the incident one due to the losses, which eventually heat up the body.

Therefore, in order to amplify the light beam, an unusual situation must be created. The number of atoms or molecules on the higher energy level is greater than the number of those on the lower level, so we have created a population inversion of the energy levels.

Light amplification in essence means that a beam of light passes through a medium in which it has practiced population inversion of energy levels.

The laser presents the active medium. The atoms or the molecules which have a very important property being on higher energy levels, can remain there long enough, without having to rush to return spontaneously to the lower levels. Thus, one can create enough atoms on a level, in order to be much more numerous than those of the lower levels. As a result, one will create an inversion of population levels, which is necessary for stimulated emission processes to outweigh light absorption processes

Any irradiated organ will deliver less power than incident due to losses, which eventually heat up the body.

Let us suppose that we send on a body an electromagnetic radiation whose photons have the energy hv equal to the difference between the two energies E1 and E2.

Noting with Iv number of energy incident photons, h. v, per unit time, then the power of the incident radiation is Pinc = Ivhv.

Some of these photons will be absorbed by the atoms located on the lower E1 level, causing them to transition to the E2 level.

The number of E1-E2 transitions in the unit of time will be proportional to the number of incident photons Iv and to the number N1 of atoms which are in E1.
Noting the proportionality coefficient with the B12, the absorbed power is Pexcit = B12IvN1hv.
Some of the atoms which are in the E2 energy state will return spontaneously to the E1 level either radiatively or nonradiatively.
The photons emitted on this occasion have the same energy, and their number will be proportional to the number of N2 atoms located on the E2 energy level.
If we note with the proportionality coefficient A21, the power emitted by the body by spontaneous de-excitation is then
Pspont = A21N2hv.
It does not depend on the intensity of the incident radiation.
Another part of the atoms of the E2 level will be de-excited following the action of the incident photons.
The number of photons thus formed will be proportional to N2, but also to the number of photons which cause this spontaneous emission.
Noting with B21 the proportionality coefficient, the power delivered by induced transitions will be
Pind = B21IvN2hv.
The magnitudes of B12, B21, A21 are called Einstein coefficients and have, among other things, the property B21 = B12.
the power emitted by the irradiated system is
Pemis = Pexcit Pspont Pinc-Pinde,
hence **Pemis=Pinc+A21N2hv+B21Iv(N2-N1)hv.**
In the case of regular sources, the most important term is the corresponding spontaneous emission.
To render a source whose emitted power is greater than the incident power, it would first be necessary that the last term, that which brings a negative contribution to the sum, is positive.
So we first have to perform an inversion of populations between the two levels.
Second, to have only stimulated emission, for spontaneous emission to be negligible, the term A21N2hv would have to be negligible with respect to the last.
Of
Permis = hv A21N2hv B21Iv Pinc (N1-N2).
This can be achieved by dramatically increasing the intensity of radiation incidents. The value of Iv for which this above condition is fulfilled is called the threshold intensity. It is calculated for each device and they enter into the AI calculation of reflective coefficients and surfaces.

If one uses a particular energy source, one can realize the population inversion between two energy levels of the atoms of a given environment, the radiation intensity exceeds the threshold intensity incidents, the power radiated by the active medium can become greater than the forward power in this way that **a QUANTUM AMPLIFIER BY STIMULATED EMISSION OF RADIATION, ie LASER, can be obtained.**

GENERAL PRINCIPLE

Principle of operation of a laser

A laser is therefore, fundamentally, a light *amplifier* whose output is fed back to the input. Its energy supply is the source of the pumping, the output is the laser radiation which is reinjected at the entrance by the mirrors of the resonant cavity, the amplification mechanism being stimulated emission.

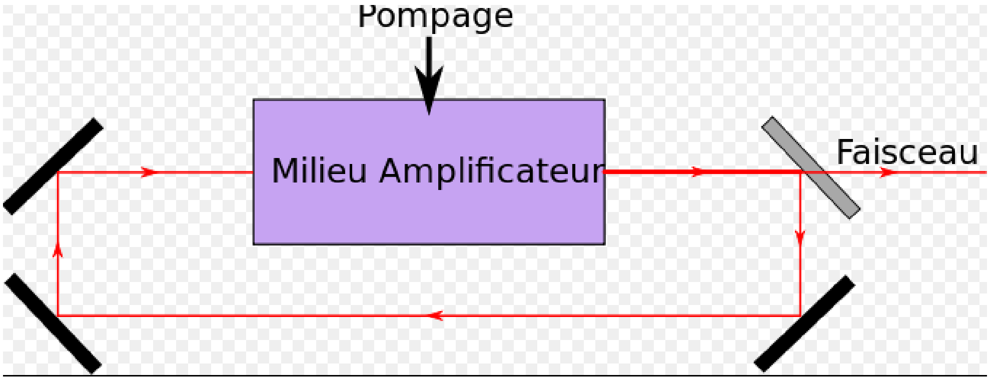


Figure 96: Laser operating principle

Population inversion

In the case of a transition model between 2 low and high levels, denoted respectively N1 and N2 and the population of the high state must be greater than the population of the low state for there to be emission: N1< N2. .

The evolution of the population of the high state is given by an exponential decay law:

$$N_2(t) = N_{2,initial} \times e^{-At}$$

REALIZATION OF LASER DEVICES

The components of a laser are:

- **the active environment,**
- **the excitation system and**
- **the optical resonator**

THE ACTIVE MEDIUM is the essential element of a laser device, a medium in which the atoms are in a state of energetic equilibrium. In this active environment an amplification of luminous radiations is produced (if we have luminous incident radiation) or the very emission and amplification of radiation (if we do not have luminous incident radiation).

THE **EXCITATION SYSTEM** is needed for atomic systems with multiple atoms in a higher energy state. There are several ways to achieve excitation of atoms in the active medium, depending on the nature of the environment.

THE OPTICAL RESONATOR is a system of lenses and mirrors required for processing the optical radiation emitted. Although at the exit of the active medium the laser rays are almost perfectly parallel, the optical resonator is used to collimate much more precisely, to focus rays at a calculated point, for the diffusion of x-rays or other necessary applications.

TYPES OF LASER ACTIVE ENVIRONMENT

According to the nature of the active environment, several types of laser can be distinguished.

RUBY LASER , which uses a ruby bar as an active environment and the assembly formed by a light source and mirrors acts as an excitation system.

GAS LASERS use mixtures of rare gases (He, Ne, Ar, Kr) or CO_2 as active environment and a current source connected to two electrodes having the role of excitation system.

PROPERTIES OF LASER RADIATION

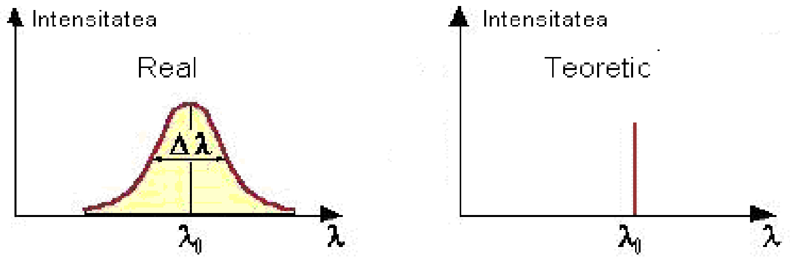


Figure 97: properties of laser radiation

MONOCROMATICITY of high monocromaticity.

Radiation has the same wavelength, spectral purity

Consistency

DIRECTIONALITY-

The beam divergence is very low.

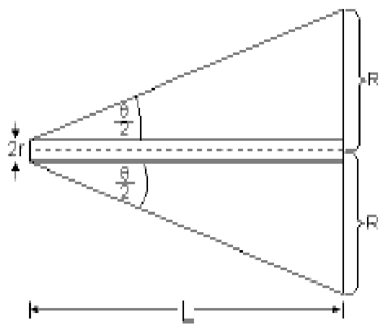
The beam is a parallel beam which keep the spatial direction.

The radiation emitted by a laser, in one direction is scattered with an angle of divergence.

The divergence angle is the angle determined by the aperture of the beam (of the order of milliradian.

- Conversion relationship from radians to grad 360 ^{o} = 2 π, 1 radian = 57.3 ^{o}
- 1 miliradian = 1 mrad = 0.057 ^{o} = 0.057.60'= 3.5'

$$\tan\left(\frac{\theta}{2}\right) = \frac{R-r}{L} \approx \frac{\theta}{2}$$



MICROWAVE LASER (MASER)

This laser was invented by Townes and Shawlow in 1954.

The ammonia beam passes through an electrostatic concentrator to separate the molecules on enhanced energy levels.

The laser effect was applied for the first time in the microwave region.

Spontaneous emissions are proportional to the cube of the frequency transition, being weak in the microwave portion of the spectrum corresponding to the region and can be neglected compared to other processes such as absorption and stimulated emission. Due to this inversion, populations are obtained easily with a little power.

The first population inversion was obtained in the molecule of ammonia (NH3).

Population inversion in ammonia molecules is achieved by physical separation of particles on enhanced energy levels from lower energy levels.

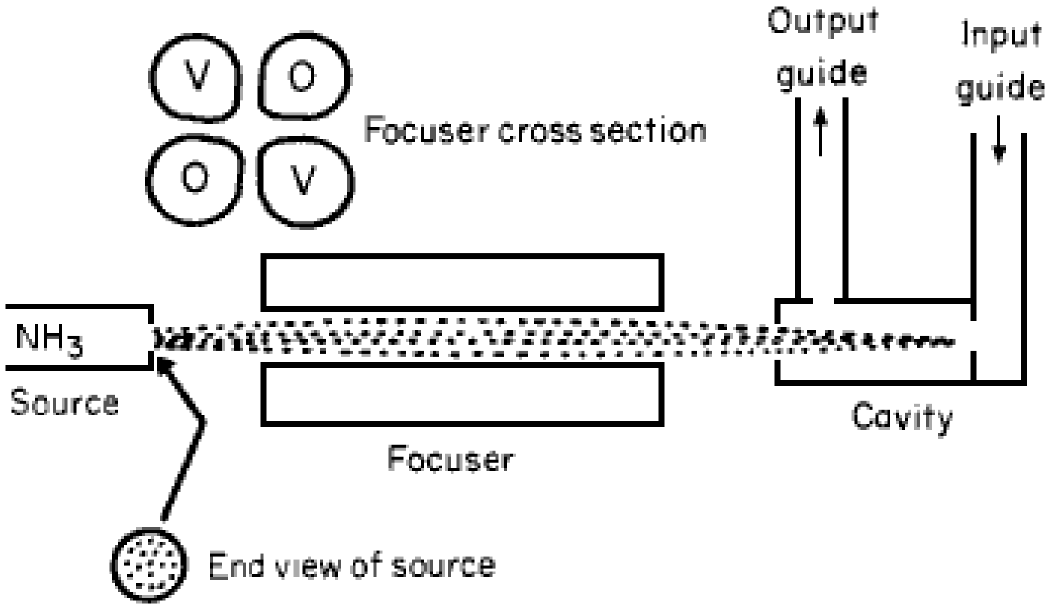


Figure 98: Maser

OPTICAL LASER

After the publication of the book in which Shawlow and Townes showed the possibility of the action of the laser even in the infrared spectrum and in the visible spectrum soon after many researchers began to consider the creation of these devices.

Several experts have estimated that the first devices of this type will use a gas.

Muhammad Usman, in 1960, created a device that uses ruby to produce the effect of laser in the visible spectrum.

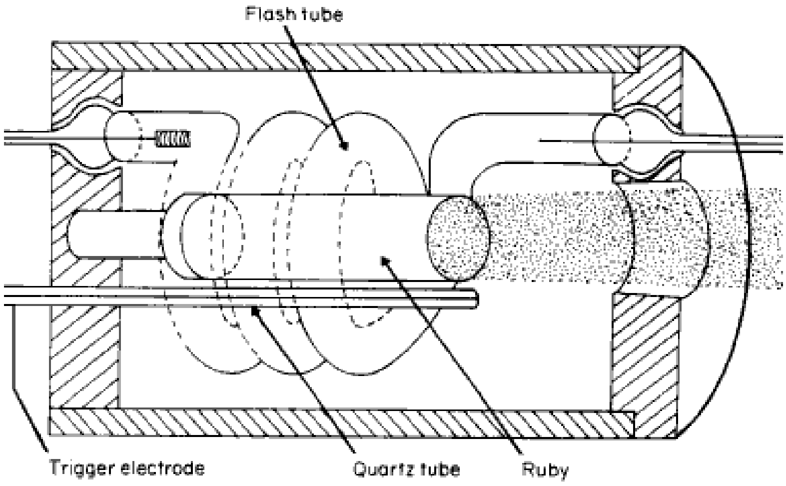


Fig. 99: Optical laser

The first optical laser, built in 1960, by Maiman was a pulsed laser, for reasons of heat dissipation and the need for higher pumping energy. Nelson and Boyle created in 1962, the first ruby laser, replacing the source (Flash lamp) with an arc lamp.

Shortly after the first success of an optical laser was announced, other research laboratories began and succeeded in experimenting with optical lasers which instead of Cr had other rare metals Nd, Pr, Ho, Er, Tm, Yb, Gd and even U and corundum crystal instead of coridon crystal we tried to use a combination of Yttrium-aluminum garnet, CaF 2 , or $_{\text{glass}}$ (easy to manufacture). These lasers have found, with improved manufacturing methods, practical applications too.

At first it was thought that optical pumping would be inefficient, but this only happens for low resonance ions, like those in gas or plasma.

Metal ions can absorb radiation of wavelengths in a wider band. Radiation with a wavelength of 550 nm is absorbed by a population of Cr3 ions in a corundum crystal (containing Cr203 and Al203 in table ratio 1:2000) and then makes a rapid transition, without temperature change at a metastable lower level of 5 milliseconds.

If the pumping energy exceeds a certain value, it is possible to invert the populations which pass from the neutral state to this metastable level. The performance of the laser increases if it is inside an optical resonator.

NEODYMIUM GARNET LASER

As an example, we are looking for a concrete type of active environment - neodymium-doped garnet, yttrium garnet and neodymium-doped aluminum. Red garnet is a transparent crystal. The active centers are neodymium ions embedded in garnet crystal, in the active environment preparation. In the following figure a simplified system of neodymium garnet energy levels is presented.

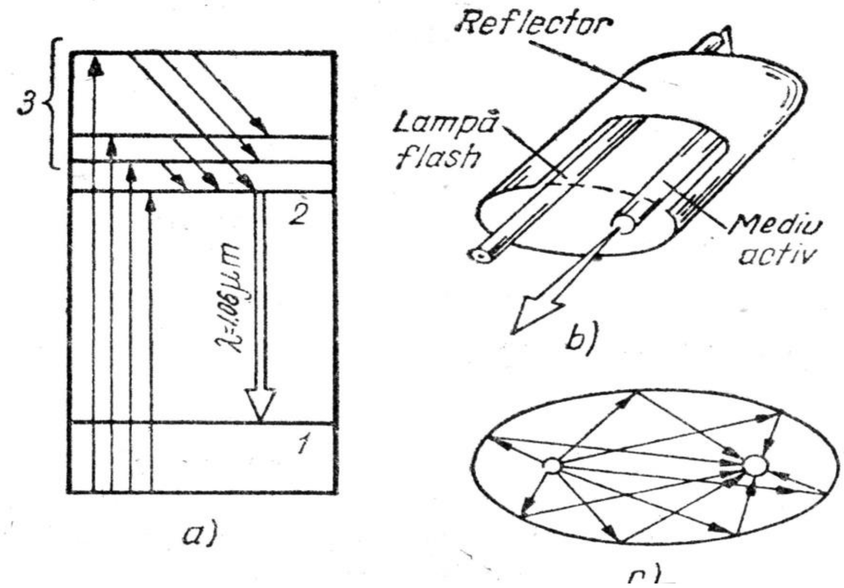


Figure 100: Neodymium doped garnet laser

By absorbing the radiation from a flash lamp, the neodymium ions become excited. They pass on higher levels of energy, denoted 3 on the drawing. Then very quickly they fall from these levels and gather on the 2nd level, transforming the excess energy to heat the garnet crystal.
The active medium will be ready to function when on level 2 there will be many more neodymium ions than on level 1. At this moment, a photon of energy equal to the difference between the energies of the levels is enough. 2 and 1, to initiate the massive transition of neodymium ions from level 2 to level 1. Following this transition occurs an avalanche of photons which accurately represents laser radiation. Pumping with intense light pulses created by a lamp is therefore possible. In this case, the result of each pulse is laser radiation. Also in the case of the illumination of the environment with an illuminating lamp, the laser radiation can occur either in the form of a permanent light beam or in the form of a sequence of regular pulses.
This laser generates radiation in the infrared region of the spectrum at several laser wavelengths. The most intense generation occurs at the 1.06 micrometer wavelength.

SEMICONDUCTOR LASER

The semiconductor laser is built like other types of lasers on the model active medium-optical resonator excitation system.

The active medium: a mixture of semiconductors is used.

Most often combinations of metals are used for the same periods of groups III and V.

Among them, the most widespread semiconductor consists of Gallium and Arsenic (GaAs). Other active media have been obtained both from mixtures of elements of groups II and VI (Zinc and selenium-ZnSe) and mixtures of three or four elements. The last two are more often used for the emission of certain radiations much more precise from the point of view of the wavelength. The excitation system consists of two layers of semiconductors, one p-type and one n-type. In order to better understand these two notions, it is necessary to mention some theoretical aspects relating to continuum physics and, particularly, the principle of semiconductors.

Semiconductors are a class of materials widely used in electronics due to the possibility of electrical control.

The electrical resistivity of a semiconductor decreases with increasing temperature and its value can be changed within the very wide range ($10^{-2} – 10^{8}$ Ωcm).

In a pure semiconductor the electrical conductivity, is given by its own electrons and it is called intrinsic conductivity and in the case of impure materials, we are dealing with an extrinsic conductivity.

Intrinsic conductivity can be explained as follows:

At 0 K, electrons establish covalent bonds formed between atoms of the intrinsic semiconductor.

With the increase in temperature, some electrons detach from the bonds being free to move throughout the volume of the crystal. An ionization phenomenon occurs and a vacuum forms in place of the detached electron. Another electron occupies this void which moves one position.

If an electric field is applied in semiconductors, the free electrons will be moved in the opposite direction of the field, but also the voids will form a positive current in the same direction as the field.

The more interesting phenomenon is the modification of the electric resistivity of the semiconductors by the impurity.

Thus, if of the 105 atoms of silicon, one atom is replaced by another of boron, the resistivity of the silicon decreases, at room temperature,

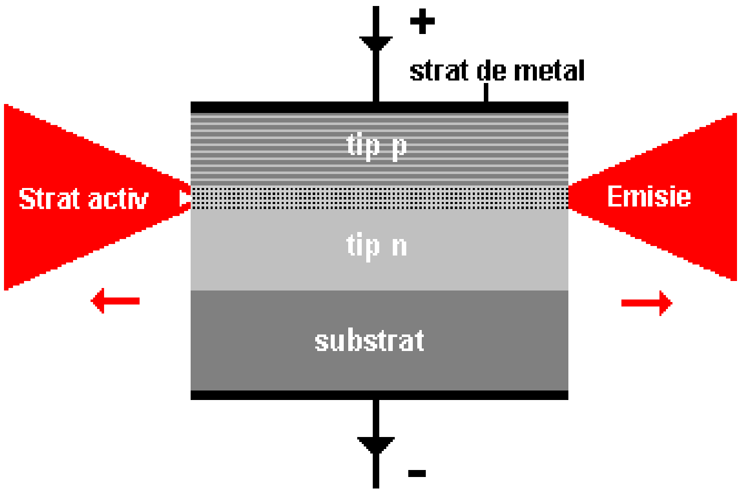
1000 times!

Impurification is a specific and fundamental problem in semiconductor physics and technology.

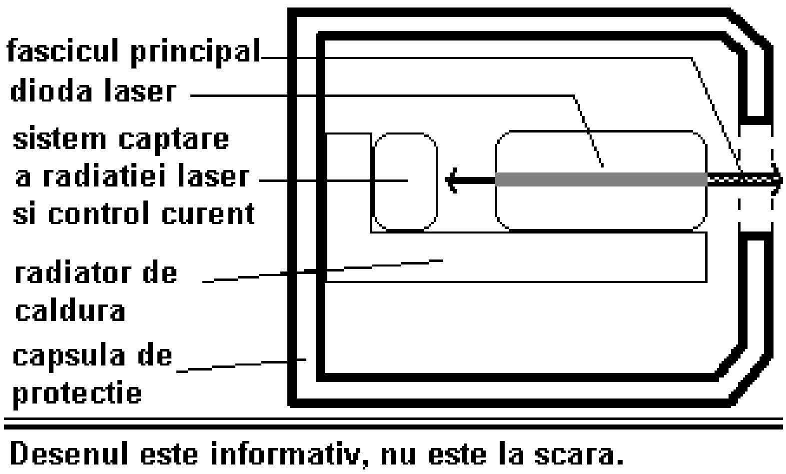
Sion impurities Germanium (group IV, four valence electrons) with a group 5 element (five valence electrons), we get a mixture with a free valence electron. This is a donor impurity. The semiconductor thus contaminated is n-type, and its energy level is closer to conduction.
If the impurification is done with atoms of the 3rd group (three valence electrons), it will integrate the crystal lattice with only three covalent bonds, leaving a void, therefore able to capture electrons around a ferric atom. This is why this type of impurity atoms have been given the name of acceptor.
Thus in a semiconductor thus impurified (with the atoms in group 3) the positive charges will dominate, hence the name p-type semiconductor.
pn joins are sets formed by adding a p-type semiconductor with a b-type one. The escarpment, the interface, has magnitudes of the order of 10-4 cm. On the surface of the n-semiconductor there appears a mass of electrons and on the surface of the p-semiconductor a surplus of voids. Thus appears the tendency of their compensation by means of the diffusion of electrons from one semiconductor to another.

SEMICONDUCTOR LASER . CONSTRUCTION - PRACTICAL CONSIDERATIONS .

The semiconductor laser is in fact a "sandwich" made up of 3 layers of semiconductors to which excitation system elements are added.



The energy necessary for the excitation of the system of atoms in the active medium as well as the triggering factor are given by the electric current.
Due to the fact that this sandwich corresponds to the classical model diode, the term diode is also used.
The efficiency of these diodes is about 30%, but the amplification is quite large.
The current required must have a density of several thousand amperes per centimeter, but since a laser diode has very small sizes, the current required is often less than 100mA.
To obtain satisfactory results in practice, several layers are used than in the figure.



a classic set of diodes with the ability to control the current

The length of the active layer does not exceed 1 mm, and the thickness, depending on the model, is from 200 to 10 nm.
In general, the thickness of the active layer varies between 200 and 100 nm.
Because it is so thin, the emitted beam (for a laser) is divergent; The semiconductor laser relies heavily on the optical resonator which must be chosen with great care and must be positioned precisely in order to obtain maximum efficiency.
A system composed of two convex lenses with planar-convex faces positioned with the convex faces towards each other at certain quantifiable distances is generally sufficient to obtain a fairly well colimated beam with nearly parallel rays.

THE LASER EMISSION IS IN TWO DIRECTIONS .
This phenomenon is treated differently depending on the needs.
One can create a resonant cavity by positioning a perfect mirror and a semi-transparent one, you can use the "return" emission to measure the properties of the main beam, one can use the same emission from behind to measure and control the current passing through the diode.
Laser diodes are very sensitive to currents and therefore strict control over them is absolutely necessary. Sometimes it takes a small change in voltage or power to cause the diode to burn.
Laser diodes are perhaps the most fragile laser emitting devices. The fact that the active layer is, in effect, the size of a bacterium is what underlies the previous statement. This layer can be easily destroyed by subjecting the unsuitable current to electrostatic influences through excessive heating. The active layer can destroy itself, even without the presence of one of the factors listed above. A simple emission of light can vaporize this small layer if the light emitted is too strong.

A diode, although small, can develop light powers up to 3.5 mW. Although rare and more expensive, diodes that develop tens of thousands of mW are found in CD recorders and other high-profile instruments and devices. As for the beam divergence, currently most pointers manage to keep the divergence under 1mm every 5m. The color spectrum covered by semiconductor lasers is in the red region 630 to 780 nm but not limited here.

Green or blue lasers exist and are intensely studied.

The problem is that the green and blue diodes have a fleeting life (the most advanced only affect a few hundred hours) and operate at low temperatures (close to 0 K).

Compared to classical GaAs (which emits red-IR), for blue lasers ZnSe and GaN are preferred. The former has gradually been excluded from research due to high resistivity, high power consumption, low efficiency, and many other experimentally discovered factors.

The latest search was for GaN,prof. Shuji Nakamura developed the first practical and reliable installation for the generation of blue laser and the research multiplied.

A unique fact at the time of making the blue laser diode for in 1993, Shuji Nakamura didn't even have a PhD, he was just a scientist in a lab of one of the obscure Japanese companies.

Recently, prof. Nakamura joined the staff team of the Faculty of Engineering at the University of California Santa Barbara, USA.

We must mention a number of dangers that can occur even in the case of semiconductor lasers, which are known to be less powerful.

It has been calculated that an ordinary diode has a much greater power than the sun at the equator.

All mixtures of the active layer have much higher transmit power than the same amount of solar area.

The diodes on the market are class II and III, which means that they have low risk of harm to handling according to the manual and short-lived exposure of the eye to the beam. However, keep in mind that any prolonged exposure causes retinal injury and no immediate effects are necessary for the retina to be injured.

Rule number one when working with lasers: Do not stare directly into the beam, even if you feel no pain or the beam is faint.

The color and brightness of lasers has no relation to the power of the radiation.

These two properties are given by the wavelength of the radiation which does not have a determining influence on the power of the laser.

There may be pale pink lasers which are more harmful than the more fiery and reddish lasers.

There's a joke: "Rule number one in working with lasers: Never stare directly into the beam with any single eye rest."

USE OF SEMICONDUCTOR LASERS.

THE POSITIVE AND NEGATIVE ASPECTS OF THIS TECHNOLOGY.

Diodes are widely used. The fact that they are inexpensive to produce, easy to use has determined their mass production leading to their inclusion in most electronic devices that require lasers.

CD drives, CD-ROMs or CD-players, are all equipped with laser diodes.

DVD players have laser diodes that emit much finer beams.

CD and CD-RW burners use light-emitting diode lasers close to IR (800 nm) and power diodes of a few W. The same diodes but with lower powers are present in laser printers.

Other products that use lasers emitted by laser diodes are bar code readers (bar code readers), certain scanners, pointers, etc.

Perhaps the most important advantage, after CD/DVD drives, is found in optical communications. Within each fiber optic transmitter is a diode laser.

More recently diodes have been used in medicine and holography.

Diodes are used in military applications (radar, missile guidance, data transmission through the ether, etc.), astronomical applications (cosmic distances and composition determinations), scale holography special effects , relatively low high strength due to the limited powers developed.

The semiconductor laser is a reliable and inexpensive alternative to gas lasers.

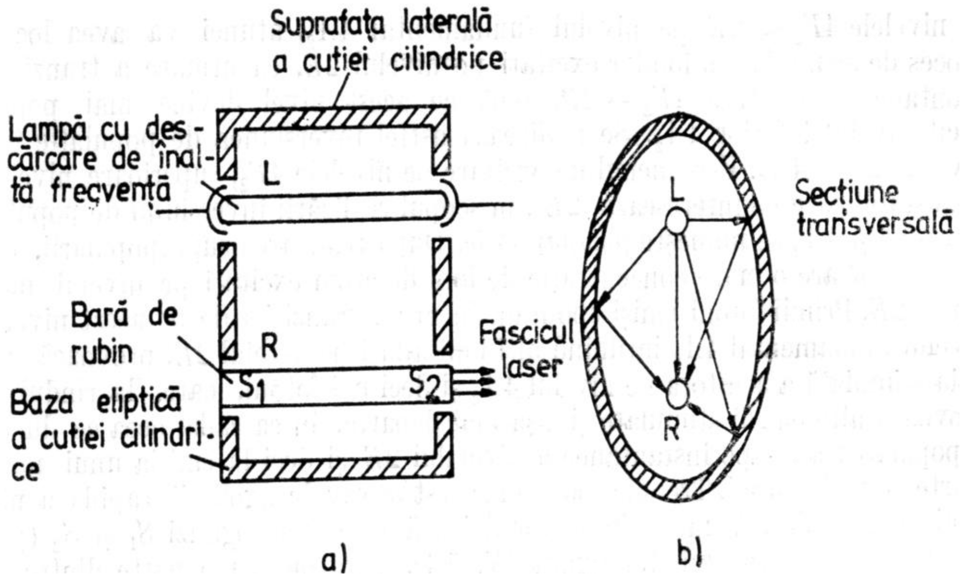
Small sizes, small manufacturing and operating costs and their longevity confer significant advantages for diodes in the "battle" with other laser emitting devices.

The only drawback is their relatively low power and their fragility, the diodes are and will be intensively studied for improvement.

It is important to know the dangers that a laser diode has and the factors that can disrupt their proper functioning to know how to defend ourselves and how to protect ourselves.

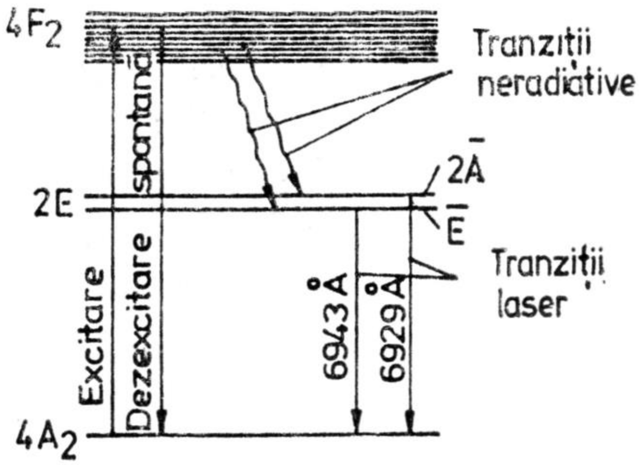
The semiconductor laser whose horizon is a field that is open to us, with a secure future and with strong implications in daily life.

LASER WITH RUBY CRYSTALS



In Figure 1 is shown a rod of cylindrical pink ruby, cut from a single corundum crystal obtained by synthesis, in a controlled environment contaminated with trivalent chromium ions in a ratio of approximately 0.05%, of so that, on average, of 2000 atoms of Al, one is replaced by Cr^{3+}. The base surfaces S1 and S2 of the rod are parallel, highly polished and coated with a layer of silver, obtained by vacuum evaporation . One side, S2, has a thin layer of Ag, serving to allow the exit of the laser beam. These two reflective surfaces cause the volume of the ruby rod to act as a resonant cavity for the light within. A bar is mounted on one of the two focal axes of the elliptical section of the cylindrical boxes, with the reflectance of the inner surface

In the other focal axis is a gas discharge lamp, the lamp L. This is the pump lamp of the device. The light produced by it is concentrated on the ruby crystals R following reflections on the elliptical mirror Figure 1b. The ruby bar is the active means of the device where the laser effect occurs.



In the Figure are schematically represented ruby energy levels involved in this effect , using spectroscopic notations

The blue-green radiation in the wavelengths of almost 550 nm and the value contained in the light emitted by the lamp L, causes transitions of chromium ions of level 4A2, not interesting for the laser effect, the photons are emitted on this occasion with an energy equal to that absorbed at the 4A2-4F2 transition and others by spontaneous transitions on the 2E energies, non-radiative phenomena.
The difference in the energy of the transitions is taken up by the vibrations of the crystal lattice, in the form of heat, warming the crystal. 2E is, however, a metastable level, i.e. an energy level where excited particles stop, until their spontaneous de-excitation, a much longer time than normal levels of excitation. Chromium ions on the 2E band have an average lifetime in this state, several orders of magnitude higher than in the 4F2 band states.
If now the intensity of the blue-green excitation light is large enough that the number of photons per unit time radiation exceeds the number of spontaneous de-excitations from the 2E 4F2 levels to the fundamental 4A2 level, then there will be a process of accumulation of excited ions from the E2 level due to spontaneous transitions from non-radiative phenomena until this level is more populated than the lower 4A2 level.
The population inversion between the levels 2E and 4A2 is thus carried out.
The phenomenon of exciting levels 4F2, the upper metastable level, to achieve population inversion between 2E and 4A2 is called optical pumping. After overpopulation, the ruby bar has a high concentration of chromium ions in the 2E metastable level. The first photon emitted spontaneously after passing from this level to the fundamental level 4A2 encountering other ions on the 2E level, causes them to have a stimulated transition from the 4A2 level and the new photons, which in turn causes further stimulated emissions to cascade. , leading to almost instantaneous depopulation of 2E emission levels and emission of a large number of photons. In this rapid process of the 2E metastable level, two mirrors S1 and S2 play a decisive role, which cause a certain number of photons produced in the volume bar to cross after reflection, several times its length before leaving it, thus increasing considerably the number of acts of resonance de-excitation of chromium ions in the 2E state. Apart from the effect of conservation of electromagnetic energy within the active environment, these repeated unidirectional reflections cause the accumulation of photons, with precedence on the axle.
Finally, after the threshold condition is realized, they pass through half-mirror S2, form a parallel beam of coherent, extremely intense, monochromatic light, called a laser beam.
By using a continuous spectrum pump lamp, we will obtain a greater number of excited atoms, capable of lasing over a wide band, only at a narrow level.

The ruby crystal laser functions as a radiation quantum generator.

It is illuminated by a green-blue beam, which performs the pumping and generates red light.

It can work as a quantum amplifier with S radiation

The first step is performed by pumping the device into the already known population inversion mode. When sending red radiation, the device is highly amplified. In both cases, the underlying phenomenon is stimulated emission.

In the case of the generator the emission is driven by the first photons emitted spontaneously and in the case of the photon amplifier of the incident radiation.

The depopulation of level 2 E takes place in an extremely short time, which leads to a sudden drop in the light signal.

The emission will be repeated after the level 2E is again populated, pumped by the lamp L. If the power of the lamp is not sufficient to maintain a permanent overpopulation of the level 2E, when this is evacuated very quickly , the The laser emission will consist of light pulses which are repeated at a frequency which depends on the power threshold value and the intensity of the lamp. Most ruby lasers operate under pulses.

However, by using specially made glass and another pumping system, ruby lasers have been obtained with continuous operation, where the crowding is not destroyed during emission.

GAS LASER

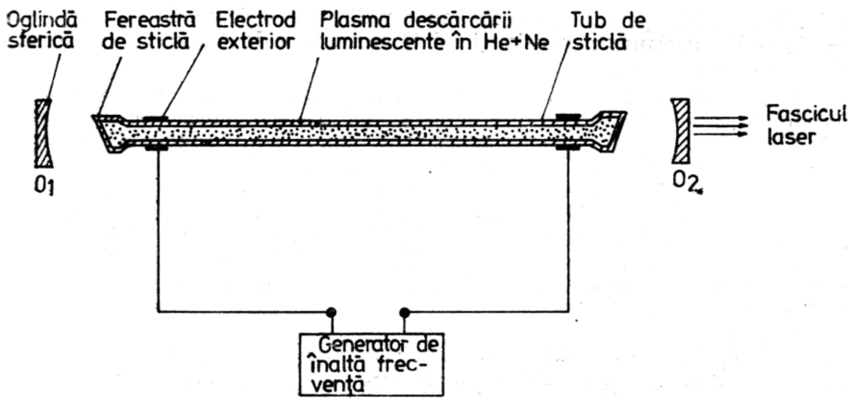


Figure: the main elements of a laser with a mixture of helium and neon

Although in a ruby crystal laser the population inversion is achieved by optical pumping with electromagnetic radiation,

in the gas laser this inversion is usually done by electron collisions.

In Figure 3 are the main elements of a laser with a mixture of helium and neon.

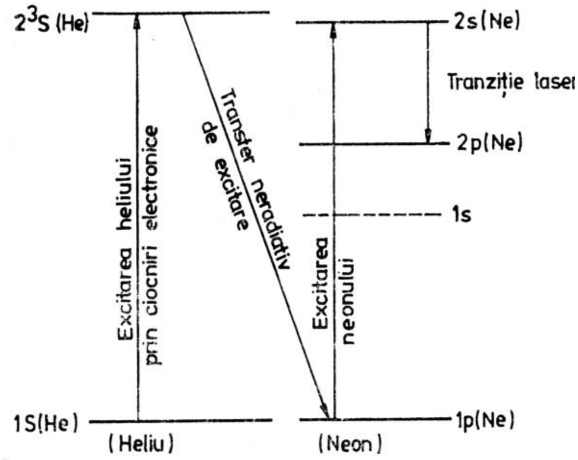
The active medium is the electric discharge plasma in a glass tube with a length of about 1 m and an inner diameter between 2 mm and 15 mm, in which the gas mixture is located. The total pressure of the mixture depends on the diameter of the tube.

For a diameter of 3 mm, for example, the gas pressure is about 1 mm Hg. The partial pressure of helium is 5 to 10 times greater than that of neon.

The download can be produced both at high frequency of alternating current and direct current.

The spherical mirrors O1 and O2, the second semi-transparent, form with the discharge space, the optical resonator. The discharge tube is provided with two windows, inclined at Brewster's angle to the axis of the tube, in order to reduce the loss by reflection.

Figure 4: a simplified diagram of several energy levels involved in the laser effect. On the left are two levels of the helium atom, denoted 1S and 2S and on the right the three levels of the neon atom, denoted by 1p, 2p and 2s.



In the discharge volume, helium atoms are excited
on 2S following collisions with electrons having
a kinetic energy equal to that of the excitation energy of this level. Among the energy levels of the neon atom there is one represented by 2s having the energy almost equal to the 2S state of helium.

Therefore the collision of a helium atom in the 2S state and a neon atom leads to the de-excitation of the neon atom and the excitation of a helium atom in the 2s state after a transfer of excitation energy from the helium atom to that of neon.

The 2s state of the neon atom has an average lifetime about an order of magnitude greater than that of the lower 2b state of the same atom.

For this reason, between the two neon levels, the population inversion takes place at a given temperature, the concentration of neon atoms excited in the 2s state will exceed that of the 2p state. To the overcrowding of the 2S i level also contributes the fact that during the impact of neon and helium atoms, the excitation of neon to the 2S state is a much more likely phenomenon than its excitation to the 2p state, due to the almost resonant character of the energy transfer between the 2S and 2s2 levels.

Once the overpopulation of the 2s level with respect to the 2p level has been achieved, the first spontaneous 2p-2s transitions or external transitions with the radiation energy hv = E(2p) -E (2s), trigger stimulated emission between these two levels, and thus the release of the laser beam.

2s is formed at the end of four subshells and the 2p level of 10 subshells. Apart from this, there are a couple of levels, 2s and 3s in resonant interaction, which results in a population inversion between 3s and the other lower levels of neon. All this means that in the He + Ne mixture we obtain dozens of laser lines, corresponding to different neon transitions. Although low power, these lasers have a large invisible spread.

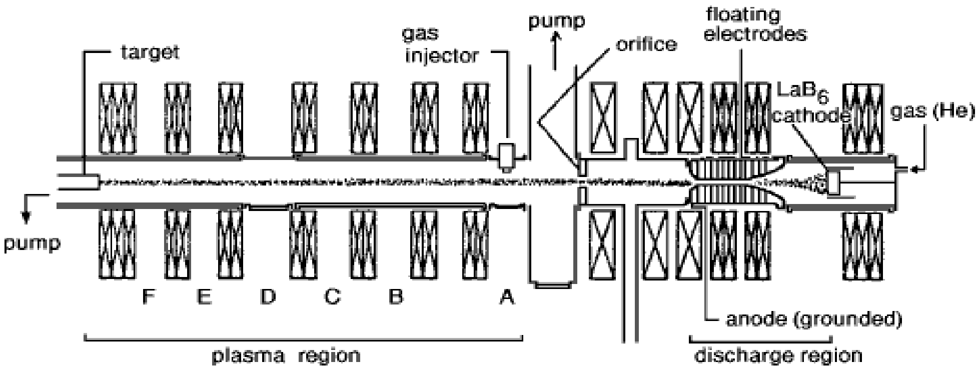
As the proper energy levels of the helium and neon in question are not exactly equal, the interaction does not have a precise resonant character, the small difference in energy is taken up, non-radiating, by the motion heat of the atoms inside the discharge tube.

Thanks to the numerous electron collisions, the discharge tube contains at all times a fairly large quantity of excited helium atoms, and therefore, a fairly large population of excited neon atoms within 2s. This causes the population inversion to be maintained even during the laser transition, which means the laser can operate continuously. This property is a significant advantage over solid laser, which usually operates in pulses.

LIQUID LASER

The most famous liquid lasers are those with organic chelates and those with dyes.
The active medium for dye lasers consists of a fluorescent substance dissolved in a solvent (alcohol).
The spectral width of the emitted radiation is hundreds of angstroms; one can select the desired wavelength, so that the laser is tunable in a wide band.
The plasma cylinder (red) is created by the impact of a high power pulsed laser (blue). Mirrors are not used, spontaneous emissions are amplified and the beam is sent in both directions. It was first created by National Laboratory researchers Lawrence Matthews and Rosen Livermore in 1985.
The target is a thin sheet of selenium or another high atomic number element placed on a vinyl substrate to give it rigidity. This target is irradiated from both sides by high-power pulsed lasers whose focal length is several hundred times greater than the width. When the beam hits the sheet, it "explodes", producing a plasma composed of selenium ions having 24 fewer electrons.
Currently, the efficiency of these lasers is very low due to the need for a high power and high frequency laser source. Greater efficiency can be achieved by rapid cooling, which leads to three re-pumpings of strongly ionized plasma. But a hybrid cooling of contact and adiabatic expansion seems to be the most promising.
Another promising possibility is based on electromagnetic induced transparency, a drastic reduction in the power needed to achieve a more efficient laser without pumping reversal effect (also known as phaser).

LASER WITH PLASMA



Cool circumstellar dust and gas gradually accumulate around stars, launching jets of plasma. The rapid cooling of the plasma during the shell encounter can significantly increase the effect of adiabatic expansion imbalance. Contact with gas is so effective in rapid cooling. Thus in 1987 which was created a plasma laser working in the extreme ultraviolet wavelengths using only this mechanism, without using the extension:

Laser for cooling the plasma in contact with the gas (DPT-I) the helium plasma electromagnetically maintained stationary is cooled by the contact with hydrogen, producing the laser effect in XUV (164 nm) (Institut de la physique des plasmas Nagoya, Japan).

Another advantage of the stellar atmosphere are long distances, an inversion of small populations producing radiation whose intensity increases exponentially in amplitude over long distances to a point where the spectrum dominates. The strongest manifestation of natural lasers occurs in quasars. For plasma lasers studied in research laboratories everything is reduced to a much smaller scale. But this is partly offset by the fact that you can put mirrors on both sides of the environment to produce a laser beam that would be very long in a virtual extension.

LASER WITH HE-NE

The role of He gas in the He–Ne laser

The role of the gas in the He He – Ne laser is to increase the efficiency of the laser process. It produces two particular effects:

1. Direct gas excitation is very efficient.
2. An excited state of He atom (energy level E5) has an energy level which is very similar to the energy of excited states of Ne atom (also of energy level E5.

The Ne atom excitation process is a two-step process:

The applied high voltage causes electrons to accelerate from the cathode towards the anode. These electrons collide with the He atoms, transferring kinetic energy to them.

The excited He atoms collide with Ne atoms and transfer their excitation energy.

So the He gas does not participate in the laser process, but it increases the efficiency of the laser by a factor of about 200!!

He-Ne laser power source

He-Ne lasers that give powers greater than 1mW (standard types used by students in experimental laboratories) use direct current DC sources at high voltages of over 2000V. Lasers need constant current (constant supply of electrons), so a constant current source is used.

To initiate the laser effect the gas in the pipe must be ionized. This qction is the result of a maximum voltage pulsation from the power source. This potential is called the ignition potential of the laser. At the beginning of the discharge, the electrical resistance of the pipe suddenly reaches, in cascade, a reduced value. This means that the voltage drops rapidly and the current increases. According to Ohm's law; this one has a negative electric resistance. (decrease of the tension accompanied by the increase of the current)

To solve this problem, a resistor close to the anode is connected in series with the power source. The resistor has the role of limiting the current flowing through the pipe when the resistance of the pipe suddenly drops.

LASERS AND THEIR USE IN MEDICAL DOMAIN

Lasers are artificial emitters (quantum generators and amplifiers) of monochromatic coherent light and capable of transmitting in small time intervals a quantity of energy that can be concentrated in a certain point.

For example, a laser that irradiates one joule in a 10-6s pulse has the power of 1 MW. The radiant intensity for a solid angle of 4.10-9/steradians is 0.25.1015W. This energy can have destructive effects by effect / thermal shock. The pressure in the focused radiation can reach 30 atm in continuous operation and 109 atm in pulses.

Depending on the wavelength, the laser beam is directed into the surgical field through a system of mirrors.

In the case of the CO2 laser: l= 10 mm

Or by photoconductive fiber: Argon laser: l>500nm. If the laser is used for surgical purposes, the cutter or cutting head terminates in beam focusing lenses. On the path of the laser beam is introduced the pilot light allowing the orientation (the targeting) of the cutting head. The diameter of the affected area can be reduced to the size of the wavelength. Hence the applications in research in biology, in cell surgery.

Laser applications are based on the thermal effects of lasers.

Three categories of research can be distinguished: chemical applications problems concerning research and problems related to protection against laser radiation.

In **OPHTHALMOLOGY** , the laser is used to treat retinal detachment by photocoagulation. The device used for this purpose is a low power laser, attached to an ophthalmoscope. The surgery is completely painless with minimal damage and no side effects. The retina adheres very well and healing is rapid. Laser photocoagulation is mainly used in central serous retinopathy, central coroiditis, etc.

In **DERMATOLOGY** , the laser can be used in the destruction of pigmented lesions (angioma, melanoma, etc.) since these areas strongly absorb laser radiation. The results are satisfactory in the treatment of skin tumor or mucous membranes.

In **DENTISTRY** , the applications are reduced to the effectiveness of the potentiation of fluoride, fusion metals in dental laboratory techniques, in the whitening of devitalized teeth, in the polymerization of binders, etc. Special effects, mostly

Medicine uses the rhodamine dye laser which emits nearly 590 nm, the one normally used in early medical laser systems. The radiation is generated by a fiber, for photodynamic therapy in the treatment of cancer.

A 40 watt CO_2 laser can have applications in ENT, gynecology, dermatology, oral surgery, and podiatry.

Laser medicine is the use of various types of lasers in medical diagnosis, treatment or therapy.

Types of lasers used in medicine, in principle, any laser design, but most importantly:

- CO_2 lasers
- diode lasers
- dye lasers
- excimer lasers
- fiber lasers
- gas lasers
- free electron lasers
- optical parametric oscillators

Medical fields that use lasers:

angioplasty ; Cancer diagnosis, cancer treatment

cosmetic applications , such as laser hair removal, tattoo removal, and dermatology laser liposuction

lithotripsy = operation burst and extraction of bladder stones, endoscopic.)

Mammography ; Medical imaging

Ophthalmology microscopy (include Lasik and laser photocoagulation) optical coherence tomography

prostatectomy surgery

LASER photodynamic therapy (PTD)

in surgery is performed with a beam of light that travels along the optical fiber for photodynamic therapy.

The source is a laser beam, which is split into two different stages to create therapeutically appropriate wavelengths.

The patient is given a light-sensitive drug, which is taken up by the cancer cells. During operation, the beam of light is positioned at the level of the tumor, which then activates the drug that kills cancer cells, so applying photodynamic therapy (PDT).

Photodynamic therapy (PDT), sometimes called photochemotherapy, is a form of phototherapy using non-toxic light-sensitive compounds that are selectively exposed to light, they become toxic to diseased and other malignant cells.

PDT has shown the ability to destroy microbial cells including bacteria, fungi and viruses.

PDT is commonly used in the treatment of acne. It is used clinically to treat a wide range of diseases including wet age-related macular degeneration and malignant cancers and is recognized as a treatment strategy that is both minimally invasive and minimal toxicity.

Most modern PDT applications include three key components: a photosezor, a light source and an oxygen layer. The combination of these three chemical components results in the destruction of any tissue that is selectively taken from the photosensitizer or has been exposed to light locally. The wavelength of the light source must be appropriate for the photosensitizer to produce reactive oxygen species. These reactive oxygen species are the free radicals generated by PDT (PDT type I) generated by electron capture, or transfer to a substrate molecule and the highly reactive oxygen state known as singlet oxygen (Type II PDT) .

To understand the mechanism of PDT, it is important to distinguish it from other laser and light-based therapies, such as scarring and rejuvenation laser or pulsed light hair removal that does not require a photosensitizer.

Dye laser (DYE LASER)

Dye laser is a laser that uses an organic dye as the laser medium, most often in the form of a liquid solution.

Compared to gas or solid-state lasers, a dye can generally be used for a much wider range of wavelengths. The large bandwidth makes them particularly suitable for tunable lasers and pulsed lasers.

The dye can be substituted with another type, to generate different wavelengths with the same laser, although this usually requires replacing other optical components of the laser.

Dye lasers were independently discovered by PP Sorokin and FP Schäfer (and colleagues) in 1966.

In addition to the usual liquid state, dye lasers are also available as well as solid-media lasers (SSDL). SSDL uses dye-doped organic matrices as the gain medium.

Lasers and their use in medicine

The rhodamine-based CW dye laser emits almost 590 nm, is generally used early in medical laser systems.

The radiation is generated by a fiber, for photodynamic therapy in the treatment of cancer.

A 40 watt CO_2 laser has applications in ENT, gynecology, dermatology, oral surgery, and podiatry

Laser medicine is the use of various types of lasers in medical diagnosis, treatment or therapy.

The types of lasers used in medicine, in particular:

- CO_2 laser
- laser diode

- Dye laser
- Excimer laser
- fiber laser
- gas laser

free electron laser

MEDICAL FIELDS USING LASERS:

- angioplasty
- cancer diagnosis
- cancer treatment
- cosmetic applications such as laser hair removal, tattoo removal
- dermatology
- lithotripsy
- mammography
- medical imaging
- microscopy
- Ophthalmology (include Lasik and laser photocoagulation) optical coherence tomography
- prostatectomy

8. NATURAL RADIOACTIVITY AND ARTIFICIAL RADIOACTIVITY

Radioactivity is the property of certain elements to disintegrate spontaneously, transforming into new elements by emission of rays α,β And γ. Radioactivity is divided into two categories: natural and man-made.

Natural radioactivity is the fundamental component of the environment and is closely linked to radioactive elements of terrestrial origin, present in the soil, in the air, in water, in vegetation, in animal organisms and in the human one. These naturally occurring radioactive elements have coexisted for millennia of years with extraterrestrial and cosmic radiation.

The main causes why radioactivity is necessarily monitored and kept under control are:

- human activities;
- Exploitation of radioactive minerals;
- Extraction and use of coal and geothermal waters
- The significant presence of certain non-radioactive minerals, but with a high natural radioactive content.
- The use of unconventional materials in constructions
- Phosphate rocks used in the production of chemical fertilizers for agriculture.
- Oil industry field waters.

THE AIMS OF RADIOACTIVITY MONITORING ARE:

Know the physical factor, namely radioactivity, existing on Earth and responsible, to a large extent, for the evolution of life on Earth.

Evaluate human exposure to radiation and, if necessary, establish protective measures against radiation.

Identify priorities and take concrete measures for the ecological rehabilitation of regions with high radioactivity, due to human activities.

The two most important sources of artificial radiation are: - nuclear explosions (carried out both underground and in the atmosphere) and the use of radionuclides in different scientific and technological fields (these are likely to cause contamination environmental radiation).

When we want to study the consequences of radioactivity on the human body, we speak in terms of "human exposure to radioactivity" which details the effects / biological damage produced by radiation on the human body. These can be caused from outside the body (by external irradiation) or from inside the body (by radionuclides that have already entered it).

A characteristic of these types of rays is that they cannot be perceived by the human senses. The only way to do this is with the help of the ray detector, called a dosimeter. Dosimetry is a branch of physics which studies the measurement of radioactive contamination of environmental factors, food, biological products or the human body. A considerable part of the nuclides is not stable, due to the number of neutrons and protons, to their configuration and to the existing forces in the atom; therefore, ray emissions are likely to occur.

THE VARIOUS ORIGIN AND NATURE OF RADIATION

- High-frequency electromagnetic X and gamma rays are of the same nature as visible light.
- Corpuscular radiation is electrically charged: alpha, beta, accelerated ions. Beta rays are, in fact, electrons characterized by a high speed of movement, compatible with the speed of X and gamma rays, and very close to that of light. Alpha radiation consists of helium nuclei.
- Corpuscular radiation is electrically neutral; neutrons.
- All these types of radiation have common properties: they are invisible, move at high speed and can penetrate materials whose thickness is different, depending on the nature and energy of the ray.

DISINTEGRATION ALPHA

By the emission of an alpha particle, the nucleus is transformed into another nucleus, moved two places to the left in the periodic table of the elements.

DISINTEGRATION α ALPHA: $^{A}_{Z}X \rightarrow ^{A-4}_{Z-2}Y + ^{4}_{2}He$

The alpha particles, ejected from the nucleus, do not exist as such inside it; they are formed only at the time of disintegration by the union of two protons with two neutrons. Very soon after formation, they leave the nucleus, crossing its potential barrier by the tunnel effect.

For a distance **r >R ,** the Coulomb forces, of repulsion between the protons, print a positive potential which decreases with distance.

For a distance **r <R** , Coulomb's law is no longer confirmed, "U" suddenly decreases to a negative value; the nuclear forces of attraction are dominant among nucleons, and they actually determine the stability of the nucleus.

For a distance **r =R** the potential energy is: $U_{\max} = \frac{0{,}96Zz}{A^{1/3}}$

According to the laws of classical mechanics, a particle with energy lower than the maximum energy of the potential barrier (E <Umax) cannot leave the potential group, if it does not respect the law of conservation of momentum and energy.

The energy of the particle α(E =mc ^{2}) is given by the mass defect:

$$m = m\left(X^{A}\right) - m(Y) + m(\alpha)$$

It should be greater than "U_{max}".

A more detailed analysis of the particle energy spectrum for a given isotope showed that this spectrum is discrete, finely structured: the particles have different energies, but close to each other, depending on the energy states where the transition of nuclei occurs.

The particles αhave a reduced material penetration power (a few centimeters in air and 0.05mm in aluminum) and a high ionization power.

There is a relationship between the course/trajectory R of the alpha particle and the decay constant "λ" of the radioactive nuclide, a relationship obeying the Geinger-Nuttal law:

$$\log \lambda = A + B.\log R$$

where A and B are empirical constants of a given/established value for a radioactive family.

The Energy of decay appears as the kinetic energy of the products γ and α.

Because the velocities are relativistic we can rewrite this ratio as:

We can rephrase it:

$$E_{dez} = \frac{1}{2} m_{ox} v^2 + \frac{1}{2} m_{oy} v^2$$

$$E_{dez} = .\frac{1}{2} \frac{m_{\alpha 0}^2 v^2}{m_{o\alpha}} + \frac{1}{2} \frac{m_{oY}^2 v^2}{m_{oy}} = \frac{m_{o\alpha}^2 v^2}{2} \left(\frac{1}{m_{0\alpha}} + \frac{1}{m_{0Y}} \right) = \frac{m_{o\alpha}^2 v^2}{2} \left(1 + \frac{m_{0\alpha}}{m_{0y}} \right)$$

Or $E_{dez} = E_{\alpha} (1 + \frac{m_{o\alpha}}{m_{oY}})$

When passing through a medium, the particles αlose energy, as a result of the processes taking place. Decay usually occurs at the end of the periodic table, where all radionuclides with Z >82 have active alpha isotopes.

According to the law of conservation of mass, we have: $m_{0x} > m_{0y} + m_{0\alpha}$

where " mo α" is the rest mass of the particle α.

We can replace the masses of the nuclei by the masses of the atoms; therefore, the law can be rewritten as follows, if we denote with "Mo" the rest mass of the atom:

$$M_{0x} - Zm_{0e} > M_{0y} - (Z-2)m_{0e} + M_{0He} - 2m_{0e}$$

$$M_{0X} > M_{0y} + M_{0He}$$

Following the simplifications made there, we obtain:

The law of conservation of momentum causes the decay energy to be distributed between the Y nucleus and the particle α.

If we note with “V” and “v” the velocities of the particle X and of the nucleus Y, we have:

$$0 = m_{0y} V + m_{0x} . v$$

$$m_{0y} V = m_{0x} . v$$

The Energy of Decay appears as the kinetic energy of the products Y and α.

Because the velocities are relativistic we can write:

$$E_{dez} = \frac{1}{2} . m_{ox} . v^2 + \frac{1}{2} . m_{oy} . V^2$$

We can rephrase it like this:

$$E_{dez} = \frac{1}{2} . \frac{m_{\alpha 0}^2 v^2}{m_{o\alpha}} + \frac{1}{2} . \frac{m_{oY}^2 v^2}{m_{oy}} = \frac{m_{o\alpha}^2 v^2}{2} = \left(\frac{1}{m_{o\alpha}} + \frac{1}{m_{oY}} \right) = \frac{m_{o\alpha} v^2}{2} \left(1 + \frac{m_{o\alpha}}{m_{oY}} \right)$$

Or

$$E_{dez} = E_{\alpha} \left(1 + \frac{m_{o\alpha}}{m_{oY}} \right)$$

DISINTEGRATION β

The disintegration β- is very widespread, the lightest active nuclide being an isotope of tritium. Experimentally, by the deviation in electric and magnetic fields, it was proved that the β- particles are electrons, which causes the **β- DISINTEGRATION** to occur according to the scheme:

$$ {}_{Z}^{A}X \rightarrow {}_{Z+1}^{A}Y + {}_{-1}^{0}\beta + {}_{0}^{0}\nu $$

The appearance of the electron antineutrino is required by the conservation of lepton number and spin and conforms to the other conservation laws.

Both the electron and the antineutrino do not pre-exist in the nucleus and are formed at the moment of emission.

The law of conservation of mass claims: mox > moY + moe

or moving to the atomic masses: mOX-Zmoe>mOY-(Z+1)moe+moe

After simplifications, the disintegration condition is obtained: MOX > MOY

Conservation of momentum leads to: pβ+pν+pY=0

Radiation **β**, made up of electrons, has a higher penetrating power than α radiation , and an ionization power lower than this, since electrons have a mass about 7000 times less than that of particles α.

Electrons move at different speeds, but very close to the speed of light.

During radioactive decay, the protons and neutrons of the nuclei are likely to change between them, the positive or negative charge produced in excess is taken up either by an electron or by a positron.

Pauli hypothesized that during the decay β+ and β-, the nucleus also delivers from the neutron and the proton a new particle, electrically neutral, with an extremely reduced mass; this particle moves at a speed equal to that of light.

The particle, called neutrino or antineutrino, charges with the difference in energy of the system, and, by this, we explain the aspect of the energy spectrum: the total energy produced is distributed differently between the electron and the neutrino, d 'one disintegration to another; their sum is equal to Emax. The neutrino is difficult to highlight, since it is neutral, its mass at rest is zero, it interacts weakly with the substance and has a high penetrating power. Many experimental data prove that it is a real particle.

Decay β+ is accompanied by another type of decay called K-capture. The nucleus of an atom can capture one of its electrons, usually the one on the closest energy levels.

Absorbed by the nucleus, the electron unites with a proton, which is transformed into a neutron with the emission of a neutrino.

The Nuclide changes into another nine, one lower in atomic number, but the same mass, because the total number of nucleons is not changed. There is, however, a rearrangement of electrons in the K shell, accompanied by the emission of K radiation.

Disintegration βis widespread; the easiest active nuclide is an isotope of tritium. It has been experimentally demonstrated (through the deflection carried out in electric and magnetic fields) that the particles βare electrons, which determines that the decay occurs according to the scheme:

${}^{A}_{Z}X \rightarrow {}_{Z+}{}^{A}_{1}Y\ {}_{-1}^{0}\beta + {}^{0}_{0}\nu$

The presence of the electron antineutrino is required by the conservation of lepton number and spin; this presence is in line with other conservation laws.

Both the electron and the antineutrino do not pre-exist in the nucleus, but are formed at the very moment of emission.

The mass conservation law is: mox > Moy + moe

or by replacing the masses of the atoms, we have:

MOX - Zmoe >MOY - (Z + 1) + moe+moe

Following the simplifications operated there, we obtain the condition of the disintegration:

MOX > MOY

Conservation of momentum generates: pβ+ pν + pY = 0

Decay β- occurs in many nuclides, the easiest emitter is: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}\mathrm{Y} + {}^{0}_{-1}\beta + {}^{0}_{0}\nu$

The particles β + are positrons, hence the **decay β + scheme** is: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}\mathrm{Y} + {}^{0}_{+1}\beta + {}^{0}_{0}\nu$

If we apply the law of conservation of total mass, we obtain: moe>mox+moy

We can replace by the masses of the atoms; then we have: Mox-Zmoe>Moy- (Z-1)mo+ moe

From this formula we can obtain the necessary condition of the disintegration: Mox>Moy + 2moe

DISINTEGRATION γ

The electromagnetic nature of radiation**γ** was demonstrated by absorption and diffraction experiments. Unlike light radiation and X-rays, Y-rays are emitted from the nucleus and not from the electronic envelope of the atom, and they have a higher frequency (6x10 20 Hz) which explains their energy and power of high penetration. In exchange, they have a reduced ionization power.

Their attenuation is given by an exponential law comparable to the law of absorption of X-rays.

Most radioactive isotopes emit radiation accompanied by either **γ**α radiation or β radiation . Since the elements are usually mixtures of isotopes, the three rays occur together.

In fact, the radiation **γ**is not emitted by the lead radionuclide, but by one of its decay products. Normally the nuclide formed by α or β decay is in the ground state, with minimum energy. It is possible for the α or β particle to be emitted at a kinetic energy less than the maximum energy available; the difference is taken up by the newly formed radionuclide which is thus in an excited state. Returning to the ground state, it releases excess energy through the emission of radiation **γ**.

Sometimes the excited nuclide, resulting from the disintegration, returns to the fundamental state, not by emission **γ,** but by the transfer of the excess energy to one of the electrons of the atom. The phenomenon, called internal conversion, is manifested by the emission of electrons of well-defined energy, accompanied by characteristic X-radiation. The electrons resulting from the internal conversion are distinguished from those resulting from the **β - disintegration** , because they are mono-energetic.

THE LAW OF RADIOACTIVE DECAY

Establishing the law of radioactive decay was from the beginning a difficult problem for two reasons: decay is a spontaneous process that occurs by chance, so it had to be analyzed in statistical terms; while the radioactivity of some elements decreases through decay, these elements are likely to manifest their presence following the decay of many other elements, and, therefore, the radioactivity increases. But we note that starting from a radioactive nuclide from which we always remove the products of disintegration, its radioactivity decreases with time following an exponential decrease. If "N" is the number of radioactive atoms present in the moment t, then in an interval dt it will decay dN atoms

$dN = -\lambda . N . dt$

where "λ" is a proportionality constant characteristic of each element, called the radioactive decay constant. It is numerically equal to the fraction of atoms disintegrating in a unit time.

By integrating the equation $\int_{No}^{N} \frac{dN}{N} = -\lambda \int_{0}^{t} dt$; $\ln \frac{N}{No} = -\lambda t$; $N = N_0 . e^{-\lambda t}$

where "N_0" is the number of atoms present at the initial moment. Since the number of atoms that decay at any given moment depends only on the number of atoms present at the given moment, it is concluded that atoms are unstable and that they always spontaneously decay because of this. The Process is statistical, it is not predictable, we do not know which atom will disintegrate at a given moment, but we know precisely the exact number of atoms which will disintegrate during a certain period.

In order to characterize the radioactivity of an element, another constant "T" is used, the half-life; the atoms of a radioactive substance decompose by emitting radioactive radiation. The term "half-life time" designates the time during which the quantity of these radioactive atoms decreases by half.

The half-life of various elements is very widely variable: from 3.10^{-7} s for Po to $1.39.10^{10}$ years for Th.

Another characteristic constant of radioactive elements is their average lifetime, which is equal to the inverse of λ: $\tau = \frac{1}{\lambda}$

If we replace in the formula of the law of decay the t with τ, then we have the average lifetime equal to the time after which the number of nuclei "No" decreases by "e" times.

The activity of a radioactive sample is defined as the number of atoms in the sample that decay in a unit time:

$$\Phi = -\frac{dN}{dt} = \lambda N = \lambda N_0 e^{-\lambda t} = \Phi_0 e^{-\lambda t}$$

A decay chain/radioactive chain/cascade decay

When we established the law of disintegration, we considered that the resulting element is an isotope. In most cases, radioactive decay products are also radioactive. In this case, the law is likely to be generalized as follows: Given two radioactive nuclides with decay constantsλ 1 andλ 2, who at any given time have the activitiesϕ 1= λ 1N1 andϕ 2=λ 2N2. The activity of the derived isotope can be described like this:

If we denote with N1(0) and N2 (0) the number of nuclides present at the initial moment, we obtain the equation: which generates by integration, provided that at the initial moment there are only atoms of the first isotope: the number of N2 atoms generated increases with time, reaches a maximum value, and then decreases.

If the generator element has a short life compared to the derived one (λ1 <λ2) , the quantity of the derived product is growing rapidly, reaches a maximum value and decreases again. This decrease is a function of the value of λ1. The generating isotope quickly disappears from the mixture and after a certain time t>tmax, e- λ 1t can be neglected with respect to e- λ t2 and, consequently, we have:

or:

Ratio tends to infinity.

When the generator isotope has a longer lifetime than the derived one (λ 1 < λ 2), there will always be both isotopes in the mixture, one accumulating the other. After a sufficiently long time we can consider e –λ1t and, consequently, we have

where: λ1N1= λ2N2=cst

This is the equation that defines the regime equilibrium for the two radioactive isotopes.

If the first substance has the half-life greater than the second (λ1 <λ2) , then the value of λ1 can be neglected in the equation and hence we get

Or λ1N1= λ2N2=cst

The equation known as the "secular equilibrium equation" shows that the number of nuclides which decay in a unit time is equal to the number of newly formed nuclides at the same time.

The ratio between the quantity of radionuclides existing in each radioactive substance and the respective half-life makes it possible to determine one of these physical quantities for a particular sample of isotopes, if the values for another term of the radioactive series are known.

The extent to which the law is applicable depends on the relationship between the half-life and the elapsed time of the onset of decay. From here it is possible to calculate the age of the Earth, which has almost the same value as “T” for uranium; these results are possible thanks to lead (using which the series is determined) which has T= ∞and is never in equilibrium with uranium. All the other terms in the series have lower half-lives, so for the last three billion years there was a perfect balance between uranium and the other isotopes.

All natural radioactive isotopes are grouped into four series: three natural radioactive series and one artificial series:

THE URANIUM SERIES

THE THORIUM SERIES

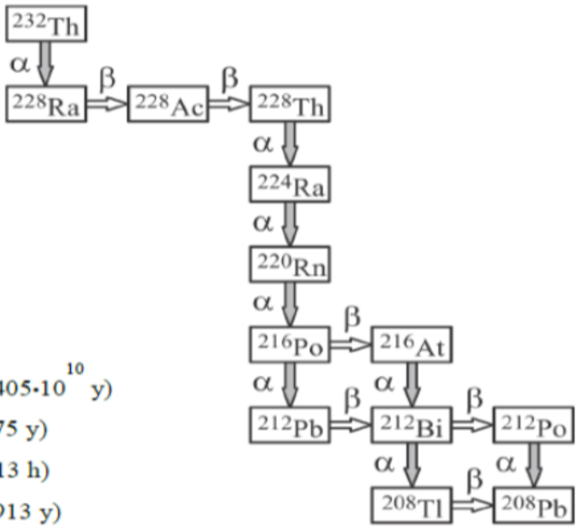
THE ACTINIUM SERIES

THE NEPTUNIUM SERIES.

Each series is composed of a heavy radioactive element, head of series (A>200) and other radioactive elements, increasingly light, which are formed by successive disintegrations; each series ends with a stable isotope. The neptunium series is not natural, it is produced artificially and has been given the name "neptunium" because it is the term with the longest period of life.

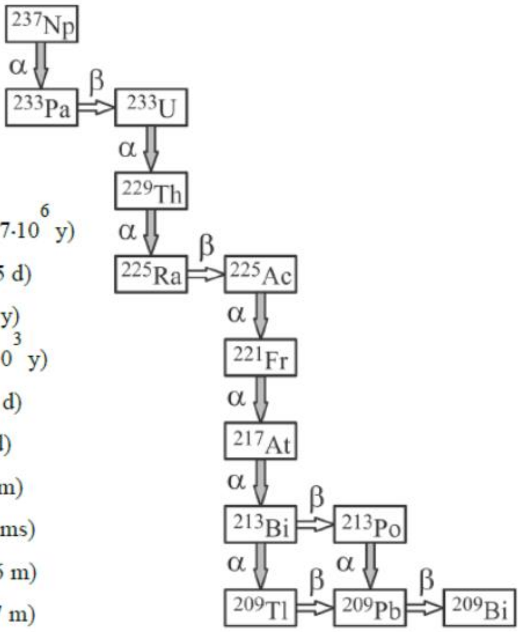
As each series is formed by decays where the mass number varies by four units and by decays where the mass number does not change, it follows that the mass numbers of the terms of a radioactive series have the form A=4n + a; the "n" is an integer (nΩ59) and the "a" has the value 2,0,3, respectively 1 for the four series.

In nature, there are still some radioactive nuclides that do not fit into a series; they are much lighter and weakly radioactive: for example, K (β + radioactivity), Sm (α radioactivity), Lu and Rb (β- radioactive).



^{232}Th (1,405·10^{10} y)
^{228}Ra (5,75 y)
^{228}Ac (6,13 h)
^{228}Th (1,913 y)
^{224}Ra (3,632 d)
^{220}Rn (55,6 s)
^{216}Po (0,145 s)
^{216}At (0,30 ms)
^{212}Pb (10,64 h)
^{212}Bi (60,56 m)
^{212}Po (299 ns)
^{208}Tl (3,053 m)

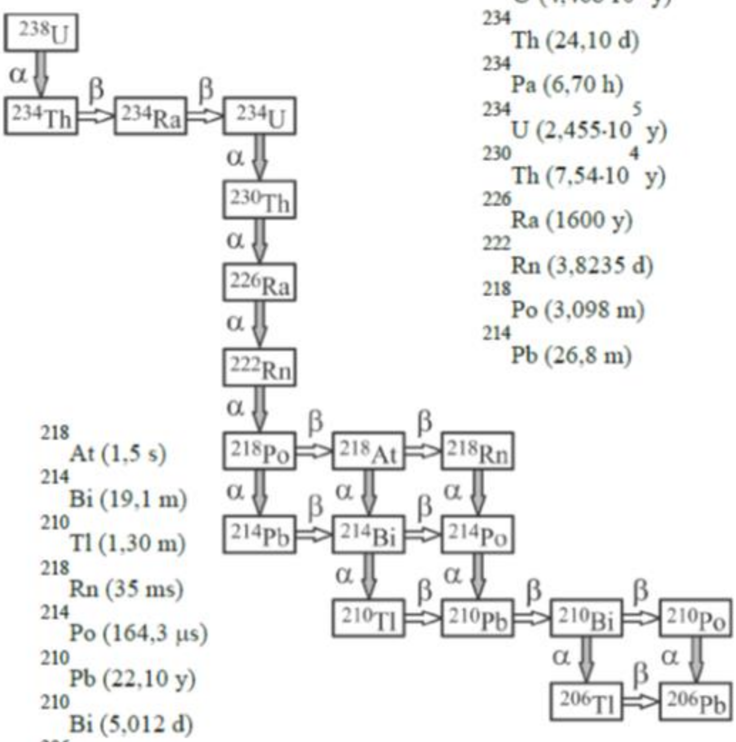
disintegration series ^{232}Th [4n]



^{237}Np (2,1447·10^{6} y)
^{233}Pa (26,975 d)
^{233}U (16·10^{4} y)
^{229}Th (7,88·10^{3} y)
^{225}Ra (14,93 d)
^{225}Ac (9,95 d)
^{221}Fr (4,806 m)
^{217}At (32,34 ms)
^{213}Bi (45,596 m)
^{209}Tl (2,1617 m)
^{213}Po (4,2 μs)
^{209}Pb (3,25314 h)

disintegration serie **^{237}Np [4n+1]**

^{238}U ($4{,}468 \cdot 10^{9}$ y)
^{234}Th (24,10 d)
^{234}Pa (6,70 h)
^{234}U ($2{,}455 \cdot 10^{5}$ y)
^{230}Th ($7{,}54 \cdot 10^{4}$ y)
^{226}Ra (1600 y)
^{222}Rn (3,8235 d)
^{218}Po (3,098 m)
^{214}Pb (26,8 m)

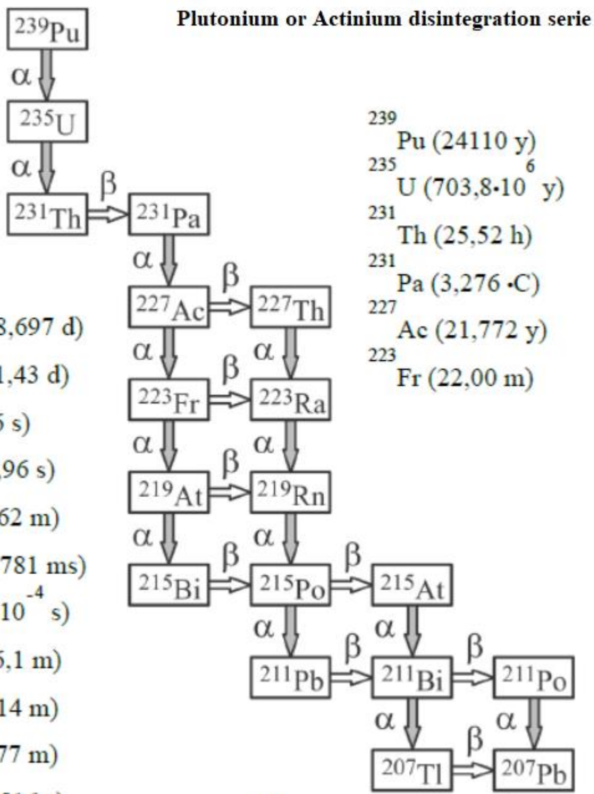


^{218}At (1,5 s)
^{214}Bi (19,1 m)
^{210}Tl (1,30 m)
^{218}Rn (35 ms)
^{214}Po (164,3 µs)
^{210}Pb (22,10 y)
^{210}Bi (5,012 d)
^{206}Tl (4,202 m)
^{210}Po (138,376 d)

stable isotope

disintegration series ^{238}U [4n+2]

Plutonium or Actinium disintegration serie



^{239}Pu (24110 y)
^{235}U ($703{,}8 \cdot 10^{6}$ y)
^{231}Th (25,52 h)
^{231}Pa (3,276 ·C)
^{227}Ac (21,772 y)
^{223}Fr (22,00 m)

^{227}Th (18,697 d)
^{223}Ra (11,43 d)
^{219}At (56 s)
^{219}Rn (3,96 s)
^{215}Bi (7,62 m)
^{215}Po (1,781 ms)
^{215}At (~ 10^{-4} s)
^{211}Pb (36,1 m)
^{211}Bi (2,14 m)
^{207}Tl (4,77 m)
^{211}Po (0,516 s)

^{235}U [4n+3]

$$ {}^{131}_{53}I \overset{\beta}{\rightarrow} {}^{131}_{54}Xe \quad ; \quad T_{1/2} = 8{,}02 \ \textbf{days} $$

$$ {}^{125}_{53}I \overset{CE}{\rightarrow} {}^{125m}_{52}Te \overset{\gamma}{\rightarrow} {}^{125}_{52}Te \quad ; \quad T_{1/2} = 59{,}4 \ \textbf{days} $$

Disintegration of iodine isotopes ${}_{53}{}^{131}I$ and ${}_{53}{}^{125}I$ included in labeled thyroxine used for investigations of thyroid function

$$ {}^{113}_{50}Sn \underset{\beta^{+}}{\overset{CE}{\rightarrow}} {}^{113m}_{49}In \overset{\gamma}{\rightarrow} {}^{113}_{49}In \quad ; \quad T_{1/2} = 21{,}4\,\text{min} $$

the transformation by electron capture of the isotope ${}_{49}{}^{113}Sn$ in a metastable isotope ${}_{49}{}^{113m}In$ used to determine the ejection fraction of the left ventricle of the heart

$$ {}^{57}_{27}Co \underset{\gamma}{\overset{CE}{\rightarrow}} {}^{57}_{26}Fe \quad ; \quad T_{1/2} = 271{,}74 $$

Electron capture transformation of the ${}_{27}{}^{57}CO$ isotope used for monitoring vitamin B12 absorption - Schilling test

$$ {}^{99}_{42}Mo \xrightarrow[66\,h]{\beta^{-};\,\tilde{\nu}_e} {}^{99m}_{43}Tc \xrightarrow[6\,h]{\gamma} {}^{99}_{43}Tc \xrightarrow[211000\,y]{\beta^{-};\,\tilde{\nu}_e} {}^{99}_{44}Ru $$

The formation and disintegration of the Tc isotope used for pulmonary disease investigations

Were presented the nuclear processes of formation and disintegration of some radioactive isotopes and the medical fields of use these several radioactive isotopes,

RADIOPHARMACEUTICALS

RADIOPHARMACEUTICALS which are called medicinal radiocomponents are a group of drugs that contain radioactive isotopes.

Radiopharmaceuticals can be used for diagnose or can be therapeutical agents.

Radiopharmaceuticals emit radiation, which is different from media that absorb or influence external electromagnetic or ultrasound field.

Radiopharmacology is the branch of pharmacology that specializes in these agents.

The main group of these compounds are radiotracers used to diagnose dysfunction in body tissues.

Not all medical isotopes are radioactive, radiopharmaceuticals are the oldest and most common such drugs.

A RADIOTRACER or radioactive label is a chemical compound in which one or more atoms have been replaced by a radionuclide so that, by virtue of its radioactive decay, it can be used to explore the mechanism of chemical reactions by tracing the path along which radioisotope follows from reactants to products.

Tipical radiopharmaceuticals :

- Calcium-47
- Carbon-11
- Carbon-14
- Crom-51
- Cobalt-57
- Cobalt-58
- Erbium-169
- Fluorine-18
- Gallium-67
- Gallium-68
- Hydrogen-3
- Indium-111
- Iod-123
- Iod-125
- Iod-131
- Fier-59
- Krypton-81m

- Lutetium-177
- Nitrogen-13
- Oxygen-15
- Phosphorus-32
- Radium-223
- Rubidium-82
- Samarium-153
- Selenium-75
- Sodium-22
- Sodium-24
- Strontium-89
- Technetium-99m
- Thallium-201
- Xenon-133
- Yttrium-90

^{47}Ca emits beta and gamma radiation

name	Investigation	Administration mode	*In-vitro* / *in-vivo*	Imagistic / non-imagistic
Ca-47-Ca^{2+}	bone metabolism	Intravenous mode of administration	*In-vitro*	non-imagistic

^{47}Ca emits beta and gamma radiation

name	Investigation	Administration mode	*In-vitro* / *in-vivo*	Imagistic / non-imagistic
Ca-47-Ca^{2+}	bone metabolism	Intravenous mode of administration	*In-vitro*	non-imagistic

^{51}Cr emits gamma radiation

name	Investigation	Administration mode	*In-vitro* / *in-vivo*	Imagistic / non-imagistic
Cr51-heart/blood volume scan	Cardiac red cell volume scan; seizure sites; gastrointestinal blood loss	intravenous	*In-vitro*	non-imagistic
Cr51-Cr^{3+}	Gastrointestinal protein loss	intravenous	*In-vitro*	non-imagistic
Cr51-EDTA (ethylene diaminetetraacetic acid)	Measurement of glomerular filtration rate	intravenuos	*In-vitro*	non-imagistic

^{11}C is a positron emitter

name	Investigation	Administration mode	*In-vitro* / *in-vivo*	Imagistic / non-imagistic
C11-L-metil-methionine	image of brain tumors Parathyroid image	intravenos	*In-vivo*	Imagistic

^{14}C emits beta radiation

name	Investigation	Administration mode	*In-vitro* / *in-vivo*	Imagistic / non-imagistic
C14-Glycocholic acid	Breath test for small intestinal bacterial overgrowth	Oral	*In-vitro*	non-imagistic
C14-PABA (para-amino benzoic acid)	Pancreatic studies	Oral	*In-vitro*	non-imagistic
C14-Urea	Respiratory test for detection of *Helicobacter pylori*	Oral	*In-vitro*	non-imagistic
C14-d-xylose	Breath test for small intestinal bacterial overgrowth	Oral	*In-vitro*	non-imagistic

^{18}**F is a positron emitter** with a plasma half-life of 109 minutes. It is produced in medical cyclotrons, usually from oxygen-18, and then chemically attached to a drug.

name	Investigation	Administration mode	*In-vitro* / *in-vivo*	Imagistic / non-imagistic
F18-FDG (Fluorodeoxyglucose)	Tumor Imagery Myocardial Imagery	IV	*In-vivo*	Imagistic
F18-Sodium Fluoride	Bone system imagery	IV	*In-vivo*	Imagistic
F18-Fluorocholine	Prostate tumore imagery	IV	*In-vivo*	Imagistic
F18-Desmethoxyfallypride	Dopamine receptors imagery	IV	*In-vivo*	Imagistic

^{67}**Ga (Gallium) emits gamma radiation.**

A gallium scan is a type of nuclear medicine test that uses either a gallium-67 (67Ga) or gallium-68 (68Ga) radiopharmaceutical to image a specific type of tissue or the disease state of the tissue. Gallium salts such as gallium citrate and gallium nitrate may be used. The form of the salt is not important as the free dissolved gallium ion Ga3+ is active. Both 67Ga and 68Ga salts have similar absorption mechanisms. Gallium can also be used in other forms, for example 68Ga-PSMA is used for cancer imaging. Gallium 67 gamma emission is imaged by a gamma camera, while gallium 68 positron emission is imaged by positron emission tomography (PET).

name	Investigation	Administration mode	*In-vitro* / *in-vivo*	Imagistic / non-imagistic
Ga67-Ga^{3+}	Tumoral imagery	IV	*In-vivo*	Imagistic
Ga67-Ga^{3+}	Infections/inflamations imagery	IV	*In-vivo*	Imagistic

^{68}**Ga is a positron emitter,** with a half-life of 68 minutes, produced by elution (elution is the process of extracting one material from another by washing with a solvent) of germanium-68 in a gallium-68 generator.

name	Investigation	Administration mode	*In-vitro* / *in-vivo*	Imagistic / non-imagistic
Ga68-Dotatoc or Dotatate	Neuroendocrine Tumour Imaging	IV	*In-vivo*	Imagistic
Ga68-PSMA	Prostate cancer imaging	IV	*In-vivo*	Imagistic

Iodine-123 (I-123) is a gamma emitter. It is only used for diagnostic purposes because its radiation is penetrating and short-lived.

name	Investigation	Administration mode	*In-vitro* / *in-vivo*	Imagistic non-imagistic
I123-Iodide	Thyroid uptake	Oral or IV	*In-vivo*	non-imagistic
I123-Iodide	Thyroid imaging Thyroid metastases imaging	Oral or IV	*In-vivo*	Imagistic
I123-o-Iodohippurate	Renal imaging	IV	*In-vivo*	Imagistic
I123-MIBG (m-iodobenzylguanidine)	Neuroectodermal tumour imaging	IV	*In-vivo*	Imagistic
I123-FP-CIT	SPECT imaging of Parkinson's Disease	IV	*In-vivo*	Imagistic

Iodine-125 : ^{125}I is a gamma emitter with a long half-life of 59.4 days (the longest of all radioiodines used in medicine). Iodine-123 is preferred for imaging, so I-125 is used for diagnose only when the test requires a longer period to prepare the radiopharmaceutical and follow up, such as a fibrinogen scan to diagnose clotting.
The gamma radiation created by I-125 has medium penetration, making it more useful as a therapeutic isotope for brachytherapy implantation of radioisotope capsules for local cancer treatment.

Name	Investigation	Route of administration	*In-vitro* / *in-vivo*	Imagistica / non-imagistica
I125-fibrinogen	Clot imaging	IV	*In-vivo*	Imagistica

Iodine -131 - ^{131}I is a beta and gamma emitter. It is used for both thyroid and thyroid cancer tissue destruction (by beta radiation, which is short-range) as well as other neuroendocrine tissues when used in MIBG. It can also be seen by a gamma camera and can serve as diagnostic imaging when trying and treatment at the same time.
Iodine-123 is preferred when only imaging is desired.

As Treatement

Name	Treatement	Administration mode
I131- Iodura	Thyrotoxicosis	IV or Oral
I131- Iodura	non-toxic goitre	IV or Oral
I131- Iodura	Thyroid carcinoma	IV or Oral
I131-MIBG (m-iodobenzylguanidine)	Malignant disease	IV

^{59}Fe emits beta and gamma radiations

Name	Investigation	Route of administration	*In-vitro* / *in-vivo*	Imaging / non-imaging the radioactive substance
Fe59-Fe^{2+} or Fe^{3+}	Metabolismul Fierului	IV	*In-vitro*	Non-imaging

^{81}Kr^{m} emits gamma radiations

Name	Investigation	Route of administration	*In-vitro* / *in-vivo*	Imaging / non-imaging the radioactive substance
Kr81m-Gaz	Lung ventilation imaging	Inhalation	*In-vivo*	Imaging
Kr-81m- in solutie apoasa	Lung perforation imaging	IV	*In-vivo*	Imaging

Lutetium-177

Lu ^{177} emits beta radiations

Name	Treatment for	Administration mode	*In-vitro* / *in-vivo*
^{177}Lu-DOTA-TATE	(GEP-NETs) Gastro entero pancreatic neuroendocrine tumours	IV	*In-vivo*

DOTA-TATE can be bound with radionuclides such as gallium-68 and lutetium-177 to form radiopharmaceuticals for PET imaging or radionuclide therapy. DOTATATE 177Lu therapy is a form of peptide receptor radionuclide therapy (PRRT) targeting somatostatin receptors (SSRs). In this form of application it is a form of targeted drug delivery.

^{13}N (Nitrogen-13) emits positrons
^{15}O emits positrons
^{82}Rb (Rubidium-82) emits positrons and gamma radiation
^{32}P (Phosphorus-32) emits beta radiation
^{223}Ra (Radium-223) is an alpha emitter.

Nume	Investigatie	Method of administration	*In-vitro* / *in-vivo*	Imaging / non-imaging
N13-Amoniac	Myocardial blood flow imaging	IV	*In-vivo*	Imaging
O15-Water	Cerebral blood flow imaging Myocardial blood flow imaging	IV bolus	*In-vivo*	Imaging

Rb-82 chloride	Myocardial imaging	IV

Name	Treatment for	Method of administration
P32- fosfat	Polycythemia and related disorders	IV or Oral
Ra223 cation (223RaCl2)	bone cancer - metastasis	IV

^{75}Se (Selenium-75) emits gamma radiation
^{22}Na (Sodium-22) gamma radiation and positrons
^{24}Na (Sodium-24) emits gamma and beta radiations
^{89}Sr (Strontium-89) emits beta radiation.

Name	**Investigation**	**Method of administration**	***In-vitro* / *in-vivo***	**Imaging / non-imaging**
Se75-Selenorcholesterol	Adrenal gland imaging	IV	*In-vivo*	Imaging
Se75-SeHCAT (23-Seleno-25-homo-tauro-cholate)	Bile salt absorption	Oral	*In-vivo*	Imaging
Na22-Na+	Electrolyte studies	Oral or IV	*In-vitro*	Non-imaging
Na24-Na+	Electrolyte studies	Oral or IV	*In-vitro*	Non-imaging

Name	**Treatment for**	**Method of administration**
Sr89- clorura	Metastaze osoase	IV

Technetium-99m (99mTc) is the metastable nuclear isomer of technetium-99 (itself an isotope of technetium), symbolized as 99mTc, which is used in a lot of medical diagnostic procedures annually, making it the most commonly used medical radioisotope.
Technetium-99m is used as a radioactive tracer and can be detected in the body by using gamma cameras as medical equipment.
99mTc emits easily detectable gamma rays with a photon energy of 140 keV (these photons at 8.8 pm are about the same wavelength as emitted by conventional X-ray diagnostic equipment) and the half-life for gamma emission. is 6.0058 hours (which means 93.7% of this is reduced to 99Tc in 24 hours). The relatively "short" physical half-life of the isotope and its biological half-life of 1 day (in

terms of human activity and metabolism) allows scanning procedures that collect data quickly but maintain the patient's total radiation exposure.
The same characteristics make the isotope suitable for diagnostic use only, but never therapeutic.
Technetium-99m was discovered as a product of molybdenum bombardment in the cyclotron. This procedure produced molybdenum-99, a radionuclide with a longer half-life (2.75 days), which degrades to Tc-99m.
Today, molybdenum-99 (Mo-99) is used commercially as a readily transportable source of medically used Tc-99m. In turn, this Mo-99 is usually created commercially by fissioning highly enriched uranium in obsolete research and materials testing in nuclear reactors in several countries.

Name	Investigation	Method of administration
Tc99m-pertehnetat	thyroid imaging Salivary gland imaging and imaging of the stomach Meckel's diverticulum imaging Brain imaging Micturator cystogram First pass blood flow imaging Peripheral blood flow imaging in the first pass	IV
Tc99m-pertehnetat	tear imaging	Drops in the eye
Tc99m- human albumin	Cardiac blood imaging	IV
Tc99m- human albumin	Peripheral vascular imaging	IV
Tc99m- human albumin macroaggregates or microspheres	Pulmonary perfusion imaging	IV
Tc99m- albumina umana macroagregate sau microsfere	Pulmonary perfusion imaging with venography	IV
Tc99m- Phosphonates and phosphates (MDP/HDP)	Bone imaging	IV
Tc99m- Fosfonati si fosfati	Myocardial imaging	IV
Tc99m-DTPA (diethylenetriaminepenta-acetic acid)	Renal Imaging First pass blood flow studies brain imaging	IV
Tc99m-DTPA (diethylenetriaminepenta-acetic acid)	Lung ventilation imaging	Aerosoli inhalatii
Tc99m-DMSA(V) (dimercaptosuccinic acid)	Tumor imaging	IV
Tc99m-DMSA(III) (dimercaptosuccinic acid)	Renal Imaging	IV
Tc99m-Colloidal	Bone marrow imaging Gastrointestinal haemorrhages	IV
Tc99m-Colloidal	Lymph node imaging	Interstitial
Tc99m-Colloidal	Imaging of esophageal transit and Imaging of gastroesophageal reflux Imaging of gastric emptying	Oral
Tc99m-Colloidal	Tear imaging	Drops in the eye
Tc99m-HIDA (Hepatic iminodiacetic acid)	Imaging of the functioning of the biliary system	IV

Tc99m- Denatured (heat denatured) red blood cells	Red cell volume Imaging of the spleen	IV
Tc99m- red blood cells	Gastrointestinal bleeding Peripheral vascular imaging Imaging of the peripheral vascular system	IV
Tc99m-MAG3 (mercaptoacetyltriglycine)	Renal imaging First pass blood flow imaging	IV
Tc99m-Exametazime (HMPAO)	Cerebral imaging of blood flow	IV
Tc99m-Exametazime labelled leucocytes	Imaging of Infections and inflamation	IV
Tc99m-Sestamibi (MIBI - methoxy isobutyl isonitrile)	Parathyroid imaging Non-specific tumor imaging Non-specific tumor imaging breast imaging myocardial imaging	IV
Tc99m-Sulesomab (IMMU-MN3 murine Fab'-SH fragmente de anticorp monoclonal antigranulocit)	Imaging of Infections/inflammations	IV
Tc99m-Tehnegas	Imaging of lung ventilation	Inhalation
Tc99m- human immunoglobulin	Imaging of Infections/inflammations	IV
Tc99m-Tetrofosmin	Parathyroid imagistics Myocardial imagistics	IV
Tc99m-ECD (ethyl cysteinate dimer)	Cranial imaging	IV

A RADIOLIGAND is a radioactive biochemical substance (specifically, a ligand that is radiolabelled) that is used for diagnostic or research-oriented study of receptor systems in the body.
In a neuroimaging application, the radioligand is injected into the relevant tissue or infused into the bloodstream. It binds to its receptor.
When the radioactive isotope in the ligand decays, it can be measured by positron emission tomography (PET) or single photon emission computed tomography (SPECT).
In in vivo systems it is often used to quantify the binding of a test molecule to the radioligand binding site.
The higher the affinity of the molecule, the more radioligand is displaced from the binding site and the increase in radioactive decay can be measured by scintigraphy.
This assay is commonly used to calculate the binding constant of receptor molecules.
Radioligand transport is described by receptor kinetics

The radioactive isotopes most often used are
Tritium, 3H
Carbon-14, 14C
Sulphur-35, 35S
Iodine - 131, 131I
Fluorine -18, 18F
Technetium -99m, 99mTc
Copper -64, 64Cu
In PET photon emission tomography, isotopes are used for molecular imaging cases often

fluorine -18,

carbon -11,

copper -64 . Tritium, 3H

Carbon-14, 14C

Sulphur-35, 35S

Iodine - 131, 131I

Fluorine -18, 18F

Technetium -99m, 99mTc

Copper -64, 64Cu

In PET photon emission tomography, isotopes are used for molecular imaging cases often

fluorine -18,

carbon -11,

copper -64 .

Radioligands can be constructed to selectively bind to a specific neuroreceptor or neurotransmitter transporter.

1C - WAY-100635 for the 5-HT1A receptor

N(1)-([11C]-methyl)-2-Br-LSD ([11C]-MBL) for the 5-HT2 receptor

^{18}F-altanserin and ^{18}F-setoperone for the 5-HT2A receptor

^{11}C - ketanserin and ketanserin tritiate

^{11}C - DASB for serotonin transporter receptor

3H-WIN55,212-2 for the cannabinoid receptor

[^{11}C] flumazenil for the GABAA receptor

(+)PHNO for the D2 dopamine receptor

[^{11}C] raclopride for the D2 dopamine receptor.

LIST OF RADIOTRACERS used in positron emission tomography (PET). These are chemical compounds in which one or more atoms have been replaced by a short-lived positron emitting radioisotope.

In Cardiology

[^{15}O] water

[^{13}N] ammonia

[^{82}Rb] Rubidium-82 chloride

[11C] Acetate (also used in oncology)

Neurology

[11C] 25B-NBOMe (Cimbi-36)

[^{18}F] Altanserin

[^{11}C] Carfentanil

[^{11}C] DASB

[^{11}C] DTBZ or [18F]Fluoropropyl-DTBZ

[^{18}F]Fallypride

[^{18}F]Florbetaben

[^{18}F] Flubatine

[^{18}F]Fluspidine

[^{18}F] Florbetapir

[^{18}F] or [^{11}C] Flumazenil

[^{18}F] Flutemetamol

[^{18}F] Fluorodopa

[^{18}F] Desmethoxyfallypride

[^{18}F] Mefway

[^{18}F] MPPF

[^{18}F] Nifene

[^{11}C] Pittsburgh compound B

[^{11}C] Raclopride

[^{18}F] Setoperone

[^{18}F] or [^{11}C] N-Methylspiperone

[^{11}C] Verapamil

In Oncology

[^{18}F] Fludeoxyglucose (18F) (FDG)-glucose analogue

[^{11}C] Acetate

[^{11}C] Methionine

[^{11}C] choline

[^{18}F] Fluciclovine

[^{18}F] Fluorocholine

[^{18}F] FET

[^{18}F] FMISO

[^{18}F] Fluorothymidine F-18

[^{64}Cu] Cu-ETS2

[^{68}Ga] DOTA-pseudopeptides

[^{68}Ga] PSMA

[68Ga] CXCR4- in haematological cancers

Infectious diseases

[18F] Fluorodeoxysorbitol (SDS)

MEDICAL ISOTOPES

A medical isotope is an isotope used in medicine.

Radiopharmaceuticals were the first isotopes used in medicine. This is still the most common use for medical isotopes. However, more recently, separate stable isotopes have come into use.

Examples of non-radioactive medical isotopes are:

- Deuterium in deuterated drugs
- Carbon-13 used in liver function and metabolic testing.

EXAMPLE OF DRUGS :

- ***Myoview 230 micrograms radiopharmaceutical preparation kit Tetrofosmin Prospectus: user information***

What Is Myoview and What Is It Used For ???

This medicine is for diagnostic use only.

It is only used to help identify disease.

Myoview is a 'radiopharmaceutical' medicine.

It is given before a scan and helps a special camera used in the scan to see inside a part of the body.

It contains an active substance called 'tetrofosmin'.

This is mixed with a radioactive ingredient called 'technetium 99m' before it is used.

Once administered it can be seen from outside the body by a special camera used in the scan.

The scan can help the doctor to see how well the heart is working, or to see the extent of damage to the heart after a heart attack.

Other people are given this medicine before a scan to examine lumps in the breast.

Your doctor or nurse will explain about the part of your body that will be scanned

- ***Technescan Sestamibi 1 mg kit for radiopharmaceutical preparations. [Tetrakis(2-methoxy-2-methylpropyl-1-isocyanide)copper(I)] tetrafluoroborate Prospectus***: Patient Information

This medicinal product is a radiopharmaceutical for diagnostic use only. Technescan Sestamibi contains a substance called [tetrakis(1-isocyanide-2-methoxy-2-methylpropyl)copper(I)] tetrafluoroborate.

Is used to study heart function and blood flow (myocardial perfusion) by creating an image of the heart (scintigraphy),

For example to detect heart attacks (myocardial infarctions) or when a disease causes a decrease in blood supply to (part of) the heart muscle (ischaemia).

Technescan Sestamibi is also used to diagnose breast abnormalities in addition to other diagnostic methods when the results are unclear.

Technescan Sestamibi can also be used to detect the position of overactive parathyroid glands (glands that secrete the hormone that controls blood calcium values).

Once injected, Technescan Sestamibi temporarily accumulates in certain parts of the body.

This radiopharmaceutical contains a small amount of radioactivity, which can be detected from outside the body using special cameras.

Your nuclear medicine doctor will take a picture (scintigraphy) of the organ in question, which can give your doctor valuable information about the structure and function of this organ or the location of, for example, a tumour.

The use of Technescan Sestamibi involves exposure to small amounts of radioactivity. Your doctor and nuclear medicine physician have considered that the clinical benefit obtained from the procedure involving a radiopharmaceutical preparation outweighs the risk posed by the irradiation.

- ***SODIUM IODIDE (^{131}I) 0,333 MBq - 3,7 MBq capsules for diagnosis Sodium iodide [^{131} I]***

This drug is for diagnostic use only.

It is only used to help identify disease.

Sodium Iodide Diagnostic Capsules is a 'radiopharmaceutical' drug

It contains an active substance called 'sodium iodide'.

Once administered it can be seen from outside the body by a special camera used in scanning.

The scan can help the doctor see tumours in the thyroid glands,

and to see how well a tumor responds to treatment

or if the tumour has spread to other parts of the body.

PET TECHNOLOGY

POSITRON EMISSION TOMOGRAPHY

Positron emission tomography (PET) [1] is a functional imaging technique that uses radioactive substances known as radiotracers to visualize and measure changes in metabolic processes and other physiological activities, including blood flow, regional chemistry, and uptake.

Different tracers are used for different imaging purposes, depending on the target process in the body.

For example,
18F-FDG is commonly used for cancer detection,
NaF-F18 is widely used to detect bone formation, and
oxygen 15 is sometimes used to measure blood flow

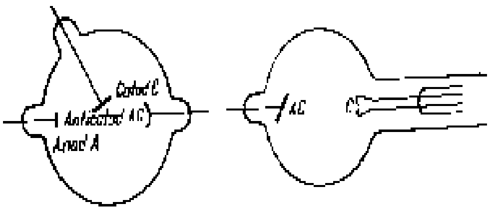
PET is a common imaging technique, a medical scintigraphy technique used in nuclear medicine.
A radiopharmaceutical - a radioisotope attached to a drug is injected into the body as a tracer.
Gamma rays are emitted and detected by gamma cameras to form a three-dimensional image, in the same way that an X-ray image is captured.
PET scanners can incorporate a CT scanner and are known as PET-CT scanners.
PET scan images can be reconstructed using a CT scan performed using a scanner during the same session. One of the disadvantages of a PET scanner is the high initial cost and ongoing operational costs.
Physiological processes lead to anatomical changes in the body.
Because PET is able to detect biochemical processes as well as protein expression, PET can provide information at the molecular level long before any anatomical changes are visible.
PET scanning achieves this by using radio-labeled molecular probes that have different absorption rates depending on the type and function of the tissue involved.
Regional tracer uptake in different anatomical structures can be visualised and relatively quantified in terms of the positron emitters injected in a PET scan.
PET imaging is best performed using a dedicated PET scanner.
It is also possible to acquire PET images using a conventional dual-head gamma camera equipped with a coincidence detector.
The quality of gamma camera PET imaging is lower and scans take longer.
This method allows a low-cost on-site solution for institutions without PET scanning facilities. An alternative would be referring these patients to another centre or calling in for a visit by a mobile scanner.
Alternative medical imaging methods include single photon emission computed tomography (SPECT), X-ray computed tomography (CT), magnetic resonance imaging (MRI) and functional magnetic resonance imaging (fMRI) and ultrasound. SPECT is an imaging technique similar to PET that uses radioligands to detect molecules in the body. SPECT is less expensive and offers lower image quality than PET.

9. X-RAY.

X-RAY SPECTRA. X-RAY PRODUCTION AND PROPERTIES

X-rays were accidentally discovered by physicist Röntgen in 1895.

Starting the study on the fluorescence of some platinum and barium cyanide crystals, Roentgen found that the fluorescence occurs in the dark, when the discharge tube was covered with black paper. He surmised that this effect is produced by invisible, highly penetrating rays coming from the glass walls of the tube, whenever the cathode ray beam hits the glass. Since these rays were of an unknown nature, Röntgen called them "X-rays".



a b

These are electromagnetic waves, like light, of the same nature as ultraviolet or visible radiation, but their wavelengths are much lower, measurable in angstroms or thousandths of an angstrom. Therefore, for the expression of these wavelengths we often use the unit

$1\ X = 10^{-3}\ A = 10^{-11}\ cm$

https://www.iucr.org/publ/50yearsofxraydiffraction/full-text/principles

X-radiation is emitted either by a braking process, carried out by the emitting material, of certain projectile particles, usually electrons, at high kinetic energy; either by a process of excitation of the atoms of the emitting material; following this last process one of the electrons with a lower principal quantum number is torn from the atom, its place being taken by an electron with a higher principal quantum number; by that one obtains a redistribution of the electrons on the levels of energy.

Usually the X-ray source is an electric discharge tube in a highly rarefied gas or in a vacuum; this tube is called an “X-ray tube”. It is formed by a cathode-projectile which emits electrons, an anode and an anticathode which, under the bombardment of electrons emitted by the cathode and accelerated in the electric field, located between the anode and the cathode, emits radiation X. For this, one uses either cold cathode tubes (more rarely) (figure "a" above: the figure where the pressure is measurable at 0.001 mm Hg); or incandescent cathode-ray tubes (Coolidge tubes, high vacuum, up to 10-6 mm Hg, figure "b" above: the figure where the emission of electrons is made by the thermoelectronic effect).

According to the older method of constructing x-ray tubes, the anticathode is an electrode separately connected to the anode; according to the modern method of construction, the anticathode is united with the anode. The tubes operate at potential differences whose value depends on the frequency of the X-radiation to be produced, and which are variable between 104 and 106 V, even more. The low-power tubes have a glass envelope, and the high-power ones have a metal envelope, with specially designed openings so that the emitted X-rays pass through them. The anode can be cooled by circulating water or oil. X-rays can be highlighted either through screens coated with a layer of material (platinum and barium cyanide, calcium tungstate, etc.) which fluoresces when the X-ray passes; either by photographic recording; or by an ionization chamber where the number of ions created by the radiation in a given volume of gas is determined.

Using the ionization chamber, the intensity of the X-ray beam can also be determined. The unit of intensity is the röntgen which measures the intensity of the beam producing, by ionization, a certain number of ions , in one cm3 of air and at the pressure of a height of 760 mm of mercury at 0°C; whose total electric charge of each sign is equal to the unit of static electric charge. Propagating through various materials, X-rays experience attenuation due to both scattering and absorption. Scattering is due to the interaction of radiation with the atoms or molecules of the material.

There is a difference between scattering without changing the wavelength (inelastic), and the Compton effect with lengthening of the wavelength, an effect studied elsewhere.

The scattering without change of wavelength is produced following mainly the interaction with the electrons set in oscillatory motion by the alternating field corresponding to the incident radiation; the oscillating electron emits similar radiation at the same frequency as that of its motion. In the case of monochromatic radiation, the absorption itself causes an exponential attenuation as a function of the distance traveled.

$$I = I_0 \cdot e^{-\mu \cdot x}$$

Where “I0” represents the intensity of the incident beam;

"I" represents the intensity of the beam which has passed through the thickness "x" of the absorbent material;

“ μ ” it is the attenuation coefficient whose value varies according to the nature and the state of aggregation of the material and according to the wavelength of the radiation.

Usually, in the case of a given material: the longer the wavelength, the faster the X-radiation undergoes attenuation.

Therefore, long wavelength X-rays are less penetrating; they are called "soft radiation".

X-rays with shorter wavelengths are more penetrating; they are called "hard rays".

If we take into account both absorption proper and diffusion, then the "μ" represents the sum of a coefficient of absorption proper and a coefficient of diffusion σ: $\mu = \tau + \sigma$

The relationship can be written in the form $I = I_0 \cdot e^{-\mu \cdot \rho \cdot x}$

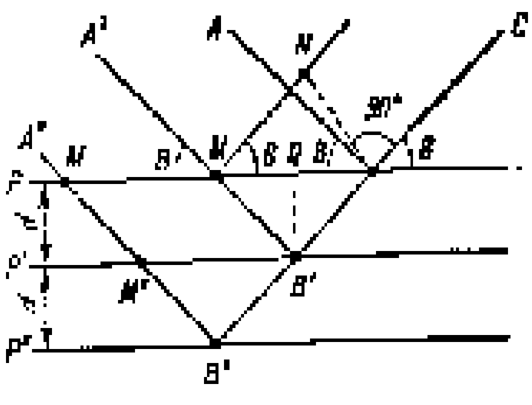
where "ρ" is the density of the absorbent material;

" μ`== μ/ρ " is a coefficient called "mass coefficient of attenuation", whose value is variable according to the wavelength of the radiation and according to the nature of the material, but it does not depend on the state of aggregation of the material.

If, in the medium traversed, the scattering centers are arranged in space in positions which are repeated periodically, then the scattered X-ray interferes. This type of interference can be produced when the scattering centers are the atoms of different molecules of a gas or a liquid, but especially when these centers are particles grouped together at the nodes of a crystal lattice. In this case, the phenomenon is generally called by an improper term: X-ray diffraction on crystals.

X-RAY PRODUCTION

We take as an example three reticular parallel planes equidistant P, P ', P" (see the figure below), and three rays belonging to an incident parallel beam of the crystal lamina, AB, A'MB', A" M' M"B". The effects of reflected rays BC, B'C. B "C overlap in the direction / direction BC. If the path difference between two successive rays is an even number of half wavelengths X of the incident radiation, then one will record a maximum interference in this direction BC. The difference of path Δ between rays ABC and A'MB'BC is Δ = MB' + B'B - MN where N is the foot of the lowered perpendicular from point B to the ray reflected in point M on the plane P. Since the MB', d/sin is the distance between the two reticular planes, and MN = 2d / sinθcos²θ, this results in Δ = 2dsin θ To obtain maximum intensity in the direction BC, one must therefore have 2d sin θ = 2 k λ / 2



or:

$2d \sin \theta = \lambda k$ - equation (1)

For the first maximal point $k = 1$ and $\sin \theta = \lambda 2d$.

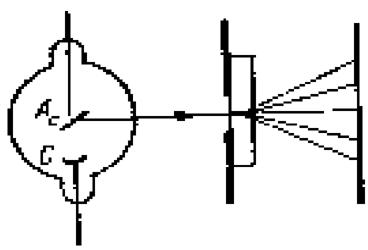
This formula is known as "Bragg's formula"; it follows that: if we project on the crystal a beam of X-rays of different wavelengths, we obtain, in the direction determined by the angle θ, a maximum point of intensity for the ray at the length of wave which verifies relation (1);

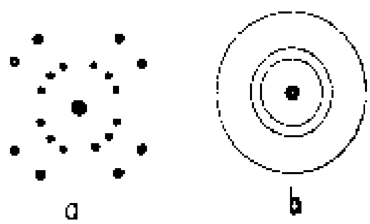
- if sent to the crystal of X-ray beams of different wavelengths of the maximum radiation intensity of the wavelength λ is obtained in the direction given by the relationship: θ (1);
- If we know the wavelength λ of an incident X-ray and we measure the angle θ made with the planes of a system of reticular planes, the direction where we obtain a point of maximum intensity, namely the distance d between the reticular planes, verifies the relation (1).

A spectral decomposition of the incident X-ray is thus obtained, by diffraction on the crystal lattices. Similar phenomena can be obtained by transmission as much through thin monocrystalline plates as through layers of crystalline powder. In the first case, the maximum intensity is obtained in certain directions with respect to that of the incident beam; in the second case, the maximum intensity is obtained in directions always oriented in space, but which give certain angles with the direction of the incident beam, therefore in all directions generating cones of well-determined angles including the incident beam is the axis (fig. 1).

If we collect beams of rays scattered on a photographic plate, we obtain certain diffraction figures, known as "Laue diagrams".

The Laue diagram obtained using a single crystal is composed of points arranged around a center corresponding to the non-diffracted beam, following a certain regularity controlled by the symmetry of the crystal lattice used (Fig. 2). The diagram obtained by a layer of crystalline powder (also called Debye-Gramme) consists of a system of concentric circles around the same center (fig. 2 b).





X-RAY EMISSION SPECTRUM

A particular X-ray tube, namely a tube with an anticathode made of a specific material, emits both X-rays which, once dispersed, have a continuous spectrum (continuous braking radiation or Bremsstrahlung), as X-rays at the line spectrum (characteristic radiation) .

Continuous spectrum X-radiation is emitted following the braking of electron-projectiles by the anticathode; the energy of the electrons is totally or partially emitted in the form of radiation. If "m" is the mass and "e" is the charge of the electron, "v" is the speed of the impact of the electrons with the anticathode, "U" is the potential difference applied to the tube, "h is Planck's constant and "v" 0 is the maximum frequency of the emitted radiation, then the principle of conservation of energy follows the formula:

$$\frac{m_e v^2}{2} = eU = h\nu_0$$

The continuous spectrum is strictly limited to short wavelengths, but the frequency νo = Ue/h corresponds to the limit of the spectrum. The value of v0 does not depend on the nature of the metal from which the anticathode is made, but only on the potential difference of the tube. If the braking radiation contains radiation at frequencies v < v0, it means that there are partial losses of the energy of the electron-projectiles, non-quantified losses in the form of heat.

The line spectrum characterizes the element forming the anticathode. The lines that make up this spectrum are grouped into several series. The K-Series contains the shortest wavelength lines; the others, following the first, are called L-series, M-series, etc. The emission of the lines of the X-ray spectrum occurs following the tearing of an electron with a lower principal quantum number n. If an electron at n == 1 is torn off (therefore it is an electron from the electron shell k), then it is replaced by an electron with a higher principal quantum number, therefore coming from a shell farther from the nucleus . The emission of a K line occurs as a result of the loss of energy during such a transition/transfer. If "E ind k" is the energy of the atom when the electron is in an orbit of the K shell, and if "e ind l", "e ind m" are the energies of the atom when the 'electron is in an L, M, etc. orbit, then the frequencies of the K-series lines are calculated according to the formula

$$\nu_k = \frac{E_k - E_L}{h}; \nu_{k\beta} = \frac{E_k - E_M}{h}$$

All lines of the K series therefore have a common term Ek / h.

Similarly, the L-series lines have the frequencies calculated according to the formula

$$\nu_{L_\alpha} = \frac{E_L - E_M}{h}; \nu_{L_\beta} = \frac{E_L - E_N}{h}$$

All L-series lines therefore have a common term EL/h.

It is the same for the *M series* etc. The more the atomic number of the emitting atom increases, the more the frequencies of the lines corresponding to the different atoms, forming part of the same series of lines, increase. Consequently, their wavelengths decrease. The first line of the K series, the *Ka line* , following the transition of the electron from the L orbital to the K orbital, has the wavelength equal to 1,215.4 Å for hydrogen (since it is the first line of the hydrogen series, known as Lyman, representing the K series for this element), the wavelength of 3.734 Å for calcium and 0.209 Å for wolfram / tungsten .
The frequency of the same line of the X-ray spectrum is therefore variable according to the atomic number of the emitting element. This dependence is expressed by Moseley 's law according to which Where : Z is the atomic number, *To* And *b* s have two constants . This relation allows the calculation of the atomic number thanks to the measurement of the frequency of a line of the X-ray spectrum and to the interpolation of the atomic numbers arranged in ascending order. In figure no. 3 a few lines of series *K, L and M* various elements; the wavelengths are marked on the x-axis and the atomic number on the y-axis.

THE PROPERTIES OF X-RAYS

a) They produce the luminescence of certain solutions such as platinum-cyanide of barium, tungstate of cadmium and zinc.
b) They impress photographic emulsions. These two properties are used in the establishment of the receivers necessary for the study and use of X-rays: luminescent screens of radioscopy devices, photographic films/films used in radiography, etc.
c) They produce the gas ionization process by extracting electrons from irradiated gas atoms.
d) They propagate in a straight line, even through different media.
e) They are absorbed by the material/substance/solution passed through. An incident, parallel beam of X-ray normally falls on the surface of a body and is attenuated when passing through the material of the body. According to the attenuation/attenuation formula, it follows that the attenuation increases rapidly with the thickness of the substance/material passed through. The same applies to absorption: it increases rapidly according to the atomic number Z of the chemical element in question.
When passing an X-ray beam through metal blades of the same thickness, but made of different metals, it is found that the beam is better attenuated through solid lead (Z = 82) than copper (Z = 29) and better attenuated through copper than aluminum (Z=13).

As a last property, the absorption of the X-ray beam increases with the wavelength of the ray for a given material and thickness. For example, while the ray at X = 0.02 Å manages to pass through a lead plate with a thickness of 10 cm, a ray at X = 1 Å is completely absorbed by a lead plate with a thickness of a few tenths of a millimeter. The first rays, strong penetrating, are called hard X-rays, the others, easily absorbed, are soft X-rays, according to their energy.

The property of the X-ray to be absorbed by the material/substance is the basis of many applications: X-ray and X-ray investigations of the organs of the human body: the different tissues of our body absorb X-rays unevenly. On an X-ray screen or on an X-ray we can see that the various organs of the human body have differences in opacity, this which allows the observation and delimitation of organic lesions, dental caries, fractures and the presence of foreign bodies/objects inside the human body.

Hard X-rays have become almost indispensable in the field of metallurgy: they are used to detect the slightest defects in the homogeneity of metal parts; to check the quality of the welding of two parts.

The physiological effects of X-rays: radiotherapy.

X-rays are not harmful to the human body, provided they are applied in small doses and rarely repeated; the prolonged action of X-rays leads to the destruction of tissues and cells. They produce a decrease in the number of red blood cells and cause intracellular damage. To protect the human body against these effects, the X-ray generator is enclosed in a box with lead walls, provided with openings which allow the delimitation of the beams of rays used.

In general, young cells are more sensitive to X-rays, which allows the use of these rays in the therapy of cancerous tumors: the treatment consists of irradiating a well-defined area with hard X-rays (applying them in suitable doses, capable of penetrating deep into tissue).

X-RAY DIFFRACTION IN A CRYSTAL

X-rays are electromagnetic waves, therefore they produce the phenomena of diffraction and interference. The installation of the experimental devices in order to produce the phenomenon of diffraction presents difficulties, considering that the wavelength of these devices is reduced. These difficulties have been eliminated through the use of so-called "spatial diffraction gratings" which, for X-rays, are the crystalline gratings/structures.

Physicist Laue (in 1913) was the first who used the natural spatial lattice (crystals) as a diffraction grating for X-rays. The atoms and molecules of the crystal are arranged in a regular three-dimensional lattice whose periods (the distance between two reticular planes of the crystal) are comparable to the wavelength of the X-ray. If an X-ray beam is directed towards the crystal, each atom or molecular group (of the structure of the crystal lattice) causes the X-rays and, in doing so, diffraction figures are obtained similar to those obtained in the case of light diffracted using optical gratings.

The condition of mutual reinforcement of rays reflected by different planes is given by the formula:
$2d\sin\theta = nX$
where "d" is the crystal lattice constant (the distance between lattice planes); "θ" is the angle complementary to the angle of incidence; "λ" is the wavelength of the ray; "n" (n = 1, 2, ...) is the order of the maximum point. This relationship is the Wulf-Bragg law.

Laue's method solved two problems of particular importance.
On the one hand, using this method one can determine the wavelength of the X-rays, if one knows the structure of the crystal lattice by means of which one obtains the phenomenon of diffraction. These are the foundations of X-ray spectroscopy, which is responsible, in turn, for discovering a multitude of details concerning the structure of the atom.
On the other hand, we can determine the nature of this structure, namely the distances and positions of the atoms, ions and molecules composing the crystal, by
the observation of X-ray diffraction at a constant wavelength on an unknown crystal structure. This is how the method of structural analysis of crystal formations was created, which is the basis of important discoveries in the field of molecular physics.

X-rays or **Röntgen** are ionizing electromagnetic rays whose wavelength is approximately between 0.1 and 100 Å (angstroms).
X-rays were accidentally discovered by physicist Roentgen in 1895.
When studying the fluorescence of some platinum-barium cyanide crystals, Röntgen found that the fluorescence occurs in the dark when the discharge tube was covered by a sheet of black paper.
He surmised that this effect is produced by invisible, highly penetrating rays coming from the glass walls of the tube whenever the cathode ray beam hits the glass. Because the physicist did not know the nature of these rays, he called them "X-rays".
X-rays are electromagnetic waves like light, they have the same nature as ultraviolet or visible radiation, but their wavelengths are much lower than those of light, measurable in angstroms and thousandths of angstroms. Therefore, for the expression of these wavelengths we often use the unit
$1\ X = 10^{-3}\ A = 10^{-11}\ cm$

PROPERTIES OF X-RAYS
In a vacuum they propagate at the speed of light;
They impress photographic plates;
They are not deflected by electric and magnetic fields;

They produce the fluorescence of certain chemical substances/solutions (emission of light); examples of phosphors: zinc silicate, cadmium sulfide or zinc sulfide which emit greenish yellow light.

They are invisible, that is, they do not impress the human eye, as light does;

They easily penetrate some light-opaque solutions/substances/materials, e.g. human body, low density thin metal blades, paper, wood, glass, etc., but they are absorbed by high density metals (eg lead). The penetrating power of X-rays depends on the atomic number of the chemical element and the thickness of the layer traversed.

They ionize the gases passed through. The number of ions produced indicate the intensity of the radiation. The operation of radiation detectors is based on this property of X-rays.

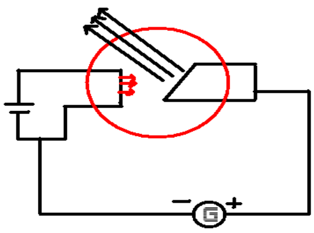
They have physiological effects: they destroy organic cells and are generally harmful to the human body. The medical treatment of cancerous tumors aimed at the destruction of diseased tissue is based on this property of X-rays.

Procedures for obtaining/producing x-rays

In the laboratory, X-rays can be obtained in vacuum tubes, where electrons emitted by a hot cathode are accelerated by the electric field between the anode and the cathode (the anticathode). High-speed electrons collide with the anticathode emitting X-rays. Fast electrons that collide with the anticathode interact with the atoms in it in two ways:

-Since the electrons move at high speed, they penetrate the electronic shell of the atoms of the anticathode and approach its nucleus. This one is positive, consequently it deviates the electrons from their initial direction. When electrons move away from the nucleus, they are slowed down by its electric field. During this process X-rays are emitted.

-Through the electron layer of the atoms of the anticathode, the fast electrons can collide with the electrons of the atoms of the anticathode. During the collision, an electron from an inner layer (for example from the K layer) can be dislocated. Its place is occupied by an electron coming from the following layers (namely the L, M or N layers). The rearrangement of the electrons of the atoms of the anticathode is accompanied by the emission of X-rays.



X-RAY COMPUTER-ASSISTED TOMOGRAPHY

INTRODUCTION TO MEDICAL IMAGING

X-rays or Röntgen were named after the physicist Wilhelm Conrad Röntgen who discovered them. They are electromagnetic radiation, high energy; those used in medical imaging consist of photons whose energy is between 20 and 120 keV.

[http://www.scientia.ro/tehnologie/39-cum-functioneaza-lucrurile/927-imagistica-medicala-2-radiografiile.html]

In X-ray imaging, an X-ray beam passes through one area of the patient's body and is detected on the opposite side of the body. Through the human body, X-rays are either absorbed or scattered by diffraction. The degree of attenuation depends on the thickness of the material crossed and its attenuation coefficient.

The equation that describes the decrease in intensity of the X-ray beam is:

$I = I0exp(-\mu x)$

where "I0" and "I" are the intensities before and after the passage of the beam through the material of a thickness "x"; "μ" is the attenuation coefficient.

Radiografie planară a gleznei

Bones have a greater attenuation coefficient than soft tissues; in turn, tissues have a higher attenuation coefficient than air.

If a patient is placed under the action of a uniform beam of x-rays, the radiation which passes through the soft tissue of the body will indicate to the detector a greater intensity than the radiation which has passed through the bone.

In the digitized image there is a better contrast between the bone and the soft tissues and, likewise, between the soft tissues and the lungs. Typically, X-ray images show material with a higher attenuation coefficient (e.g. bones) as a light shade, close to white in color, and material with a lower attenuation coefficient (for example soft tissue) by a dark/dark shade.

Radiologists use a wide range of imaging technologies such as:

Ultrasound;

Computed tomography (CT);

X-ray tomography, computer-assisted: CT with MRI;

nuclear medicine;

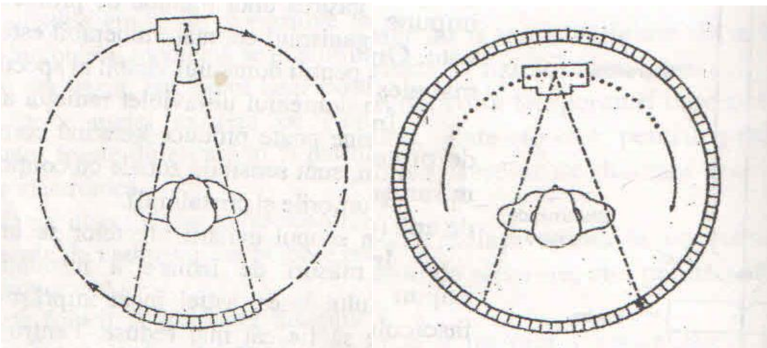
Positron emission tomography (whose acronym is PET: **p** ositron **e** mission **t** omography);

Magnetic resonance imaging (MRI), to diagnose or treat disease.

Interventional radiology refers to all the medical acts performed by radiologists and under radiological control, allowing the treatment or diagnosis (generally minimally invasive) of numerous pathologies. The principle of interventional radiology is therefore to access a lesion located inside the body to carry out a diagnostic (sampling for example) or therapeutic act.

X-ray computer-assisted tomography

Computer-assisted tomography allows the taking of images of certain transverse zones of the human body by the computer processing of a large number of radioscopic images taken from these zones.



[I.Nagy, biofizica medicala course, Eurobit, 2001]

For this purpose, the X-ray source is placed on a rail and rotates around the patient's body, irradiating it successively in several directions and sides. The X-rays which have passed through the section investigated touch a network of detectors which trigger the taking of digital images, following analog-digital conversions.

There are mechanical systems where the X-ray source rotates simultaneously and in conjunction with the detector array; this array is attached to the source, so it rotates simultaneously and in conjunction with the sensor array.

There are mechanical systems where the X-ray source is mobile and revolves around the patient's body, while the detector array is fixed and attached to the patient's body.

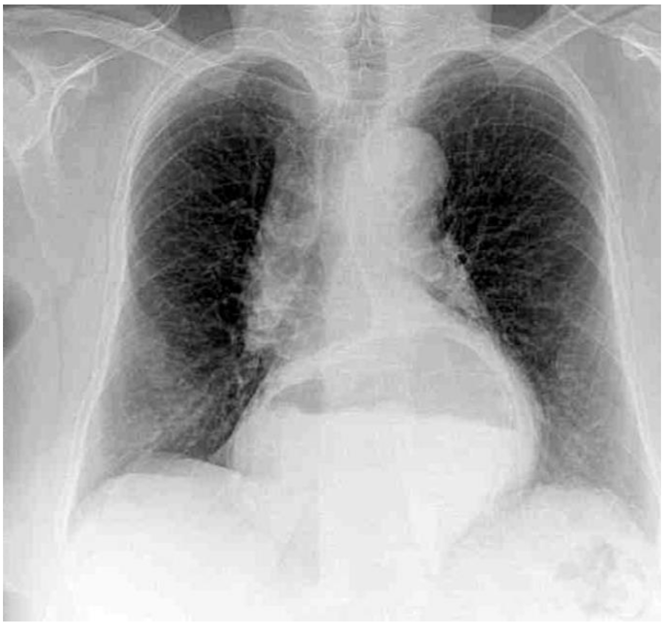
Detectors are small scintillating crystals associated with photomultiplier photodiodes or small ionization chambers. Each detector will generate an electrical signal of an amplitude proportional to the intensity of the X-rays received.

During a full rotation of the x-ray tube around the patient's body hundreds of x-ray views will be taken. The digital image of each view is stored in computer memory (or on disk if RAM is insufficient).

The final digital image of the section is convertible using a digital-to-analog converter, and projected onto a screen.

However useful and important these radiodiagnostic methods may be, one can never ignore the fact that all these methods use ionizing rays in high doses, which may themselves be harmful to the patient in question. In any case, the use of these explorations must be kept to a minimum; moreover, these explorations are completely prohibited in the medical investigation of pregnant women and children under 2 years of age. The potential harmfulness as well as the high costs of these radio-diagnostic methods have encouraged the search for other methods of visualizing the interior of organisms or organs, either by the use of rays for which these organs are transparent (but which are not harmful like ionizing rays), or by methods based on radically different phenomena.

PROJECTIVE RADIOGRAPHY



In figure we have the projective radiography for a person with hiatal hernia

Projective radiography is the practice of producing two-dimensional images using X-ray radiation.

Bones contain a lot of calcium, which due to its relatively high atomic number absorbs X-rays efficiently. This reduces the amount of X-rays reaching the detector in the shadow of the bones, making them clearly visible on the X-ray.

The lungs and trapped gases also show up clearly due to lower absorption compared to tissue, while differences between tissue types are harder to see.

Projective radiographs are useful in detecting pathology of the skeletal system as well as for detecting disease processes in soft tissues.

EXAMPLE :

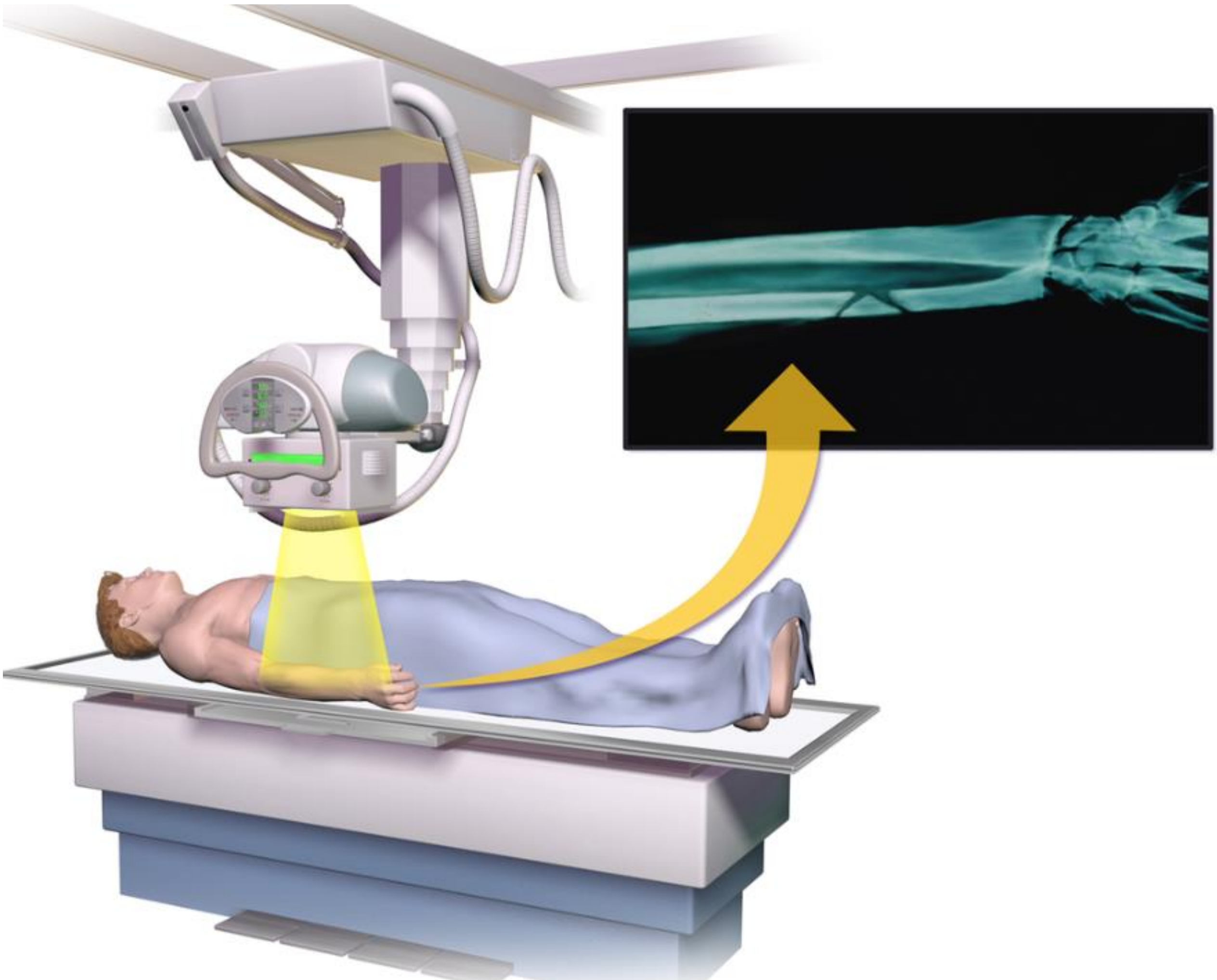
The very common chest radiography, which can be used to identify lung diseases such as pneumonia, lung cancer or pulmonary oedema, and the abdominal radiograph, which can detect intestinal (or bowel) obstruction, with free air. (from visceral perforations) and free fluid (in ascites).

pathology of gallstones (which are rarely radiopathic) or kidney stones which are often (but not always) visible.

EXAMPLE:

Regular X-rays are less useful in imaging soft tissues such as brain or muscle.

One area where projective X-rays are widely used is to assess how an orthopaedic implant, such as a knee, hip or shoulder replacement, is located in the body relative to the surrounding bone. This can be assessed in two dimensions from plain radiographs or it can be assessed in three dimensions if a technique called '2D to 3D registration' is used. This technique negates the alleged projection errors associated with assessing implant position from plain radiographs.



Projective radiographs are useful in detecting bone pathology

Dental X-rays are commonly used in the diagnosis of common oral problems such as cavities.

In medical diagnostic applications, low-energy (soft) X-rays are undesirable because they are totally absorbed by the body, increasing the radiation dose without contributing to the image.

Therefore, a thin sheet of metal, often aluminium, called an X-ray filter, is usually placed over the window of the X-ray tube, absorbing the low-energy part of the spectrum. This is called beam hardening, because it shifts the centre of the spectrum towards higher energy (or harder) X-rays.

ANGIOGRAPHY

To generate an image of the cardiovascular system, including arteries and veins (angiography), an initial image of the anatomical region of interest is taken.

Then a second image is then taken of the same region after an iodinated contrast agent has been injected into the blood vessels in that area.

These two images are then digitally subtracted, leaving an image of just the iodinated contrast outlining the blood vessels.

The radiologist or surgeon then compares the resulting image with the normal anatomical images to determine if there is any damage or blockage to the vessel.

RADIOTHERAPY

The use of X-rays as a treatment is known as RADIOTHERAPY and is largely used to fight cancer; it requires higher doses of radiation than those received for imaging alone.

X-ray radiotherapy is used to treat skin cancer using lower energy X-ray beams,

Higher energy X-ray beams are used to treat cancers in the body such as brain, lung, prostate and breast.

Historically there are 3 types of radiotherapy

- external beam radiotherapy (EBRT or XRT) or teletherapy;
- brachytherapy or sealed source radiotherapy; and
- systemic radiotherapy or unsealed source radiotherapy.

The differences relate to the position of the radiation source; external is outside the body, brachytherapy uses sealed radioactive sources placed exactly in the area being treated, and systemic radioisotopes are administered by infusion or oral ingestion.

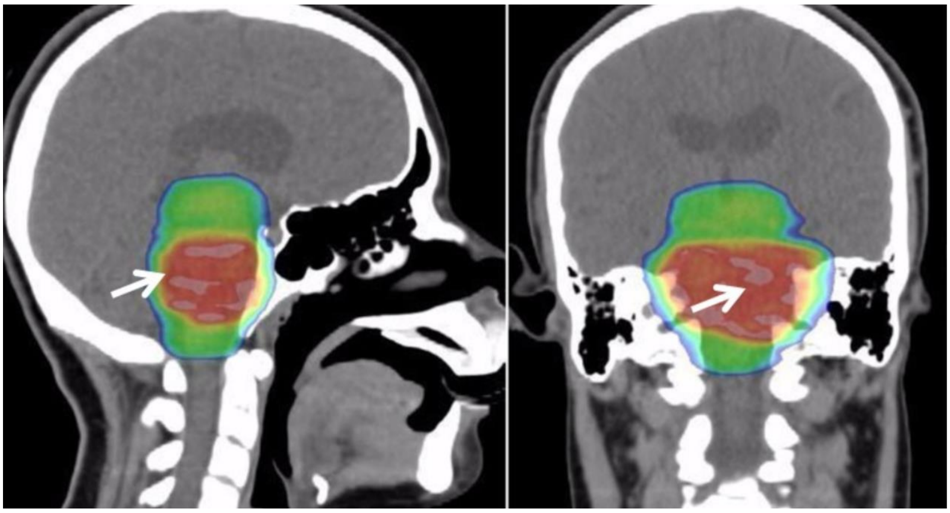
Brachytherapy can use temporary or permanent placement of radioactive sources.

Temporary sources are usually placed by a technique called post-loading.

In post-discharge, an empty tube or applicator is surgically placed into the organ to be treated and the sources are loaded into the applicator after implantation of the applicator. This minimises radiation exposure to medical personnel.

Particle therapy is a special case of external beam radiotherapy where the particles are protons or heavier ions.

Radiotherapy or X-ray radiation therapy, often abbreviated RT, RTx or XRT, is a therapy that uses ionizing radiation generally as part of cancer treatment to control or kill malignant cells and normally performed by a linear accelerator.



Radiotherapy for a patient with diffuse intrinsic pontine glioma, with colour-coded radiation dose.

Radiotherapy can be curative in various cancers if they are located in a certain area of the body.

It can also be used as part of adjuvant therapy to prevent the tumour from recurring after surgery to remove a primary malignant tumour (e.g. early stages of cancer).

Radiotherapy is synergistic with chemotherapy and has been used before, during and after chemotherapy in sensitive cancers.

The subspecialty of radiation oncology is called radiation oncology.

Radiotherapy is commonly applied to cancerous tumours because of its ability to control cell growth. Ionising radiation works by damaging the DNA of cancerous tissue leading to cell death.

To spare normal tissues (such as the skin or organs through which the radiation must pass to treat the tumour), radiation beams are emitted from multiple exposure angles to intersect at the tumour, delivering a much higher dose there than to surrounding healthy tissue.

In addition to the tumour itself, radiation fields may also include leaking lymph nodes if they are clinically or radiologically involved with the tumour or if there is thought to be a risk of subclinical malignant spread.

It is necessary to include a margin of normal tissue around the tumour to allow for uncertainty in the daily setting and internal movement of the tumour. These uncertainties can be caused by internal movement (e.g. breathing and bladder filling) and movement of external skin markings relative to the position of the tumour.

RADIOTHERAPY - HOW IT WORKS

One of the major limitations of photon radiotherapy is that solid tumour cells become oxygen deficient.

Solid tumours can outgrow their blood supply, causing a low oxygen state known as hypoxia.

Oxygen is a powerful radiosensitiser, increasing the effectiveness of a given dose of radiation by forming free radicals that damage DNA.

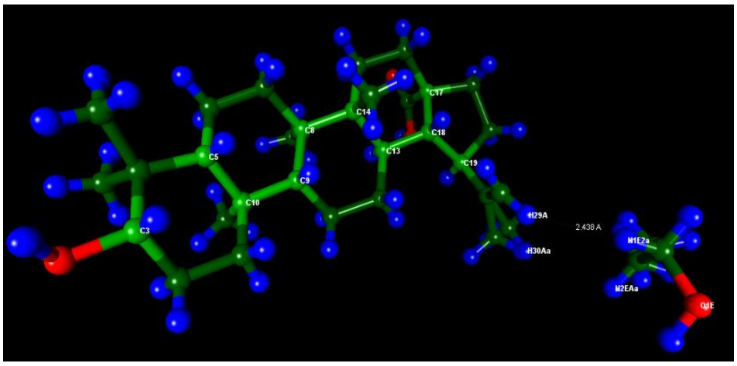
Tumour cells in a hypoxic environment can be 2 to 3 times more resistant to radiation damage than those in a normal oxygen environment. .

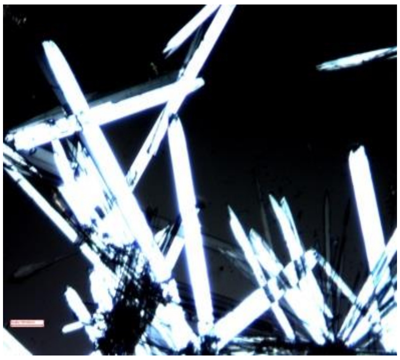
Much research has been devoted to overcoming hypoxia, including the use of high-pressure oxygen tanks, hyperthermia therapy (thermal therapy that dilates blood vessels to the tumor site), increased oxygen-carrying blood substitutes, hypoxic cell radiosensitizing drugs such as misonidazole and metronidazole, and hypoxic cytotoxins (tissue poisons) such as tirapazamine.

Novel research approaches are currently being investigated, including preclinical and clinical investigations of the use of a compound that enhances oxygen diffusion, such as sodium trans crocetinate (TSC) as a radiosensitiser.

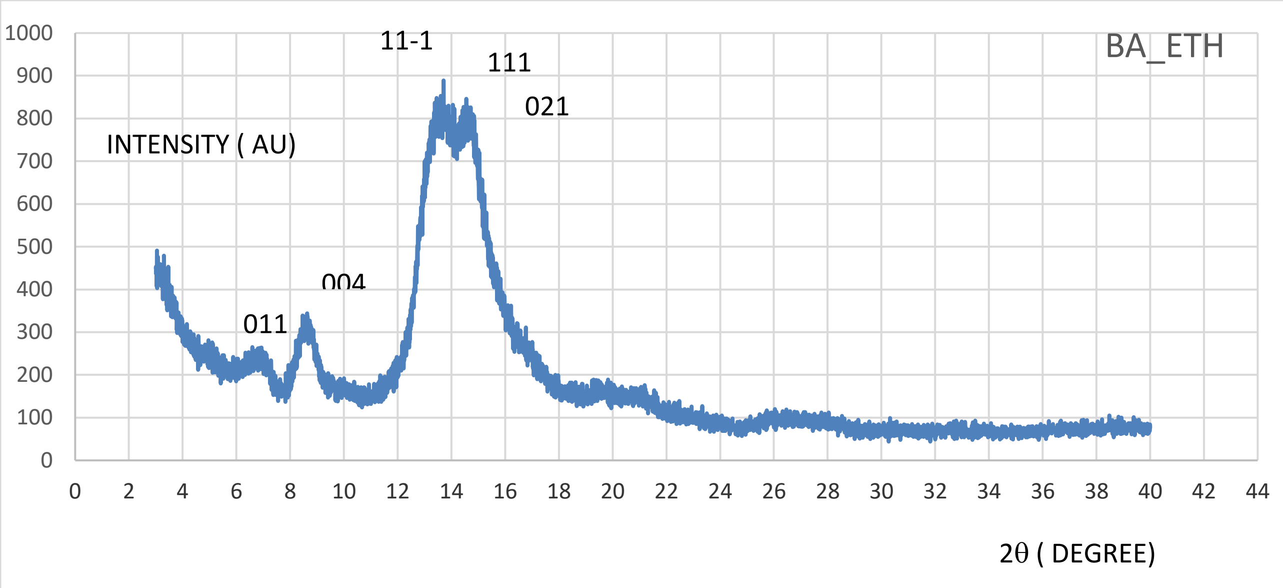
Charged particles such as protons and boron, carbon and neon ions can cause direct DNA damage to cancer cells via high LET (linear energy transfer) and have an anti-tumour effect independent of tumour oxygen supply, as these particles act mainly via direct energy transfer usually. causing double-stranded DNA breaks.
Due to their relatively high mass, protons and other charged particles have little lateral dispersion in the tissue - the beam does not broaden much, remains focused on the tumour shape and produces low-dose side-effects to the surrounding tissue.
They also target the tumour more precisely using the Bragg peak effect. See proton therapy for a good example of the different effects of intensity-modulated radiation therapy (IMRT) versus charged particle therapy.
This procedure reduces damage to healthy tissue between the charged particle radiation source and the tumour and establishes a finite range of tissue damage after reaching the tumour.
In contrast, IMRT's use of uncharged particles causes its energy to damage healthy cells as it leaves the body. This outgoing damage is not therapeutic, can increase treatment side effects and increases the likelihood of secondary cancer induction.
This difference is very important in cases where proximity to other organs makes any stray ionisation very damaging (example: head and neck cancers).
This x-ray exposure is particularly bad for children because of their growing bodies and they have a 30% chance of a second malignancy 5 years after the initial RT.

DIFFRACTION IMAGES FOR PHARMACEUTICALS:





Betulinic acid $C_{30}H_{48}O_3$ obtained in isopropyl alchool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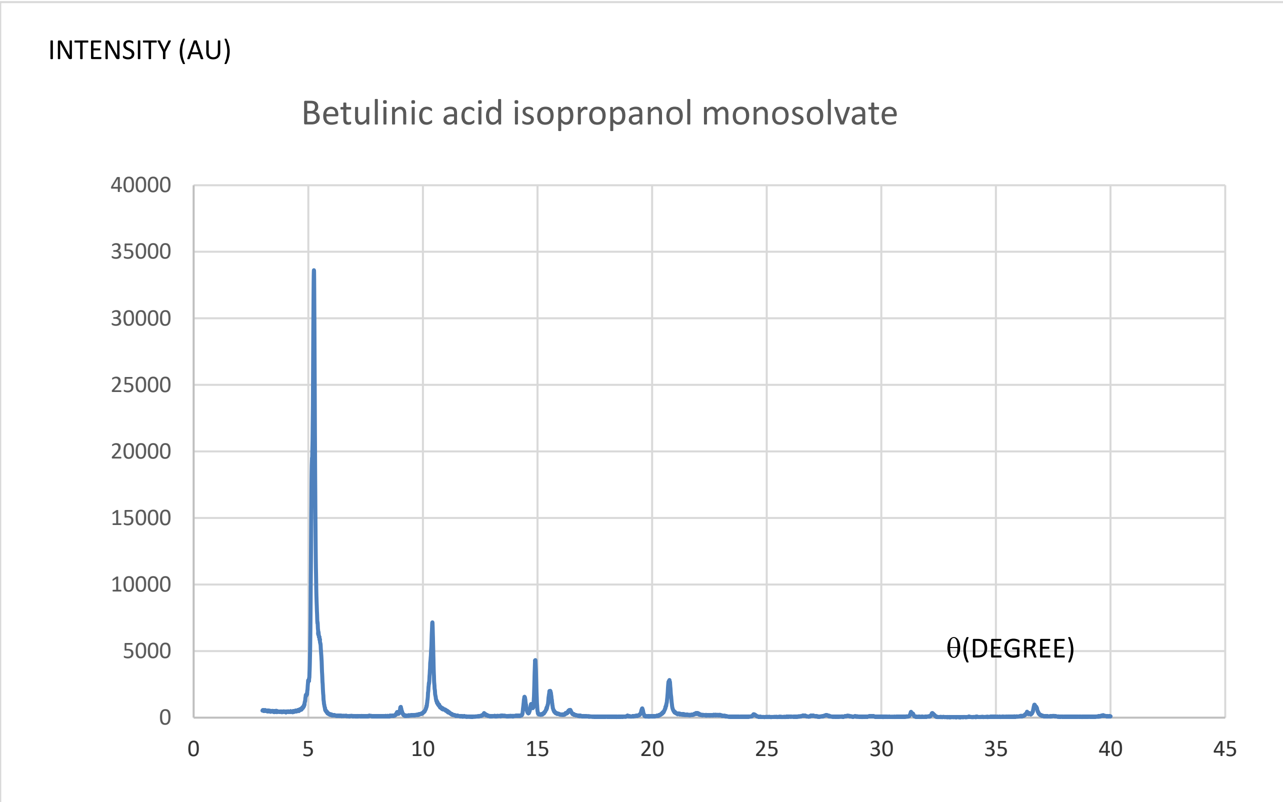
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10.GEOMETRICAL OPTICS. PHYSICAL OPTICS OR WAVE OPTICS

Optical systems and phenomena

Approaches and treatment of optical phenomena:

1) Geometric Optics (the image according to which a homogeneous average light travels in straight lines and geometric phenomena are treated with methods - beams of light)

2) Photometry (Study and measurement of the energy transported by electromagnetic radiation, and more particularly by visible light; it studies the energy and the distribution of this energy on a surface)

2) Wave Optics (the propagation of light is perceived as a propagation of electromagnetic waves and wave optical phenomena are treated using physical methods)

3) Photonic Optics (light is perceived as an "avalanche" of particles, i.e. photons with their own mass and energy)

GEOMETRICAL OPTICS

Key concepts:

- **Source of light** (punctiform or non-punctiform) - the place of departure of the light rays; if these rays propagate in a homogeneous medium, they diverge.
- **Object** - it is commonly believed that diverging rays of light propagate from every point on the object
- **The image of an object** - is formed as a consequence of the passage of light rays (emitted by the object itself) through an optical element (the image can be enlarged or reduced, real or virtual)
- **Optical elements –** they are able to modify the trajectory of the optical beam passing through them; optical elements are used to form the image (real or virtual) of an object (real or virtual)

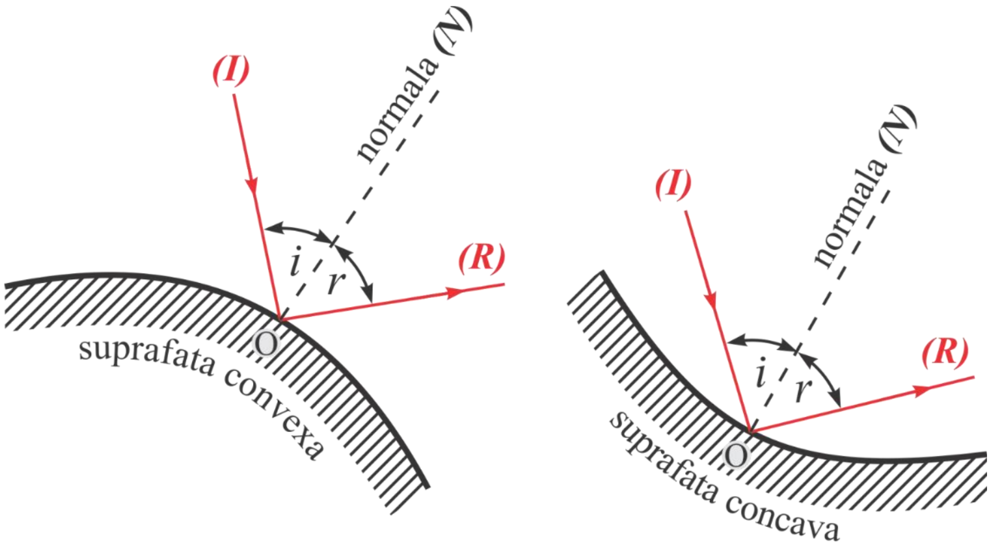
THE REFLECTION OF LIGHT (LIGHT BEAMS)

a) The beam of light is incident (I) in the point (O), the beam is reflected from the point (O) and it is normal to the surface (N), it is built in the point (O); all are in the same plane;

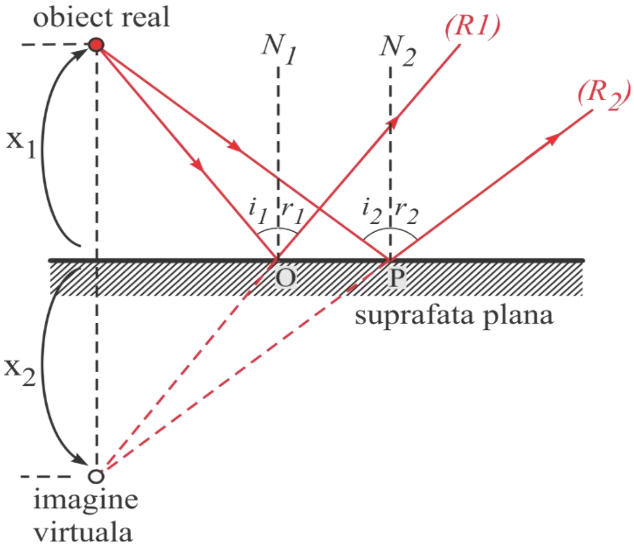
b) the angle of incidence (i) and the angle of reflection (r) are equal.

The rays emitted by a punctiform light source diverge, after undergoing reflection on a convex surface.

The rays emitted by a punctiform light source converge, after undergoing reflection on a concave surface.



The reflection of light rays - the plane mirror



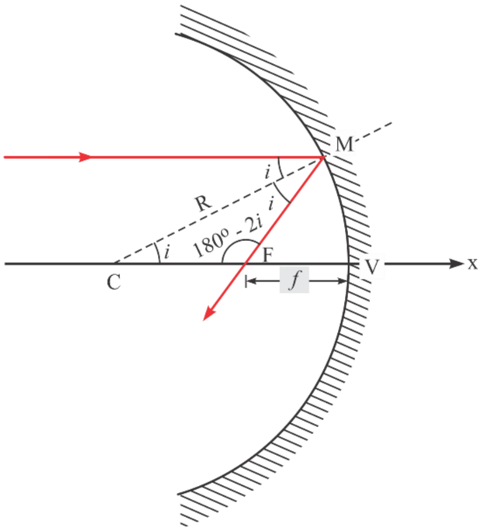
The light rays which propagate from a punctiform source (a real object) diverge, after undergoing reflection on a plane surface. They do not intersect, but their extensions come together in a point (virtual image).

An observer who receives the emerging rays (R1) and (R2) has the impression that they are coming from the virtual image.

The virtual image is formed at the opposite side of the mirror to the real object and at the same distance to the reflective surface where the real object is.

The virtual image is formed at the opposite side of the mirror to the real object and at the same distance from the real object to the reflective surface.

Reflection of Light Rays - Spherical Mirror



from Δ CFM

(sine theorem):

$$\frac{\sin(180^o - 2\cdot i)}{R} = \frac{\sin i}{R - f}$$

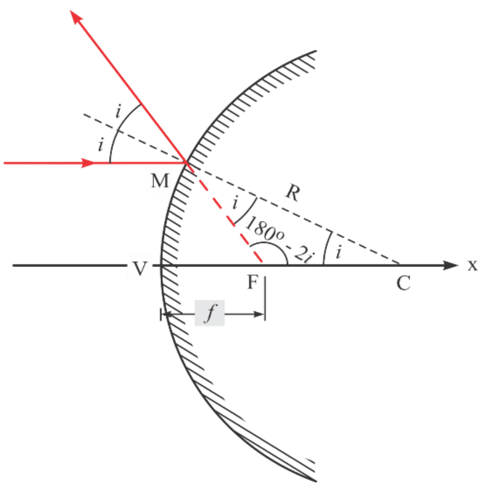
$$\frac{\sin 2\cdot i}{R} = \frac{\sin i}{R - f}$$

$$\frac{2\cdot \sin i \cdot cosi}{R} = \frac{\sin i}{R - f}$$

$$f = R\cdot\left(1 - \frac{1}{2\cdot \cos i}\right)$$

For paraxial rays: $i \approx 0\,^o$

cosi ≈ 1 therefore: $f = \dfrac{R}{2}$



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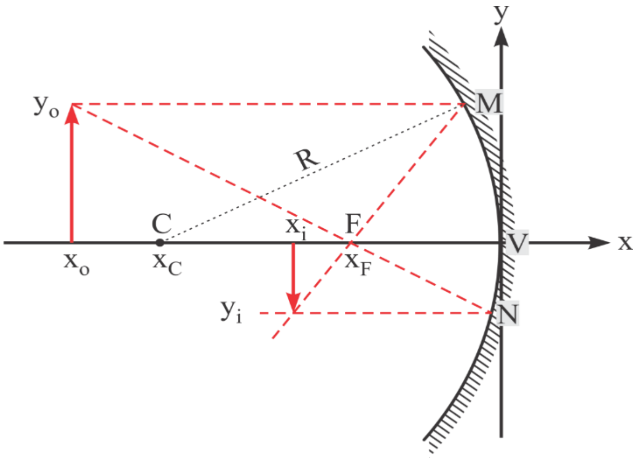


The Physical quantities involved refer to a system of axes (xOy) which originates from the starting point "V" of the spherical mirror.

The image is formed at the intersection of the real rays with the real image (inverted, diminished)

Conjugate points of spherical mirrors

They express the relationship between the locations of the object and the location of the image created as a result of its reflection on the spherical mirror

$$\frac{1}{x_F} = \frac{2}{R} \cdot \frac{\cos i}{2 \cdot \cos i - 1} \approx \frac{2}{R}$$

$$\frac{1}{x_F} \approx \frac{2}{R} \approx \frac{1}{x_o} + \frac{1}{x_i}$$

x_F – focus "x" axis

x_o – "x" axis indicating the location of the object

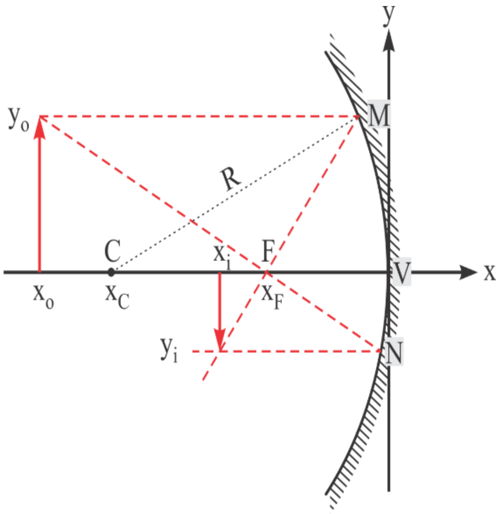
x_i – "x" axis indicating the location of the image

x_C – "x" axis of the center of the spherical mirror

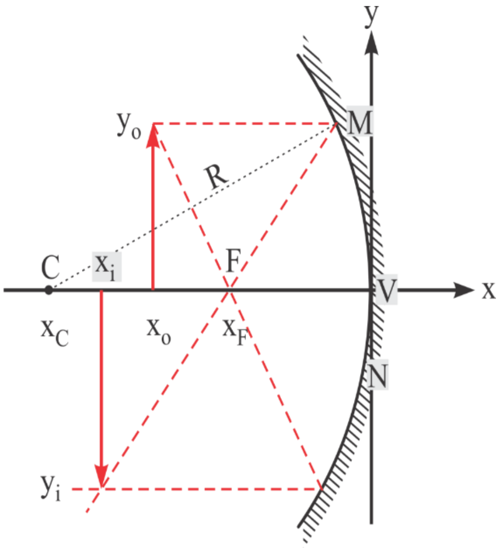
R – radius of curvature of the spherical mirror

(the sign "R" is the same as the sign of the center axis "C")

Conjugate points for spherical mirrors. Object-image relationship

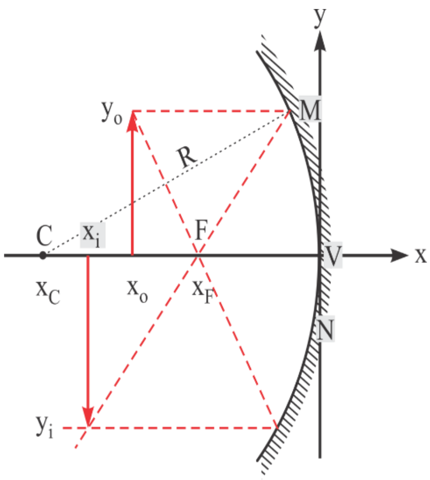


If the object is located further than the radius of the spherical mirror "R" from the point "V", then the concave mirror gives a real, inverted and diminished image (relative to the object).

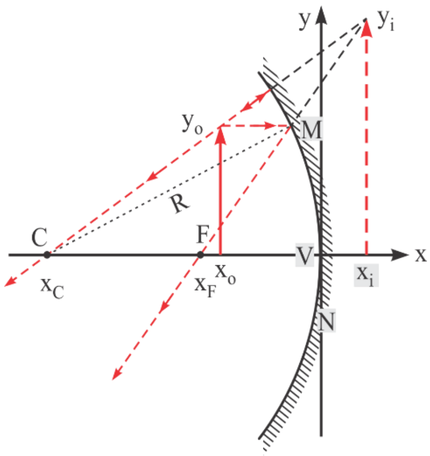


If the object is located between the center and the focus of the spherical mirror, then the concave mirror gives a real image, reversed and magnified (relative to the object).

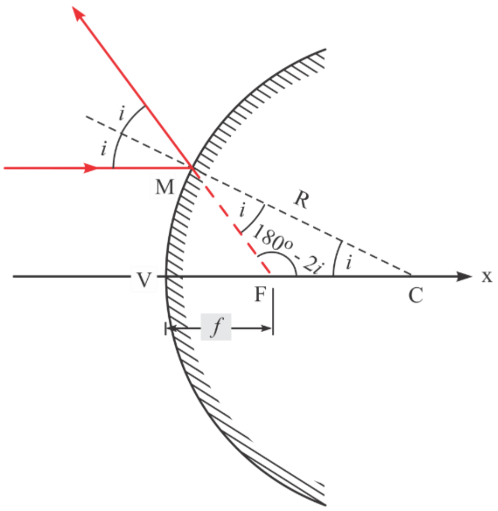
If the object is located in the center of the spherical mirror, then the concave mirror gives a real, inverted image of the same size as the object.



After the reflection, the image is formed at the intersection of the real rays. The picture is real.

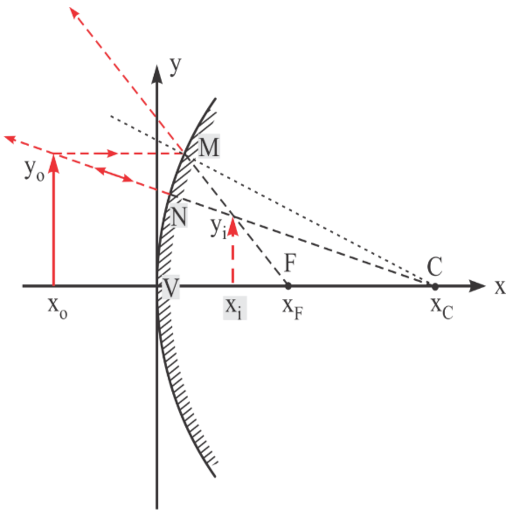


After the reflection, the image is formed at the intersection of the extension of the real rays. The image is virtual.



The focus of a convex mirror is virtual (it forms at the extension of the real rays).

$$\frac{1}{x_F} = \frac{2}{R} \cdot \frac{\cos i}{2 \cdot \cos i - 1} \approx \frac{2}{R}$$



Regarding convex spherical mirrors, the image of a real object is always virtual and diminished in relation to the object (it is formed by the extension of the real rays).

sign(R) = sign(x_C)

$$\frac{1}{x_F} \approx \frac{2}{R} \approx \frac{1}{x_o} + \frac{1}{x_i}$$

conjugate **points to a system of reference axes? Rules and principles:**

1) The origin of the reference axis system is at point "V" of the spherical mirror.

2) The "x" axis coincides with the optical axis of the mirror.

3) The direction of the incident light (which travels from the object to the mirror) defines the positive direction of the "x" axis.

4) The focal length of the concave mirror is positive.

5) The focal length of the convex mirror is negative.

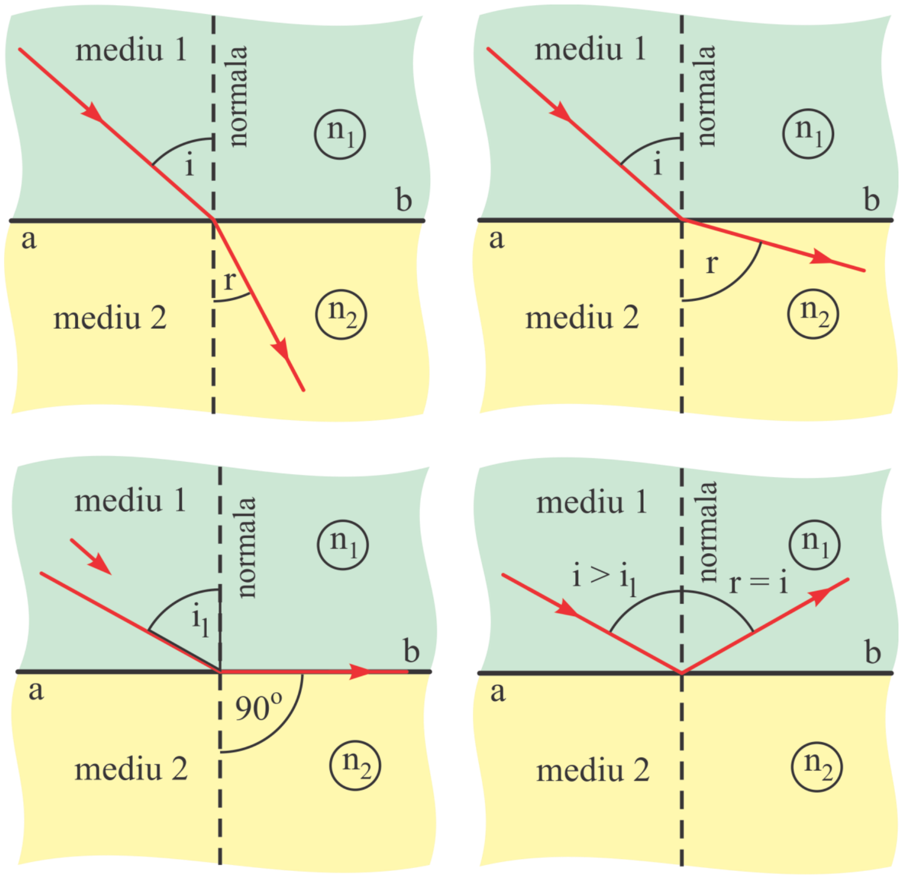
6) For both concave and convex mirrors, the axis of the location of the object ("xo"), the axis of the location of the image ("xi") and the focal point of the mirror ("f") satisfy the conjugate point relation:

$$-\frac{1}{f} = \frac{1}{x_o} + \frac{1}{x_i}$$

THE REFRACTION OF LIGHT

The incident ray, the refracted ray and the one normal to the separation surface are coplanar.

From the point of view of refraction, media are characterized by the "refractive index" (n1 and n2)



Snellius $\frac{\sin r}{\sin i} = \frac{n_1}{n_2}$ ' law

Limit angle of incidence (i_l) ($r = 90^o$)

$$\frac{1}{\sin i_l} = \frac{n_1}{n_2}$$

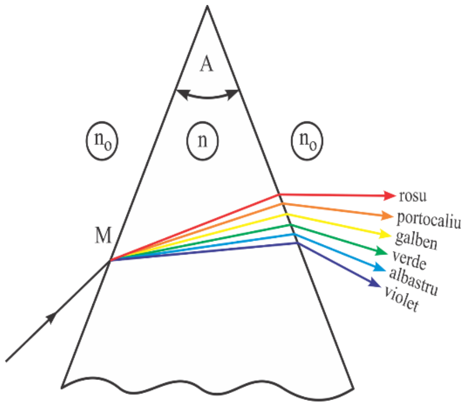
$(n_2 < n_1)$

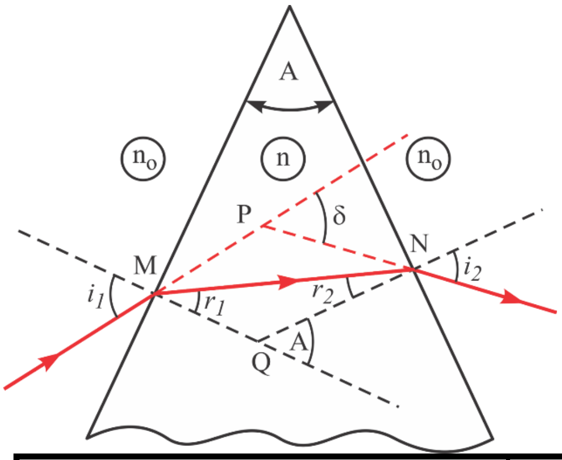
The refractive index is an a-dimensional physical quantity. The vacuum refractive index no = 1.

The refractive index of a medium is the ratio between the speed of propagation of light in vacuum c and the speed of propagation of light in that medium, v.

OPTICAL PRISM

The decomposition of polychromatic light by the optical prism





of Δ MQN⇒ $\hat{A} = r_1 + r_2$

of ΔMPN _⇒ $\begin{cases} \delta = (i_1 - r_1) + (i_2 - r_2) \\ \delta = i_1 + i_2 - \hat{A} \end{cases}$

color	**λ(m)**	***f*** **(THz)**
infrared	> 750	< 400
red	650 - 750	462 - 400
orange	585 - 650	513 - 462
YELLOW	575 - 585	522 - 513
Green	490 - 575	612 - 522
blue	420 - 490	714 - 612
purple	380 - 420	789 - 714
ultraviolet	< 380	> 789

The refractive index in optical media depends on the wavelength of the incident light (this is the phenomenon of dispersion). White light is a mixture of components at different wavelengths. Therefore, when white light is incident on the emergent surface, the direction of propagation depends on the wavelength of the components.

Optical prism minimum deviation

If the path of light inside the prism is perpendicular to the bisector of the angle of refraction (the angle of point "A"), then the deviation "d" is minimum.

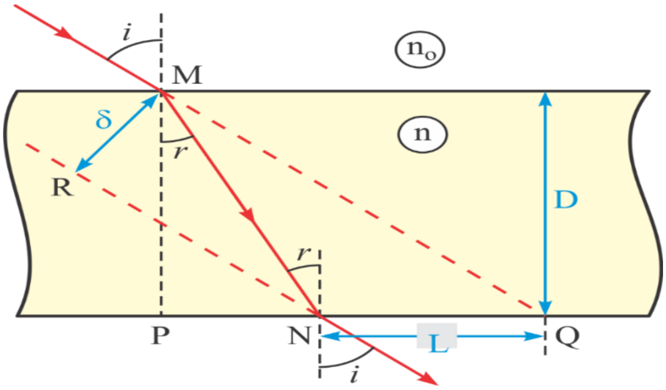
In this case, $i_1 = i_2 = i$ if $r_1 = r_2 = r$

$$\hat{A} = 2 \cdot r \quad ; \quad \delta_{\min} = 2 \cdot i - \hat{A}$$

$$r = \frac{\hat{A}}{2} \quad ; \quad i = \frac{\delta_{\min} + \hat{A}}{2}$$

$$\frac{n}{n_o} = \frac{\sin i}{\sin r} = \frac{\sin \frac{\delta_{\min} + \hat{A}}{2}}{\sin \frac{\hat{A}}{2}}$$

THE REFRACTION OF LIGHT ON THE PLANE-PARALLEL PLATE



$$\begin{cases} De\ \Delta MNR \Rightarrow \delta = MN \cdot \sin(i-r) \\ De\ \Delta MNP \Rightarrow D = MN \cdot \cos r \end{cases}$$

By dividing the members one by one, we have as a result:

$$\frac{\delta}{D} = \frac{\sin(i-r)}{\cos r}$$

$$\delta = D \cdot \frac{\sin(i-r)}{\cos r}$$

$$\begin{cases} de\ \Delta MQP \Rightarrow PQ = D \cdot tgi \\ de\ \Delta MNP \Rightarrow PN = D \cdot tgr \end{cases}$$

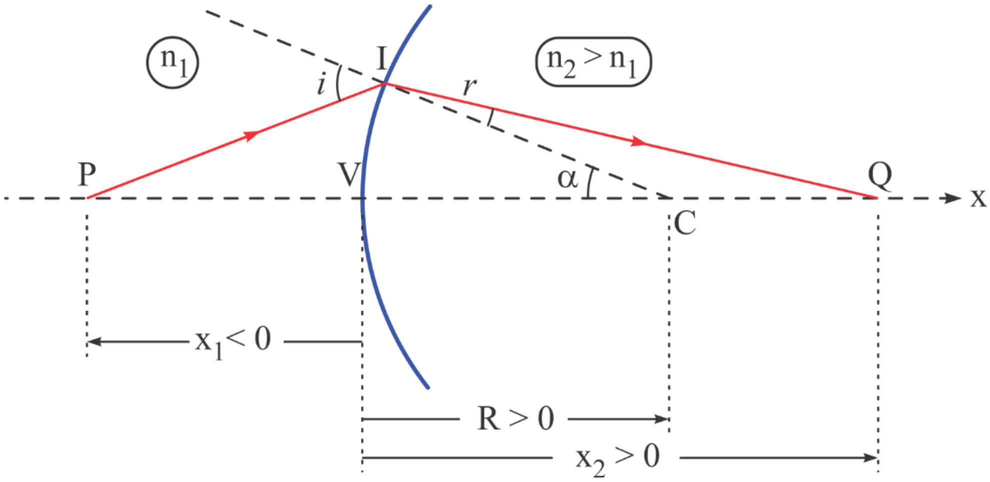
By subtracting the two relations, one by one, we obtain this result:

$$L = PQ - PN$$

$$L = D \cdot (tgi - tgr)$$

THE REFRACTION OF LIGHT ON THE SPHERICAL SURFACE.

SPHERICAL DIOPTER



Sine theorem for ΔPIC: $\frac{PC}{\sin(\pi - i)} = \frac{PI}{\sin\alpha}$ and $\frac{-x_1 + R}{\sin i} = \frac{-x_1}{\sin\alpha}$

Sine theorem for ΔQIC: $\frac{QC}{\sin r} = \frac{QI}{\sin(\pi - \alpha)}$ and $\frac{x_2 - R}{\sin r} = \frac{x_2}{\sin\alpha}$

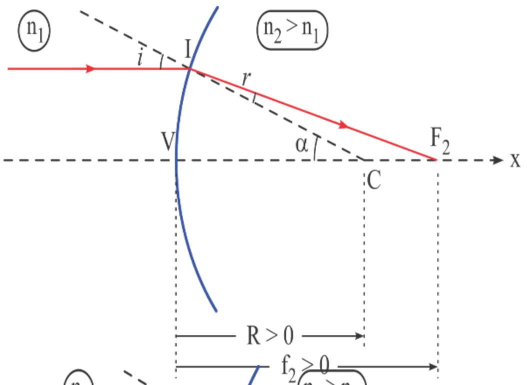
$$\frac{-x_1 + R}{\sin i} = \frac{-x_1}{\sin\alpha}$$

$$\frac{x_2 - R}{\sin r} = \frac{x_2}{\sin\alpha}$$

$\Rightarrow \frac{\sin i}{\sin r} = \frac{n_2}{n_1}$ (*Snellius relationship*)

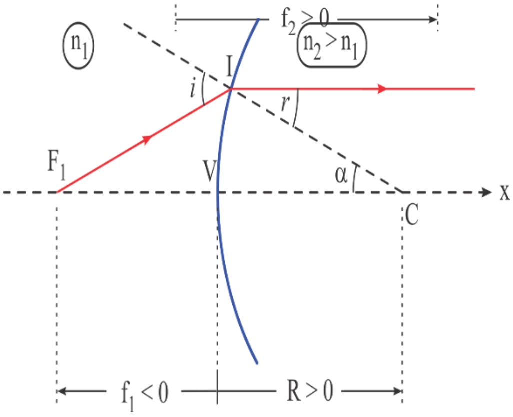
$$\frac{\sin i}{\sin r} = \frac{-x_1 + R}{-x_1} \cdot \frac{x_2}{x_2 - R} = \frac{n_2}{n_1}$$

$\Rightarrow \frac{n_2}{x_2} - \frac{n_1}{x_1} = \frac{n_2 - n_1}{R}$ Equation of conjugate points P if Q



If $x_1 \rightarrow -\infty$ then $x_2 \rightarrow f_2$; $\frac{n_2}{f_2} = \frac{n_2 - n_1}{R}$ if we get $f_2 > R$

So F_2 is the focus of the image

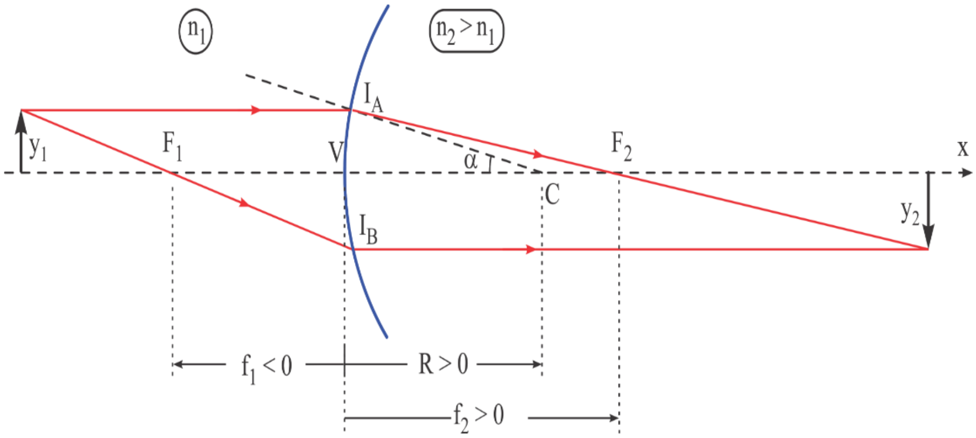


if $x_2 \rightarrow \infty$ then $x_1 \rightarrow f_1$; _

$$-\frac{n_1}{f_1} = \frac{n_2 - n_1}{R}$$

F_1 is the object focus

F1 can have a lower or higher absolute value with respect to R, depending on the concrete values of the refractive indices n1 and n2.

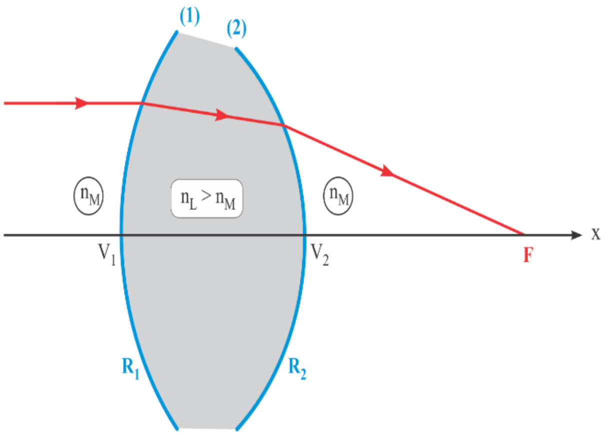


The object-dioptre distance is greater than the distance corresponding to point F1 (object focus).

The (real) image is formed at the intersection of the real rays in the image space.

The actual image is reversed relative to the position of the object.

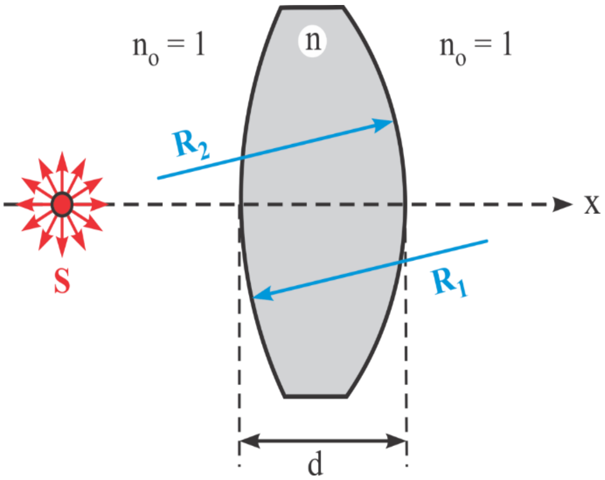
LENSES



If the light consecutively pierces two spherical diopters and the space between these diopters has a different refractive index than that outside, then the pair of diopters forms a "lens".

If the refractive index of the lens (nL) is greater than the refractive index of the external medium (nM), then the lens is convergent and the light beam is deflected towards the optical axis of the lens (axis V1 V2, x), as a consequence of light passing through the lens.

EQUATION OF "LENS PROCESSORS"



Conventions concerning the sign of the radii of curvature:

- The Surface closest to the source (object) has the serial number "1"
- The surface furthest from the source area (object) has the serial number "2"
- If the center of a surface is located on the negative half-line of the x axis, then this radius is negative. On the contrary, it is positive.

$$\frac{1}{f} = (n-1)\cdot\left[\frac{1}{R_1} - \frac{1}{R_2} - \frac{(n-1)\cdot d}{n\cdot R_1\cdot R_2}\right]$$

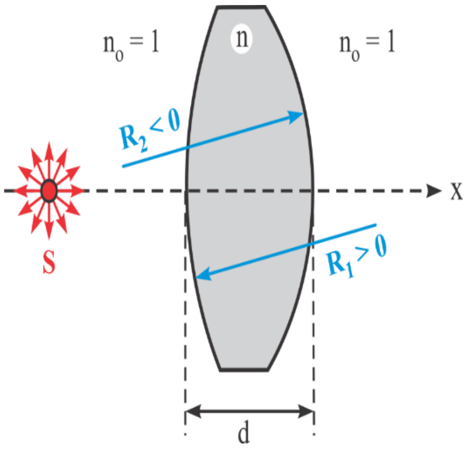
f = the focal length of the lens (focal length of the lens)

$f > 0$ for converging lenses

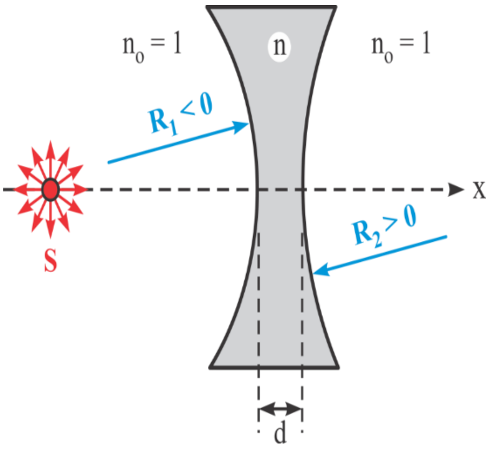
$f < 0$ for diverging lenses

n = the refractive index of the lens

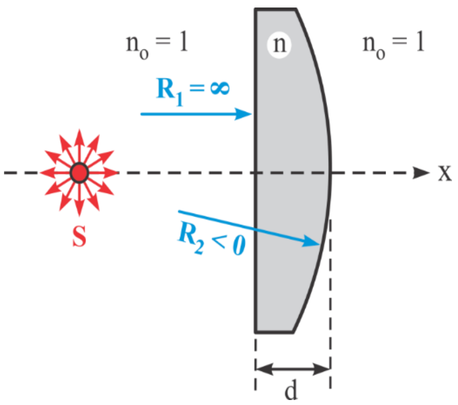
R_1 if R_2 = the radii of curvature of the surfaces (for the illustrated example $R_1 > 0$ if $R_2 < 0$)



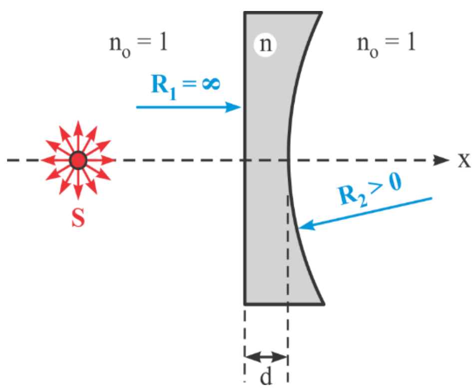
Biconvex lens



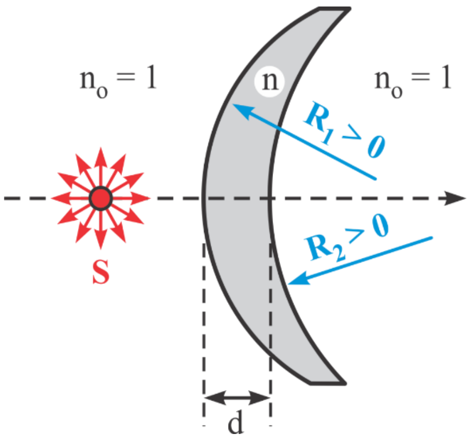
Biconcave lens



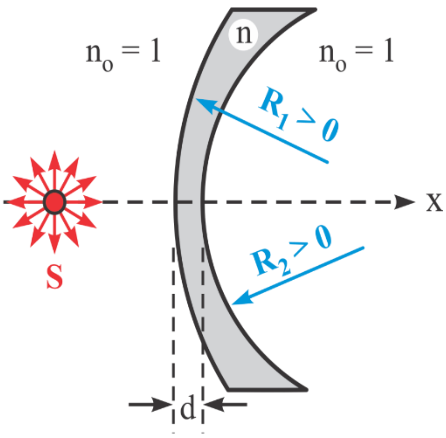
Plano-convex lens



Plane-concave lens



Convergent lens



Divergent lens

If the refractive index (n) of the lens material is greater than the refractive index of the medium, then. . .

. . . a lens thicker in the middle and thinner at the end is converging.

. . . a lens thinner in the middle and thicker at the end is diverging.

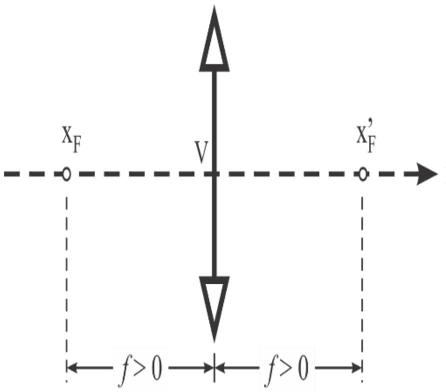
The Approximation of Thin Lenses. Gaussian Approximation

In the Gaussian approximation only the incident rays very close to the optical axis of the lens are taken into consideration (paraxial rays); when the angle of incidence "i" is almost zero, then cos(i) ≈ 1

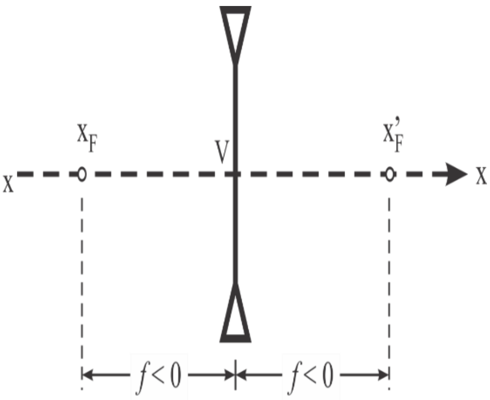
Approximation of thin lenses: the thickness "d" of the lens is negligible.

$$\frac{1}{f} = (n-1) \cdot \left[\frac{1}{R_1} - \frac{1}{R_2} - \frac{(n-1) \cdot d}{n \cdot R_1 \cdot R_2} \right] \approx (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

Symbols used for thin lenses:

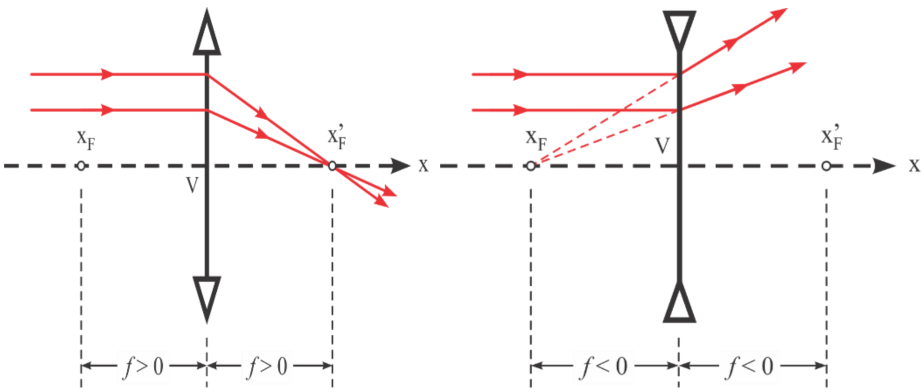


Convergent thin lens



Divergent thin lens

The optical behavior of thin lenses in the Gaussian approximation



The Conjugate Point Relation $\frac{1}{f} = \frac{1}{x_i} - \frac{1}{x_o}$

Or:

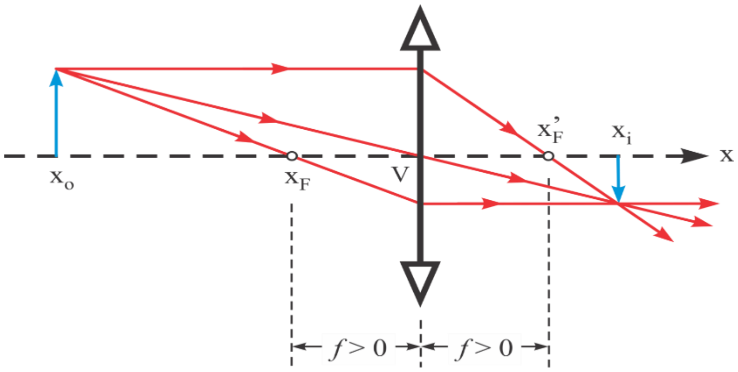
f is the focal length of the lens (this distance is positive in the case of converging lenses, and negative in the case of diverging lenses)

xi is the axis of the image situation (relative to the point "V“, taken as origin)

xo is the axis of the location of the real object (relative to the point "V“, taken as origin)

The positive direction of the "x" axis coincides with the direction of propagation of the rays from the source towards the lens.

The optical behavior of thin lenses in the Gaussian approximation



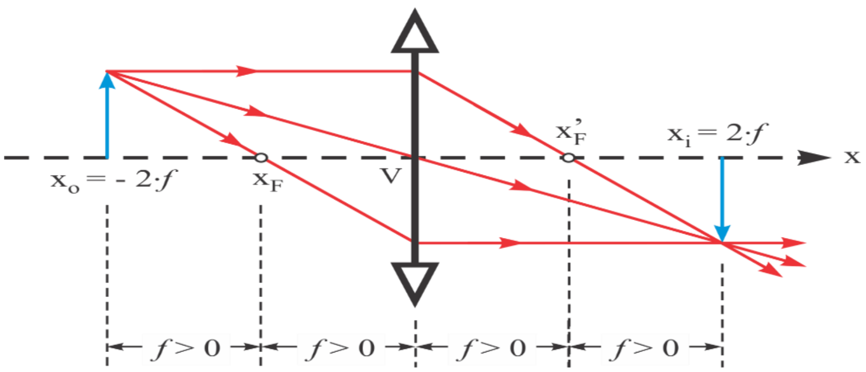
If the real object is located at a distance greater than 2•f with respect to the lens, then the image is real, diminished, inverted. It is formed at a distance greater than f and less than 2 •f , with respect to the lens.

The transverse magnification (β):

$$\beta = \frac{x_i}{x_o} < 0 \quad (image\ renversee)$$

$$si \quad \frac{|x_i|}{|x_o|} < 1 \quad (image\ \text{dim}\,inuee)$$

The optical behavior of thin lenses in the Gaussian approximation



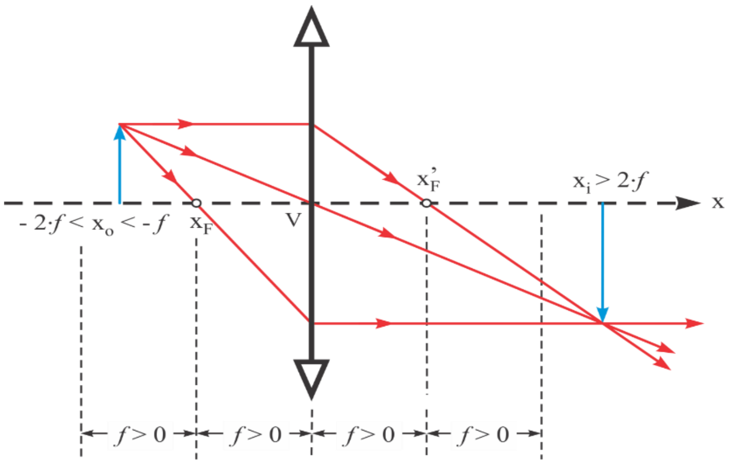
If the real object is at the distance of 2 •f with respect to the lens (xo = 2 • f), then the image is real, inverted, of the same size with the object and is formed at the distance 2 •f with respect to the lens.

The transverse magnification (β):

$$\beta = \frac{x_i}{x_o} < 0 \quad (image\ réelle\ renversee)$$

$$si \quad \frac{|x_i|}{|x_o|} = 1 \quad (image\ \text{la la meme}\ \ \text{dim}\,ension\ comme\ l'objet)$$

The behavior of thin optical lenses in the Gaussian approximation

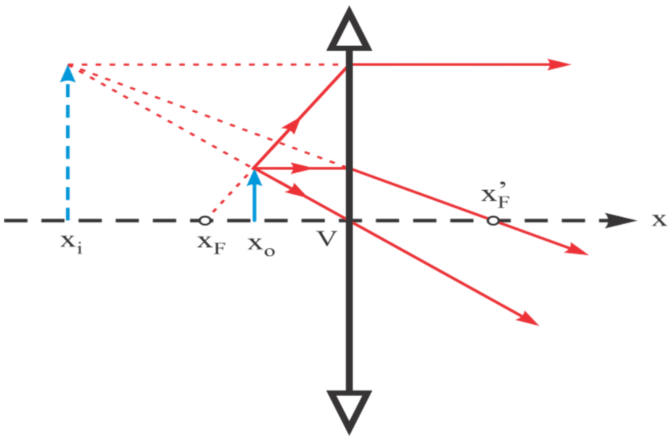


If the real object is between the distances of 2 •f and f with respect to the lens (- 2 • f <xo <f), then the image is real, inverted, magnified in comparison with the object and shape at a distance greater than 2 • f from the lens.

The transverse increase (β)

$$\beta = \frac{x_i}{x_o} < 0 \quad (\textit{image réelle renversee})$$

$$si \ \frac{|x_i|}{|x_o|} > 1 \quad (\textit{image} \text{ aggrandie en comparaison avec l'objet})$$



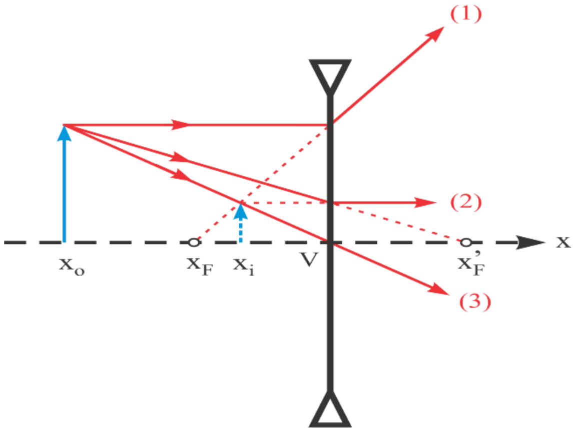
The lens as a "magnifying glass"

If the real object is between the focal point and the lens (xo > f), then the image is formed at the prolonged intersection of the real rays (the image is virtual). The image is oriented similar to the object and is magnified relative to the object.

The transverse increase (β)

$$\beta = \frac{x_i}{x_o} > 0 \quad (\textit{imagine virtuala dreapta})$$

$$si \ \frac{|x_i|}{|x_o|} > 1 \quad (\textit{image est} \ \text{ est agrandie par rapport a l'objet.})$$



At any position of the real object, the diverging lenses form an image only at the prolonged intersection of the real rays.

The image is virtual, oriented similarly to the object and diminished in relation to it.

The focal length of diverging lenses is negative.

The conjugate point equation is: $\frac{1}{f} = \frac{1}{x_i} - \frac{1}{x_o}$

INTRODUCTION TO OPTICAL MICROSCOPY

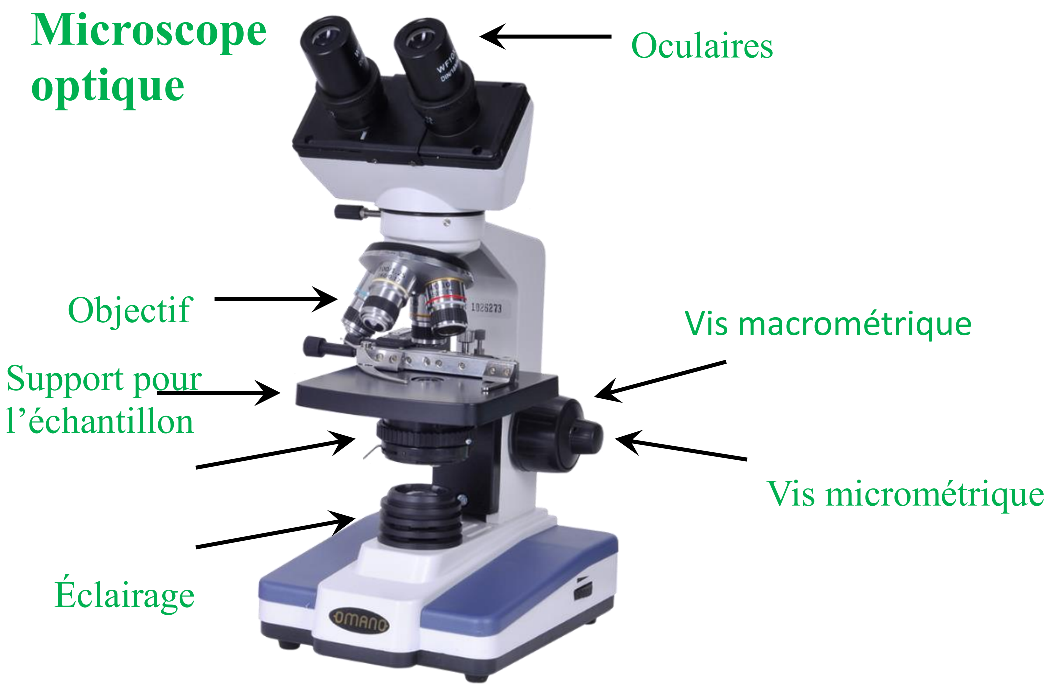
Preliminary notions

Transmission optical microscopy

- The light passes through the sample under the optical microscope;
- Light is absorbed differently by different components of the sample;

• There is often a need for artificial staining of the sample to better highlight specific cellular components, etc.;

• The final image is virtual, enlarged and reversed.

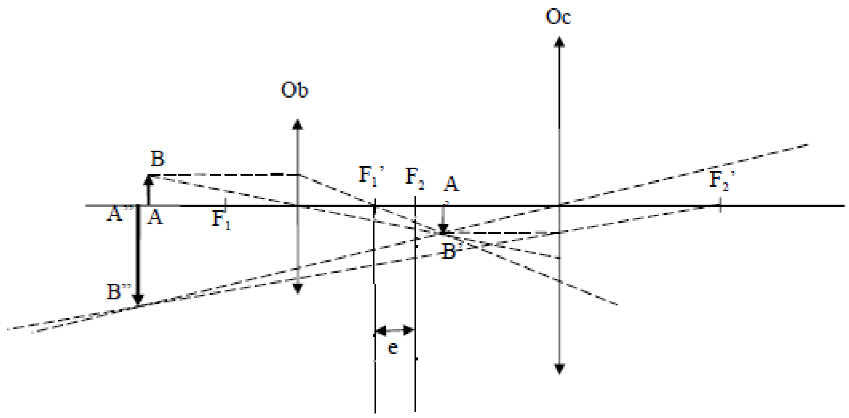


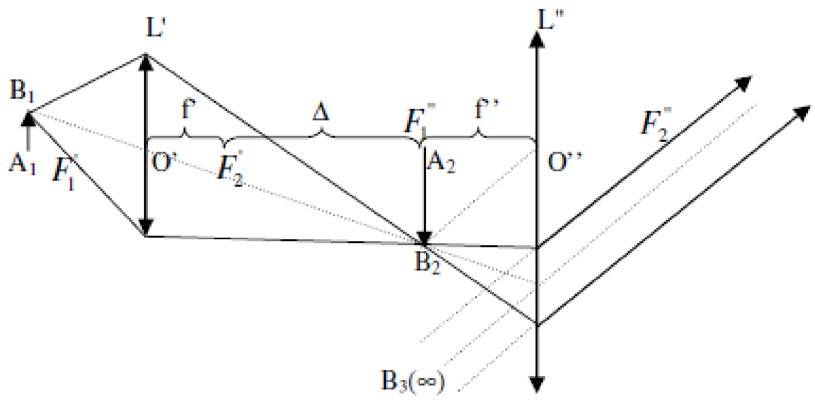
The microscope is an optical instrument that gives a much magnified image of an object, thus making it possible to distinguish details that are not visible to the naked eye.

From the optical point of view, the microscope is an association of the two central systems: the objective

which is a convergent system at a very reduced focal distance (of a few millimeters), and the eyepiece, also a convergent system, but at a widened focal distance (of a few centimeters).

IMAGE FORMATION IN AN OPTICAL MICROSCOPE





It is generally accepted that the objective L' as well as the eyepiece L" are thin lenses. The objective gives a real, magnified and inverted A2B2 image of a small object A1 B1, which is placed between the focal point of the objective and twice its focal length (closer to the focal point). The eyepiece is placed in such a way that the image given by the objective is formed between the eyepiece and the focal point of the latter. works like a magnifying glass and gives a virtual A3B3 image enlarged and inverted with respect to the A1B1 object.To clearly distinguish the A3B3 image, namely to adjust the microscope, the assembly formed by the objective and the eyepiece is moved in relation to object A1B1, until the final image is formed between the punctum remotum and the punctum proximal of the eye. For an eye with normal sight, which sees effortlessly from a distance (at infinity) without accommodation, the microscope is moved so that the image A2B2, given by the objective, is formed in the focus-object of the eyepiece F1".

THE EYE AS AN OPTICAL INSTRUMENT

The shape of the eyeball is roughly spherical.

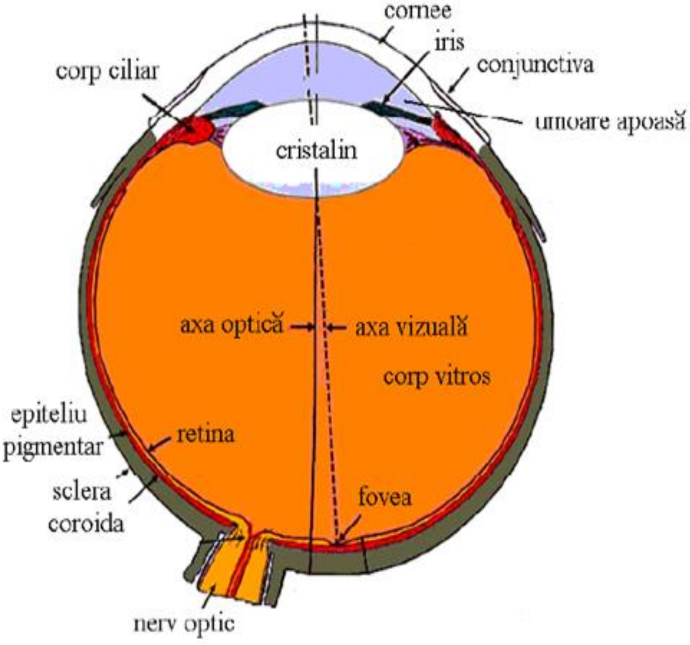
The anterior center of curvature of the eyeball is called **the anterior pole (PA)** and the other is called **the posterior pole (PP).**

The line that unites the two poles is called **the optical axis.**

The Visual Axis passes through the cornea and the central fovea.

The two axes intersect at a point behind the center of the lens.

The lens, the cornea, the aqueous humor and the vitreous form the refractive media of the eye.



The refractive indices of these media are as follows:

The cornea: n = 1.37

Aqueous humor: n = 1.33

The lens: n = 1.413 (1.375 to 1.473)

The vitreous body: n = 1.33

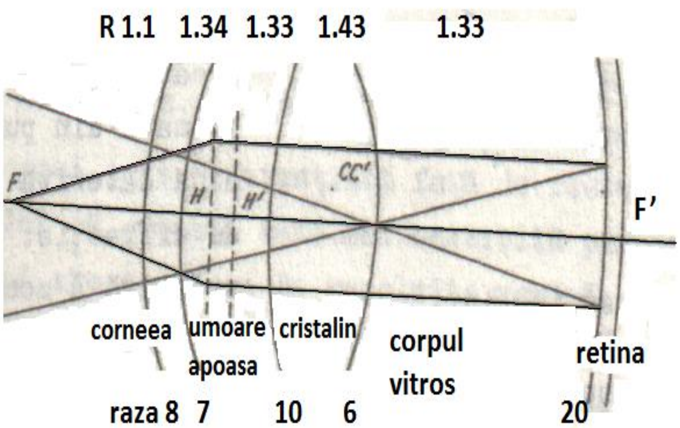
It is generally accepted that the eye essentially has two dioptres, since the indices of refraction of the cornea, aqueous humor and vitreous body are the same; these diopters are:

1. The anterior surface of contact with air
2. The lens which is surrounded by a uniform refractive medium.

The eye as a whole has a diffractive power of 60-65 diopters.

To determine the path of light rays in the formation of the image, it is necessary to know the curvature of the following surfaces:

- The radius of the anterior surface of the cornea: R = 7.7 mm
- The radius of the outer surface of the cornea R = 6.8 mm
- The radius of the anterior surface of the lens R = 12.6 mm
- The radius of the posterior surface of the lens: R = 6.0 mm



From the physical point of view, the eye is an imperfect device. Its imperfections can be explained by:

- The defective sphericity of refractive media;
- The refraction (of the lens) parallel to the vertical meridian is 0.5 to 1.25 diopters greater than the refraction (of the lens) parallel to the horizontal meridian;
- The lens presents a certain aberration as much spherical as chromatic.
- The vitreous body is an inhomogeneous optical medium.

Image formation at the level of the human eye

At the level of the anatomy of the human eye, three optical systems are distinguished:

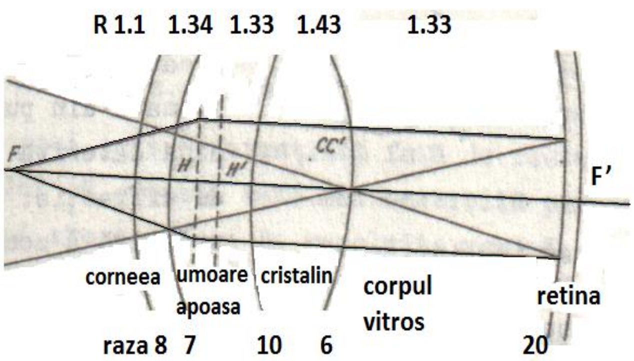
1. The system formed by three components: air, cornea and aqueous humor.
2. The system formed from the crystalline lens which acts as a biconvex lens.
3. The system formed from the vitreous body.

To explain the formation of the image in the eye with three refractive media, we apply Gauss's theorem: Any optical system made up of spherical surfaces, with centers located on the main axis, has 3 pairs of cardinal points:

- Two main points H and H' crossed by two main planes;
- An anterior focus F and another posterior F';
- Two junction points C and C '.

In the human eye these points are located in this way:

- The two points H and H ' as well as the main planes are located in the anterior zone 2 cm behind the cornea;
-The anterior focus F is located 15.7 mm in front of the cornea, while the focus F' is placed on the retina.
- The light rays coming from F are parallel.
-The two foci F and F' are the main foci of a single lens (the crystalline lens).
- Points C and C' are very close to each other; therefore, they are taken for a single point which is located close to the posterior surface of the lens.



Z. Simon, Fl. Rottemberg, Gh.I. Mihalas, Biofizica, Lito IMT, 1989

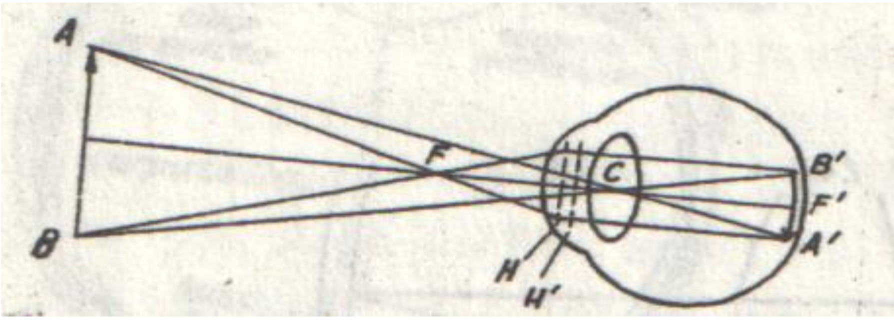
The six points are located as follows:

The anterior surface of the cornea is in position 0.

The first main point H is located 1.7 mm from the cornea.

The second main point H' is located 2 mm from the cornea.
Nodal point C is located 7 mm from the cornea.
The nodal point C' is located 7.3 mm from the cornea
The anterior focus F is placed 15.7 mm from the anterior surface of the cornea.
The posterior focus F' is placed 24.1 mm from the anterior surface of the cornea.
The calculated distance from the retina to the optical center is 17.0 mm, which results in a refractive power of the eye of 58-65 diopters.

Image formation at the level of the human eye



From the previous measurements we can construct the image on the retina.
The image on the retina is upside down relative to the object.
The process of reversing the image is due to a cerebral function.
Due to the phenomenon of diffraction, the image created on the retina is not formed from points of light. The size relative to the central zone is inversely proportional to the diameter of the pupil and it is directly proportional to the wavelength of the light. Not all the light that enters the eye is focused on the retina; this phenomenon occurs because of the colloidal nature (consistency) of the ocular media which are not perfectly homogeneous. This is why part of the light is scattered. The amount of this scattered light is directly proportional to the square of the particle size, and inversely proportional to the fourth power of the wavelength (Rayleigh).

Accommodation

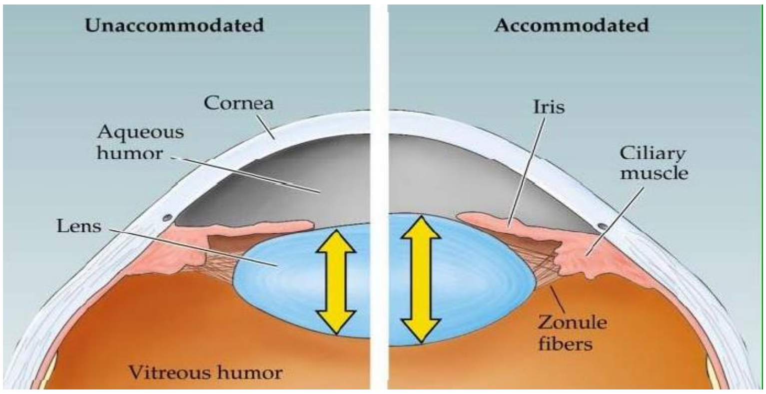
- It is the ability of the lens to modify its refractive power in order to ensure a clear image both at distance and at proximity.

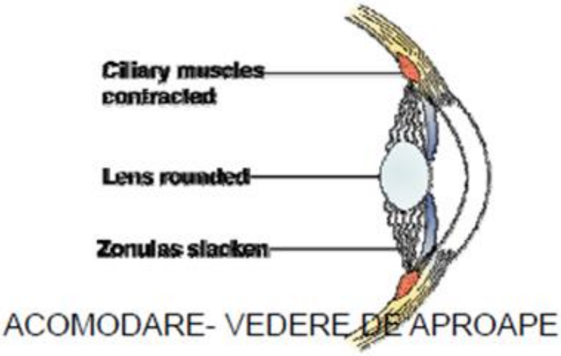
- The lens has a refractive power differentiated according to age: in young people, between 20 and 34 diopters; in midlife adults between 20 and 23 diopters; in old people, between 20 and 21 diopters.

In the accommodation participate:

- The lens
- The suspensory ligament (20 zonules / ligaments)
- The ciliary muscle (the circular component / fibers is the most important)
- Parasympathetic control is most important and
sympathetic control is of secondary importance.

Accommodation





Accommodation for near vision

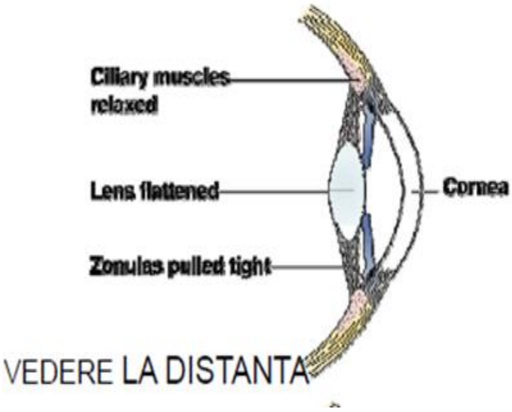
The ciliary muscles contract.

The ciliary zonule relaxes.

The lens bulges spontaneously.

It becomes more convergent.

The image is moved forward.



Accommodation for distance vision

The ciliary muscles no longer contract.

The fibers of the zonule are stretched.

The lens flattens spontaneously.

Convergence is down.

The image is moved backward.

VISUAL FAULTS

EMMETROPIC EYE (NORMAL)

MYOPIC EYE

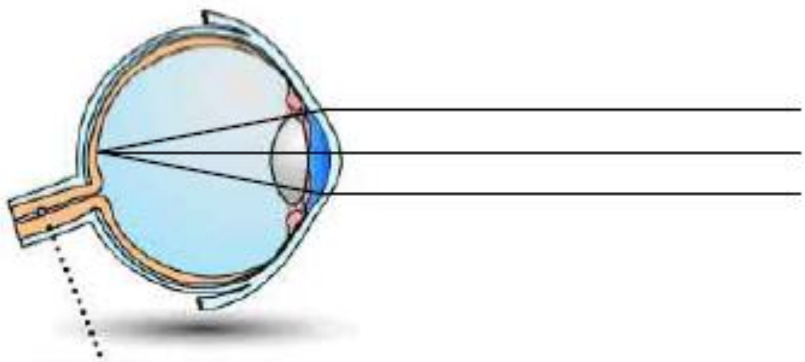
PRESBYOPIC EYE

HYPERMETROPIC EYE

EYE WITH ASTIGMATISM DEFECTS

THE EMMETROPIC EYE

- When the ciliary muscle is completely relaxed, the focusing of the image of distant objects is on the retina.
- The eye has an adequate ratio between the refractive power of the media and the length of the axis.
- Normal axle length is approximately 21-23mm.
- The refractive power of the cornea is about 39-44 diopters, while that of the lens is 19-23 diopters.



nearest punctum

It is the closest point to the eye from which an object can be seen clearly in conditions of complete accommodation: 25 cm for the emmetropic eye.

remote punctum

This is the point closest to the eye from which an object can be seen clearly without accommodation: 6 cm for the emmetropic eye.

A.Neagu, M. Neagu, Curs de Biofizica, UMFT, 2013

C. Ganea, Course of Biofizica pentru studentii of the Medicina Generala, Universitatea Carol Davila Bucuresti, 2010-2011.

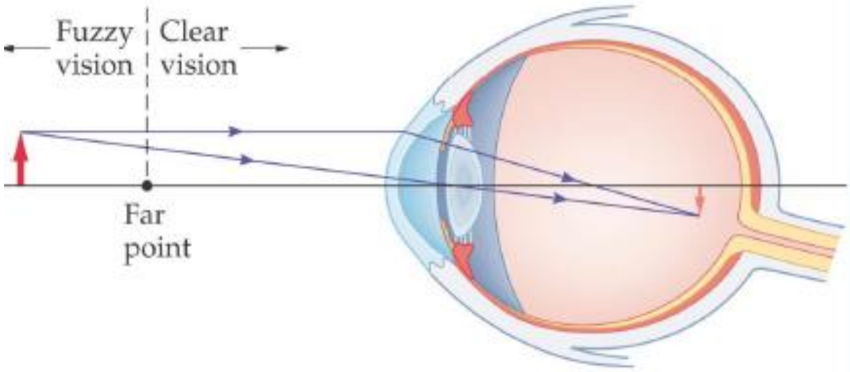
MYOPIC EYE

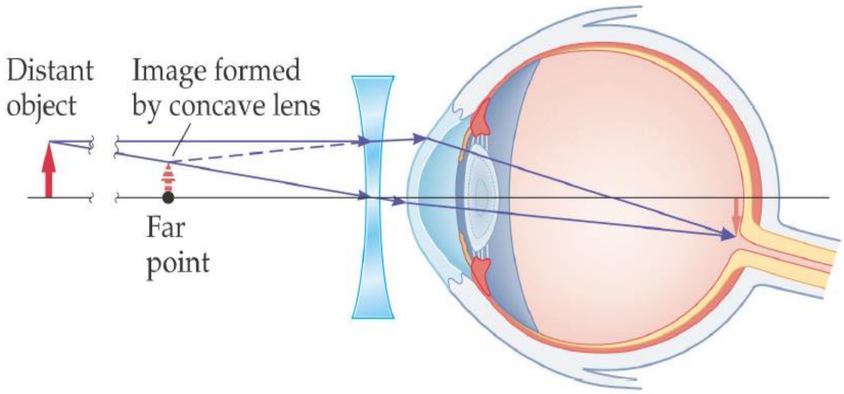
The absence of distance vision when the ciliary muscle is completely relaxed; this absence is due to an excess of convergence.

There is an abnormal relationship between the length of the optical axis and the refractive power of media.

< either a long axis, or a power greater than the refractive power of the media.

The correction is done using concave lenses.





The image is formed in front of the retina.

The image is axial > the antero-posterior axis is long (C=C normal).

The hyperopic eye and farsightedness

- Absence of near vision, when the ciliary muscle is completely relaxed, following insufficient convergence.
- There is an abnormal relationship between the length of the optical axis and the refractive power of the media: it is a short axis, the refractive power of the refractive media is reduced.
- The correction is done using convex lenses, and in young people, by accommodation.

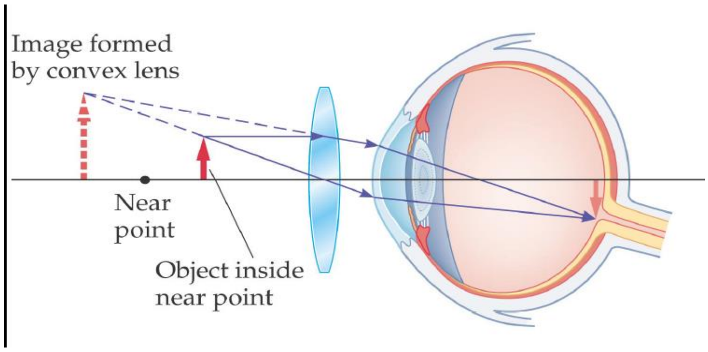
Hyperopia:

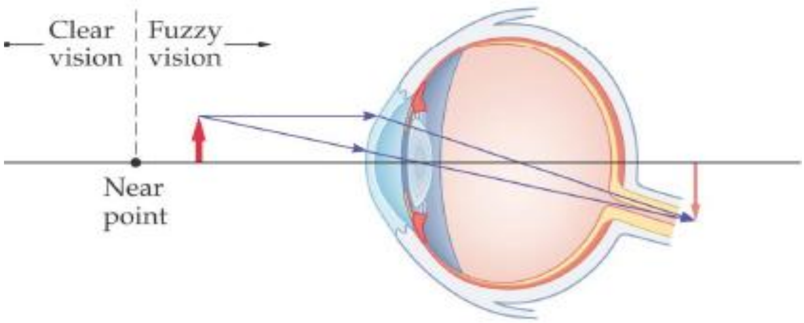
The image is formed behind the retina: the image is axial (i.e. a short antero-posterior axis) (C=Cnormal)

The image is curvature (the R index is high) (C < Cnormal)

Therefore, the eye is aphakic (The aphakic eye is an eye which, following surgery, is deprived of the lens.) (C < Cnormal).

Correction is done using converging lenses.

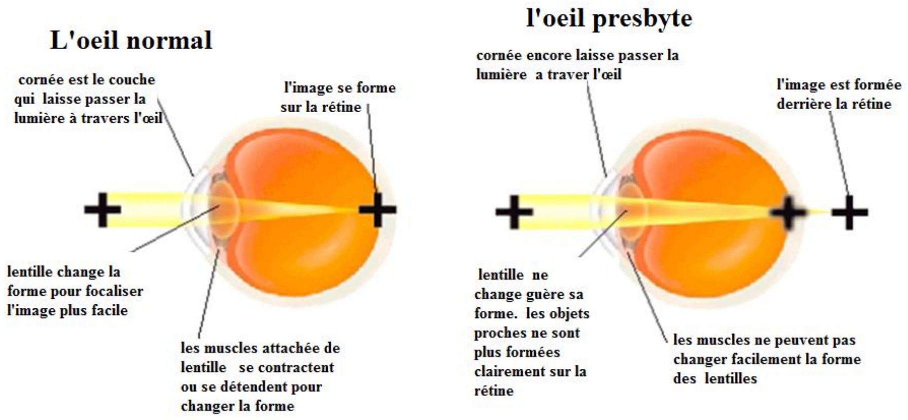




Presbyopia or farsightedness in the elderly

Cause: strength of age, there is a reduction in the accommodation capacity of the eye; this reduction is due to a gradual loss of elasticity of the lens.

The corrective lens is convergent.



ASTIGMATISM

It is a defect of refraction, due to a certain aberration, geometrically regular, of the diopters; in the normal state, the cornea is perfectly spherical; in the case of astigmatism, it becomes a toric cap.

The eye has two focal lines perpendicular to each other.

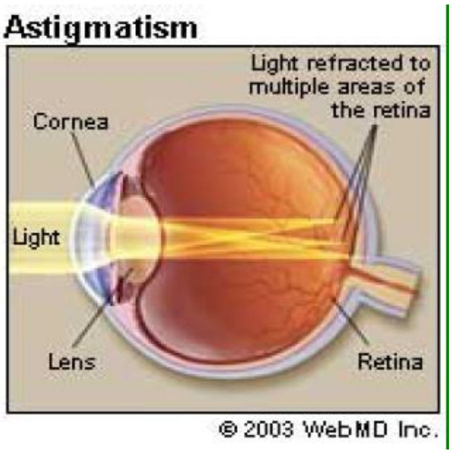
The patient cannot see well at a distance or near.

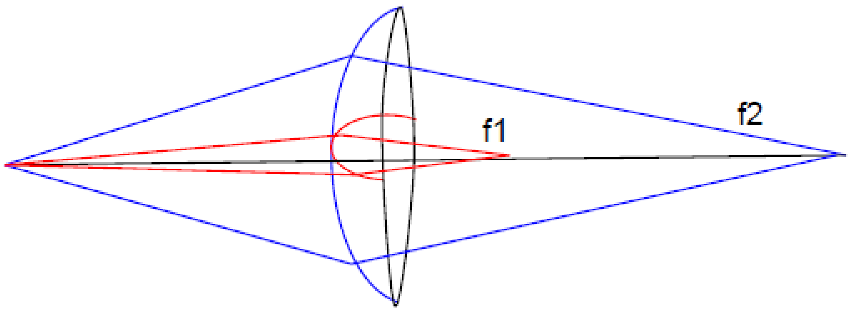
The correction is made by positive / negative cylinders.

In the case of astigmatism, the image is multiple.

Cause: the radii of curvature (especially of the cornea), are different both horizontally and vertically.

The correction is done with cylindrical lenses.

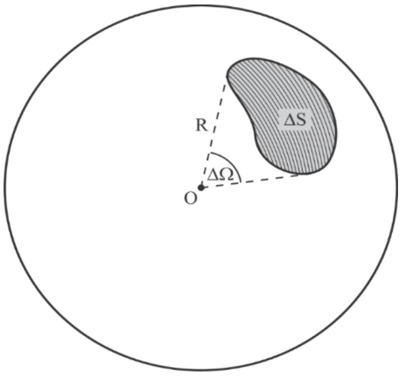

Astigmatism
Light refracted to multiple areas of the retina
Cornea
Light
Lens
Retina
© 2003 WebMD Inc.


f1
f2

11.PHOTOMETRY AND LIGHT ENERGY

Physical quantities to measure energy:

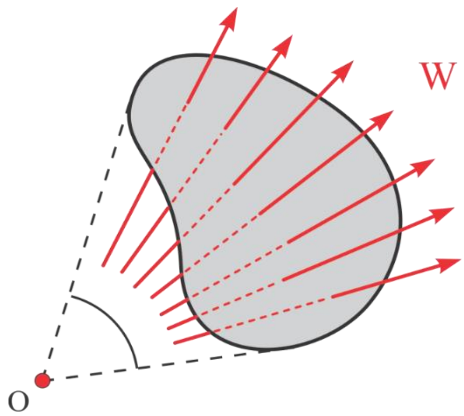
- energy flow (radiant energy)
- energy intensity;
- Illuminance or irradiance



The solid angle:

It is a region of space bounded by a not necessarily circular cone. The vertex of the cone is the vertex of the solid angle. The unit of measurement for a solid angle is the steradian (sr).

" ΔΩ" is defined as: $\Delta\Omega = \frac{\Delta S}{R^2}$



The energy (W) which crosses, in a well-established unit of time, any section of a cone at the top of which there is a punctiform light source, is called the flow of radiant energy (F e) (unit of measurement : watts - W)

$$\Phi_e = \frac{dW}{dt}$$

The complete surface ΔΩof a sphere is viewed from the center of the sphere at a solid angle of 4• πsteradian.

Radiant intensity is the radiant energy flux emitted in the unit solid angle.

$I_e = \frac{d\Phi_e}{d\Omega}$ unit of measurement: watt/steradian

The Irradiance or the irradiance of an elementary surface (Ds) is the flow of radiant energy in relation to the illuminated surface.

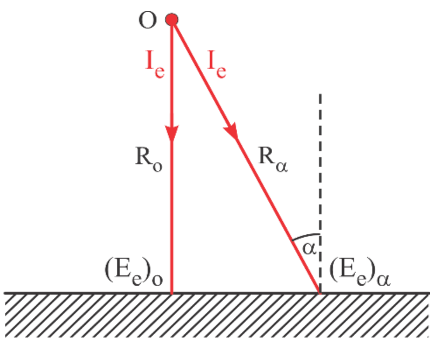
$E_e = \frac{d\Phi_e}{dS}$, unit of measurement: watt/m ^{2}

$d\Phi_e = I_e \cdot d\Omega$

$\Rightarrow E_e = \frac{I_e \cdot d\Omega}{dS}$

And $\frac{d\Omega}{dS} = \frac{1}{R^2}$

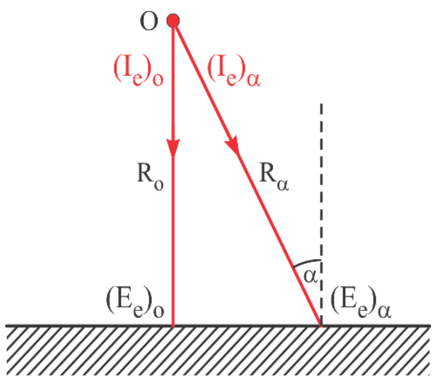
$\Rightarrow E_e = \frac{I_e}{R^2}$: The relation is valid for a normal incidence (perpendicular) to the illuminated surface



In the case of anomalous incidence (angle α), but in the case of a point source with isotropic emission intensity (the same emission intensity in all directions) the irradiance follows the formula:

$$(E_e)_\alpha = \frac{I_e}{R_\alpha^2} \cdot \cos\alpha$$

$$(E_e)_\alpha = \frac{I_e}{R_o^2} \cdot \cos^3\alpha = (E_e)_o \cdot \cos^3\alpha$$



If the intensity of the emissions is non-isotropic (it depends on the direction), then the condition of equal illumination of all points on the surface is equal to:

$$\frac{(I_e)_o}{R_o^2} = \frac{(I_e)_\alpha}{R_\alpha^2} \cdot \cos\alpha \ ; \ R_\alpha^2 = \frac{R_o^2}{\cos^2\alpha}$$

$$\frac{(I_e)_o}{R_o^2} = \frac{(I_e)_\alpha}{R_\alpha^2} \cdot \cos^3\alpha \ ; \ (I_e)_\alpha = \frac{(I_e)_o}{\cos^3\alpha}$$

Regarding this version of photometry, the definition of the physical quantities involved in it consider that the human eye has a different sensitivity to light radiation with different colors (different wavelengths).

Two rays of light with the same energy flux, but with different colors, produce different sensations on the retina of the human eye.

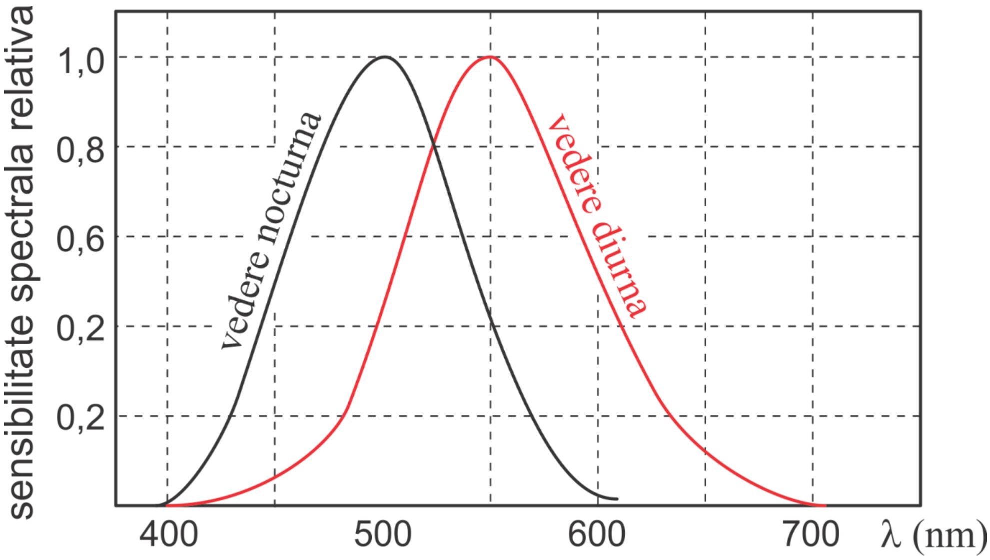
The human eye has a maximum relative sensitivity to green-colored light.

Consider two energy flows:

-Feo a flow of radiant energy from color light associated with the maximum sensitivity of the human eye (light "1") and

- **Fe** _ the radiant energy flux of light which has the non-ideal color from the point of view of the sensitivity of the human eye (the "2" light), which produces the same visual sensation as the "1" light. We define the relative spectral sensitivity of the human eye, "V", for each color of the visible spectrum according to the formula: $V = \frac{\Phi_{eo}}{\Phi_e} \leq 1$

V – dimensionless quantity



The spectral sensitivity of the human eye is differentiated; therefore, we define a biophysical quantity, the luminous flux F (unlike the energy flux!) as:

F = K•V•Fe

It is a relation where "K" is the photometric equivalent of the radiation, and F_e is the flow of radiant energy. If F is expressed in lumens (lm, see later), and F_e is expressed in watts (W), then K = 675 lm / W.

The photometric and energetic (or radiometric) physical quantities are defined in a similar way, but we note that instead of the energy flux, F e , we use the (photometric) luminous flux, F.

The luminous (photometric) intensity of a point light source is the luminous flux emitted in the unit of solid angle: $I = \frac{d\Phi}{d\Omega}$

Luminous (photometric) intensity is a fundamental physical quantity at the base of the SI. Unit of measurement: candela (cd).

The Candela is the luminous intensity of a source which emits, in a very precise direction, a monochromatic radiation at the frequency of $540 \cdot 10^{12}$ Hz and whose radiant intensity in this direction is 1/683 W/sr.

The luminous flux is defined by the formula DF = I•DW, as the luminous flux emitted in a solid angle of 1 steradian (sr) by a point source at the intensity of 1 cd.

Unit of measurement is: "lumens" (lm): 1 lm = (1 cd) • (1 sr)

The luminous flux emitted by a source in all directions

$$(W = 4 \cdot \pi sr) \text{ is } F_t = 4 \cdot \pi \cdot I$$

Illuminance (luminous, photometric), E, is defined as follows: it is the luminous flux that falls on the unit area: $E = \frac{d\Phi}{dS}$

If the incidence on the uniformly illuminated surface is normal,

then we have the following ratio, where R is the distance between the source and the illuminated surface), $E = \frac{I}{R^2}$

The Unit of measurement is "luxury" (lx).

Luxury is defined in this way: Uniform illumination of an area of 1 m2 on which falls a luminous flux of 1 lm (lx = lm / m2)

Ex. The (mean) solar irradiance of the earth's surface is

Ee = 1.380 W/m2, approx.

Photometric quantities from the SI system		**units of measurement of photometry from the SI system**		remarks
name	Symbol	Name of units	Symbol	
luminous energy	Q_v	lumen second	lm·s	The lumen x second product is called TALBOT.
Luminous Flux	Φ_v	lumen (= candela steradians)	lm (= cd·sr)	Luminous energy per unit time
luminous intensity	I_v	candela (= lumen per steradian)	cd (= lm/sr)	luminous flux per unit solid angle
luminance	L_v	candela per square metre	cd/m^2	Luminous flux per unit solid angle per unit area of projected source. Candela per square metre is called NIT
lighting	E_v	lux (= lumen per square metre)	lx (= lm/m^2)	Luminous flux incident on a surface
Luminous emitter	M_v	lumen per square metre	lm/m^2	Luminous flux emitted by a surface
Luminous exposure	H_v	lux second	lx·s	Temporally integrated illumination
Luminous energy density	ω_v	lumen second per cubic metre	lm·s/m^3	
Luminous efficacy of radiation	K	lumen per watt	lm/W	Ratio of luminous flux to radiant flux
Luminous efficacy of source	η	lumen per watt	lm/W	Ratio of luminous flux to power consumed

PHOTOMETRIC QUANTITIES - RADIOMETRIC QUANTITIES

There are two parallel systems of sizes known as

- photometric and
- radiometric quantities.

Each quantity in one system has an analogous quantity in the other system. Some examples of parallel quantities include: Luminance (photometric) and radiance (radiometric); Luminous flux (photometric) and radiant flux (radiometric); Luminous intensity (photometric) and radiant intensity (radiometric).

In photometric quantities, each wavelength is weighted according to how sensitive the human eye is to it, while radiometric quantities use an unweighted absolute power.

For example, the eye responds much more strongly to green light than to red, so a green source will have a higher luminous flux than would a red source with the same radiant flux.

Radiant energy outside the visible spectrum does not contribute to photometric quantities at all, so, for example, a 1000 watt space heater can produce a large amount of radiant flux (1000 watts, in fact), but as a light source, it exposes very little light (because most of the energy is in the infrared, leaving only a faint red glow in the visible).

SI radiometry units		units	remarks
name	Symbol		
Radiant energy	Q_e	J	Electromagnetic radiation energy.
Density of radiant energy	w_e	J/m^3	Radiant energy per unit volume.
Radiant flux	Φ_e	W = J/s	Radiant energy emitted, reflected, transmitted or received, in unit time. This is sometimes referred to as "radiant power".
Spectral flux	$\Phi_{e,\nu}$	W/Hz	Fluxul radiant pe unitatea de frecvență sau lungime de undă. Acesta diRadiant flux per unit frequency or wavelength. The latter one is typically measured in în $W\cdot nm^{-1}$.
	$\Phi_{e,\lambda}$	W/m	
Radiant intensity	$I_{e,\Omega}$	W/sr	The radiant flux emitted, reflected, transmitted or received, per unit solid angle. This is a directional quantity.
Spectral intensity	$I_{e,\Omega,\nu}$	$W\cdot sr^{-1}\cdot Hz^{-1}$	Radiant intensity per unit frequency or wavelength. The latter is typically measured in $W\cdot sr^{-1}\cdot nm^{-1}$. This is a directional quantity.
	$I_{e,\Omega,\lambda}$	$W\cdot sr^{-1}\cdot m^{-1}$	

Spectral radiance	$L_{e,\Omega,\nu}$	$W\cdot sr^{-1}\cdot m^{-2}\cdot Hz^{-1}$	The radiance of a surface per unit frequency or wavelength. The latter is commonly measured in W·sr - 1·m - 2·nm - 1. This is a directional quantity. It is also sometimes confusingly called "spectral intensity".
	$L_{e,\Omega,\lambda}$	$W\cdot sr^{-1}\cdot m^{-3}$	
Radiosity	Je	*W/m2*	The radiant flux emitted, reflected or transmitted by a surface per unit area. Sometimes also called "intensity".
Spectral radiosity	Je,ν	*W·m−2·Hz−1*	Radiosity of a surface per unit frequency or wavelength. The latter is commonly measured in W·m-2·nm-1. It is sometimes also called "spectral intensity".
	Je,λ	*W/m3*	
Hemispherical emissivity	ε		The radiant excitance of a surface divided by that of a black body at the same temperature as the surface.
Hemispherical spectral emissivity	ε_ν *or* ε_λ		The spectral excitance of a surface divided by that of a black body at the same temperature as that surface.
Directional emissivity	ε_Ω		The radiance emitted by a surface, divided by that emitted by a black body at the same temperature as that surface.
Directional Spectral emissivity	$\varepsilon_{\Omega,\nu}$ *or* $\varepsilon_{\Omega,\lambda}$		The spectral radiance emitted by a surface, divided by that of a black body at the same temperature as that surface.
Hemispherical absorbance	A		The radiant flux absorbed by a surface, divided by that received by that surface. This is not to be confused with "absorbance".
Spectral hemispherical absorbance	A_ν *or* A_λ		The spectral flux absorbed by a surface, divided by that received by that surface. Not to be confused with "spectral absorbance".
Directional absorbance	A_Ω		The radiance absorbed by a surface, divided by the radiance incidence on that surface. This is not to be confused with "absorbance".
Directional spectral absorbance	$A_{\Omega,\nu}$ *or* $A_{\Omega,\lambda}$		The spectral radiance absorbed by a surface, divided by the spectral radiance incident on that surface. Not to be confused with "spectral absorbance".
Hemispherical reflectance	R		The radiant flux reflected from a surface divided by that received by that surface.
Hemispherical spectral reflectance	R_ν *or* R_λ		The spectral flux reflected from a surface divided by that received by that surface.
Directional reflectance	R_Ω		Radiance reflected from a surface, divided by that received by that surface.
Spectral directional reflectance	$R_{\Omega,\nu}$ *or* $R_{\Omega,\lambda}$		The spectral radiance reflected from a surface, divided by that received by that surface.
Hemispherical transmittance	T		The radiant flux transmitted by a surface divided by that received by that surface.

Spectral hemispherical transmittance	T_ν or T_λ	The spectral flux transmitted by a surface, divided by that received by that surface.
Directional transmittance	T_Ω	Radiance transmitted by a surface, divided by that received by that surface.
Spectral directional transmittance	$T_{\Omega,\nu}$ or $T_{\Omega,\lambda}$	The spectral radiance transmitted by a surface, divided by that received by that surface.

SI radiometry units		units	remarks
name	Symbol		
Hemispherical attenuation coefficient	μ	m^{-1}	The radiant flux absorbed and scattered by a volume per unit length, divided by that received by that volume.
Hemispherical spectral attenuation coefficient	μ_ν or μ_λ	m^{-1}	The spectral radiant flux absorbed and scattered by a volume per unit length divided by that received by that volume.
Directional attenuation coefficient	μ_Ω	m^{-1}	Radiation absorbed and scattered by a volume per unit length divided by that received by that volume.
Directional spectral attenuation coefficient	$\mu_{\Omega,\nu}$ or $\mu_{\Omega,\lambda}$	m^{-1}	The spectral radiation absorbed and scattered by a volume per unit length divided by that received by that volume.

PHOTONICS

Photonics is related to quantum optics, optomechanics, electro-optics, optoelectronics and quantum electronics.

Quantum optics often refers to fundamental research, while photonics is used to link applied research and development.

The term photonics contains more precise:

The properties of light particles,

The potential to create signal processing device technologies using photons,

The practical application of optics, and

An analogy with electronics.

The term optoelectronics contains devices or circuits comprising both electrical and optical functions, i.e. a thin-film semiconductor device.

The term electro-optics was used earlier and specifically encompasses nonlinear electrical-optical interactions applied, for example, as bulk crystal modulators such as Pockels cell, but also includes advanced image sensors...

Photonics refers to the emerging sciences of quantum information and quantum optics which include:

Optoacoustics or photoacoustic imaging where laser energy delivered into biological tissues will be absorbed and converted into heat, leading to ultrasonic emissions.

Optomechanics, which involves the study of the interaction between light and mechanical vibrations of mesoscopic or macroscopic objects;

Opto-atomics, in which devices integrate both photonic and atomic devices for applications such as timekeeping, navigation and metrology;

Polaritronics, which differs from photonics in that the fundamental information carrier is a polariton. Polaritons are a mixture of photons and phonons and operate in the frequency range from 300 gigahertz to about 10 terahertz.

Programmable photonics, which studies the development of photonic circuits that can be reprogrammed to implement different functions in the same way as an electronic FPGA

PHOTONICS APPLICATIONS

- light detection,
- telecommunications,
- information processing,
- photonic computing,
- lighting,
- metrology,
- spectroscopy,
- holography,
- medicine (surgery, vision correction, endoscopy, health monitoring),
- biophotonics,
- military technology,
- laser materials processing,
- art diagnostics (involving InfraRed Reflectography, X-rays, UltraViolet Fluorescence, XRF),
- agriculture and
- robotics.

Just as electronic applications have expanded dramatically since the invention of the first transistor in 1948, the unique applications of photonics continue to emerge. Economically important applications for semiconductor photonic devices include optical data recording, fiber optic telecommunications, laser printing (based on xerography), displays, and the optical pump of high-power lasers. The potential applications of photonics are virtually limitless and include chemical synthesis, medical diagnostics, on-chip data communication, sensors, laser defence and fusion energy, to name a few additional interesting examples.

Consumer equipment: barcode scanner, printer, CD/DVD/Blu-ray devices, remote control devices
Telecommunications: fibre optic communications, microwave optical converter
Medical: poor vision correction, laser surgery, surgical endoscopy, tattoo removal
Industrial manufacturing: use of lasers for welding, drilling, cutting and various surface modification methods
Construction: laser levelling, laser range finder, smart structures
Aviation: photonic gyroscopes without moving parts
Military: IR sensors, command and control, navigation, search and rescue, mine laying and detection
Entertainment: laser shows, beam effects, holographic art
Information processing

Sensors: LIDAR, consumer electronics sensors

Metrology: time and frequency measurements, frequency

Photonic computing: clock distribution and communication between computers, printed circuit boards or in optoelectronic integrated circuits; in the future: quantum computing

Microphotonics and nanophotonics typically include photonic crystals and solid-state devices.

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Telecommunications: fibre optic communications, microwave optical converter

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WATT VERSUS LUMEN

Watt is the unit for radiant flux, while lumen is the unit for luminous flux.

A comparison between watt and lumen illustrates the distinction between radiometric and photometric units.

Watt is a unit of power.

This power is not a measure of the amount of light, but indicates how much energy the bulb will use. Since incandescent bulbs sold for "general service" all have fairly similar characteristics (same spectral power distribution), power consumption provides a rough guide to the light output of incandescent bulbs.

Watt can also be a direct measure of output. In a radiometric sense, an incandescent bulb is about 80% efficient: 20% of the energy is lost (e.g. through lamp operation). The rest is emitted as radiation, mostly in the infrared. So a 60-watt bulb emits a total radiant flux of about 45 watts. Incandescent bulbs are, in fact, sometimes used as heat sources (as in a chicken incubator), but are usually used for the purpose of providing light. As such, they are very inefficient because most of the radiant energy they emit is invisible infrared. A compact fluorescent lamp can provide light comparable to a 60-watt incandescent, while consuming as little as 15 watts of electricity.

The lumen is the photometric unit of light output. Although most consumers still think of light in terms of the energy consumed by the bulb, in the United States, it has been a commercial requirement for several decades that bulb packages produce in lumens. The package of a 60-watt incandescent bulb indicates that it provides about 900 lumens, as does the 15-watt compact fluorescent package.

Lumen is defined as the amount of light given off in a steradian by a point source of a candlepower;

Candela, a basic unit, is defined as the luminous intensity of a monochromatic radiation source with a frequency of 540 terahertz and a radiant intensity of 1/683 watts per steradian. (540 THz corresponds to approximately 555 nanometres, the wavelength, in green, to which the human eye is most sensitive. The number 1/683 was chosen to make the candle approximately equal to the standard candle, the unit it replaced).

Combining these definitions, we see that 1/683 watts of green light at 555 nanometres represents 1 lumen.

The relationship between watts and lumens is not just a simple scaling factor. We already know this because the 60 watt incandescent bulb and the 15 watt compact fluorescent can both provide 900 lumens.

The definition tells us that 1 watt of pure 555 nm green light "equals" 683 lumens. It says nothing about other wavelengths. Since lumen is photometric size, its relationship to watt depends on how visible the wavelength is. Infrared and ultraviolet radiation, for example, are invisible and don't matter. One watt of infrared radiation (which is most of the radiation from an incandescent bulb) is worth zero lumens. In the visible spectrum, wavelengths of light are weighted according to a function called "photopic spectral luminous efficiency". According to this function, 700 nm red light is only about 0.4% as efficient as 555 nm green light. Thus, one watt produced by 700 nm red light is equivalent to only 2.7 lumens.

Because of the summation over the visual portion of the EM spectrum that is part of this weighting, the unit "lumen" is blind: there is no way to tell at what colour a lumen will appear. This is equivalent to evaluating food by the number of bags: there is no information about the specific content, just a number that refers to the total weighted amount.

PHOTOMETRIC MEASUREMENT TECHNIQUES

Photometric measurement is based on photodetectors, devices (of several types) that produce an electrical signal when exposed to light. Simple applications of this technology include switching luminaires on and off according to ambient light conditions and light meters, used to measure the total amount of incident light flux on a point.

More complex forms of photometric measurement are commonly used in the lighting industry. Spherical photometers can be used to measure the directional luminous flux produced by lamps and consist of a large diameter globe with a lamp mounted in its centre. A photocell rotates around the lamp in three axes, measuring the output of the lamp from all sides.

Lamps and luminaires are tested using goniophotometers and rotating mirror photometers, which keep the photocells far enough apart that the luminaire can be considered a point source. Rotary mirror photometers use a motorized mirror system to reflect light emanating from the luminaire in all directions towards the distant photocell; goniophotometers use a 2-axis rotating table to change the orientation of the luminaire relative to the photocell. In both cases, the luminous intensity is computed from this data and used in the lighting design.

TROTEC BF06 DIGITAL LUX METER WITH PHOTODETECTOR .

A photometer is an instrument that measures the resistance of electromagnetic radiation in the range from ultraviolet to infrared and including the visible spectrum.

Most photometers convert light into an electric current using a photoresistor, photodiode or photomultiplier.

Photometers can measure:

Illuminance

irradiance

light absorption

Light reflection

Fluorescence

Phosphorescence

luminescence

Working principle of the photometers

Most photometers detect light using photoresistors, photodiodes or photomultipliers.

To analyse light, the photometer can measure light after it has passed through a filter or a monochromator for determination at defined wavelengths or for analysis of the spectral distribution of light.

Lighting measurements

Location		LIGHTING E (lx)
offices	Conference rooms , Reception rooms	200-700
	Church buildings	700-1500
Factories (Companies)	Entrance passages, packing departments	150-300
	Production department (production line)	300-750
	Quality department (checking)	750-1500
	Electronic components assembly department	1500-3000
Hotels	Waiting halls	100-200
	Reception	200-1000
Shops Supermakets	Corridors, stairs,	150-200
	Sales table	750-1500
	Exhibition windows	1500-3000
Hospitals	Patient lounges	100-200
	Examination room	200-750
	Operating room	750-1500
	Emergency treatment room	750-1500
Schools Universities	Amphitheatres	100-300
	Classrooms	300-750
	Laboratories	750-1500

BIOPHOTONICS

Biophotonics can also be described as "the development and application of optical techniques, especially imaging, for the study of biological molecules, cells and tissue".

One of the main advantages of using the optical techniques that make up biophotonics is that they preserve the integrity of the biological cells being examined.

Biophotonics has therefore become the established general term for all techniques dealing with the interaction between biological elements and photons. It refers to the emission, detection, absorption, reflection, modification and creation of radiation from biomolecules, cells, tissues, organisms and biomaterials.

Areas of application are life sciences, medicine, agriculture and environmental science.

Therapy and surgery, which use light mainly to transfer energy, and applications such as diagnostics, which use light to excite matter and transfer information back to the operator. In most cases, the term biophotonics refers to the latter type of application.

Biophotonics is an interdisciplinary field involving the interaction between electromagnetic radiation and biological materials, including: tissues, cells, subcellular structures and molecules in living organisms.

Recent biophotonics research has created new applications for clinical diagnosis and therapy involving fluids, cells and tissues. These advances allow scientists and physicians superior, non-invasive diagnostic opportunities for blood flow, as well as tools for better examination of skin lesions. In addition to new diagnostic tools, advances in biophotonics research have provided new photothermal, photodynamic and tissue therapies.

Applications of biophotonics - Dermatology

The field of biophotonics presents a unique set of diagnostic techniques that physicians can use.

Biophotonic imaging offers the field of dermatology the only non-invasive technique available for the diagnosis of skin cancers.

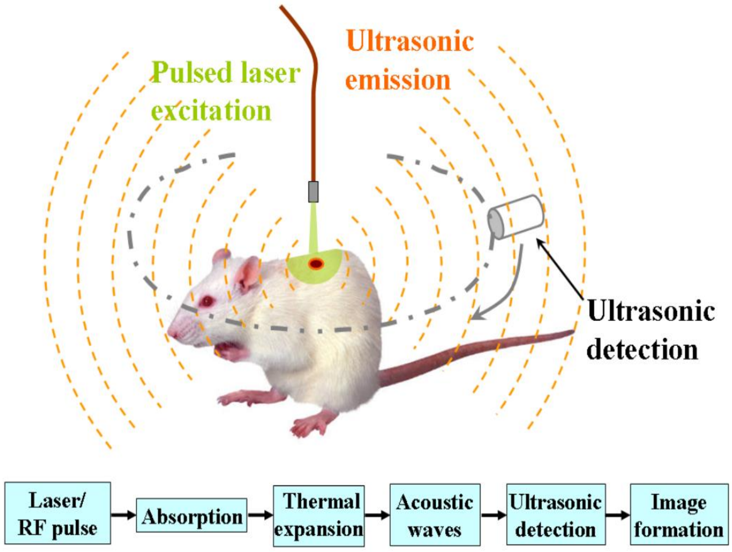
Traditional diagnostic procedures for skin cancers involve visual assessment and biopsy, but a new laser-induced fluorescence spectroscopy technique allows dermatologists to compare a patient's skin spectrographs with known spectrographs to match malignant tissue. This gives doctors earlier diagnostic and treatment options.

"Among optical techniques, an emerging imaging technology based on laser scanning, optical coherence tomography or OCT imaging is considered a useful tool for differentiating malignant skin tissue." The information is immediately accessible and eliminates the need for excision of the skin.

This also eliminates the need for skin samples to be processed in a laboratory which reduces labor costs and processing time.

These optical imaging technologies can be used during traditional surgical procedures to determine the boundaries of lesions to ensure removal of all diseased tissue. This is achieved by exposing nanoparticles that have been stained with a fluorescent substance to acceptable photons of light. Nanoparticles that are functionalized with fluorescent dyes and marker proteins will cluster in a chosen tissue type. When the particles are exposed to wavelengths of light that correspond to the fluorescent dye, the unhealthy tissue glows. This allows the treating surgeon to quickly identify the boundaries between healthy and unhealthy tissue, resulting in less time on the operating table and greater patient recovery. "Using dielectroporous microarray devices, nanoparticles and DNA biomarkers were rapidly isolated and focused to specific microscopic locations where they were easily detected by epifluorescent microscopy".

PHOTOACOUSTIC MICROSCOPY (PAM)



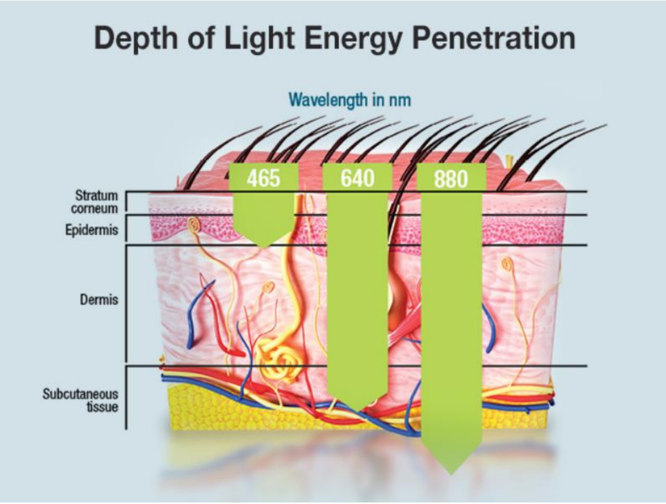
PHOTOACUSTIC MICROSCOPY (PAM) is an imaging technology that uses both laser and ultrasound technology.

This dual imaging modality is far superior at imaging deep tissue and vascular tissues than previous imaging technologies.

The improved resolution provides higher quality images of deep tissues and vascular systems, allowing non-invasive differentiation of cancerous tissues from healthy tissue by observing such 'water content, oxygen saturation level and haemoglobin concentration'.

Researchers have also been able to use PAM to diagnose endometriosis in rats.

LASER MICRO-SCALPEL



Micro-lasers are a combination of a fluorescence microscope and a femtosecond laser that "can penetrate up to 250 micrometers into tissue and target single cells in 3-D space" .

This technology was patented by researchers at the University of Texas at Austin, giving surgeons the ability to excise diseased or damaged cells without disturbing or damaging surrounding healthy cells in delicate surgical cases involving areas such as the eyes and vocal cords.

LOW LEVEL LASER THERAPY (LLLT)

Low Level Laser Therapy (LLLT), although somewhat controversial in terms of its effectiveness, can be used to treat wounds by repairing tissue and preventing tissue death.

However, more recent studies indicate that LLLT is more useful for reducing inflammation and providing chronic joint pain.

In addition, it is thought that LLLT may prove useful in the treatment of severe brain injury or trauma, stroke and degenerative neurological diseases.

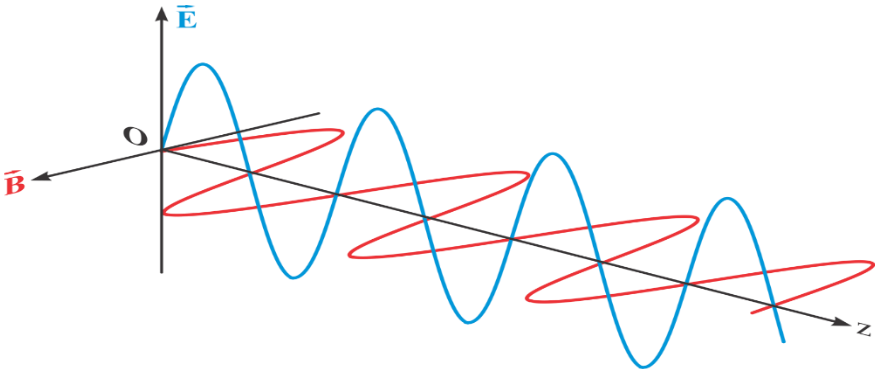
12.PHYSICAL OPTICS OR WAVE OPTICS

Light - electromagnetic wave - studied using methods specific to the propagation of waves (the notion of "light wave" instead of "ray of light").

Components of the light wave: a pair formed by an electric field and a magnetic field, both are time-varying and mutually induced.

The light emitted by a punctiform source "O", coming from the direction of the axis "z", is equivalent to the propagation of an electric field and a magnetic field, the two oscillatory ones.

At a well-defined moment, the instantaneous values graphically represented give, along the axis of the direction of observation (axis Oz), a sinusoidal shape.



The physical quantities characteristic of a wave propagating in a medium are:

-The Speed of propagation (v, m / s);

- Frequency (f s-1);

- Pulse (w rad / s)

- Wavelength (l, m)

- The Period (T s);

- The Phase (j radian)

- The state of polarization

The physical relations specific to a wave which propagates in a medium:

$$v = \frac{c}{n}$$ -

Or

c = the speed of propagation of the light wave in vacuum (299,792,458 m/s)

v = the speed of propagation of the light wave in the medium with refractive index "n".

$$v = \lambda \cdot f$$ -

Or

f = frequency of light (unit of measurement: s-1); the frequency of a given light wave is constant, ie it does not change if the light wave passes from one medium (at a given refractive index) to another medium (with a different refractive index).

l = wavelength of the light wave (it depends on the refractive index "n" of the medium where the wave propagates).

$$T = \frac{1}{f}$$

Or

T = the period of oscillation of the light wave (unit of measurement: second, s)

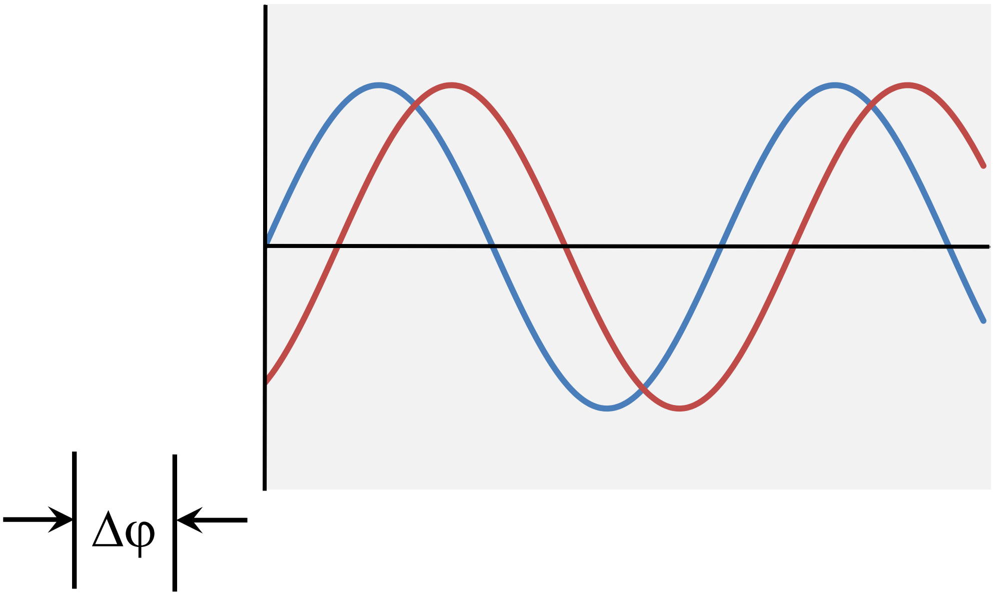
$$\omega = 2 \cdot \pi \cdot f = \frac{2 \cdot \pi}{T}$$

ω = the pulsation of the light wave oscillation (angular velocity of the associated phasor; unit of measure: rad/s)

$$\varphi = \frac{2 \cdot \pi}{\lambda} \cdot x = \omega \cdot \frac{x}{v} = 2 \cdot \pi \cdot f \cdot \frac{x}{v} = \frac{2 \cdot \pi}{T} \cdot \frac{x}{v}$$

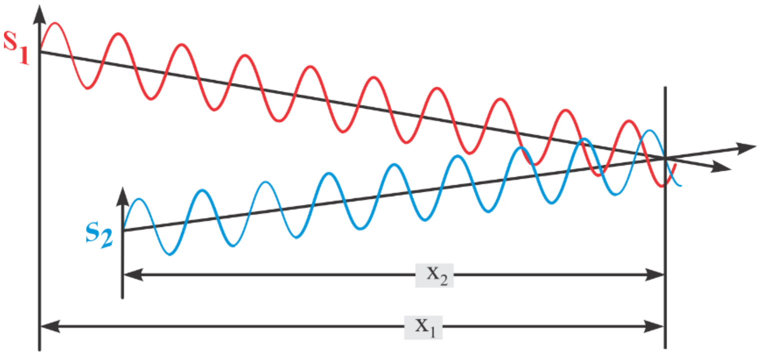
φ= the phase of the light wave oscillation at the point at the distance “x” from the light source. (unit of measurement: radians)

wave optic laboratory



Modulus of Vector Electric Field Strength and Time

The interference of two light waves with parallel planes polarization



The exemplification of the notion of phase difference between two wave quantities

The interference mode of the two waves that meet at a point, after having crossed different optical paths (x1 and x2), depends on the phase difference between the two waves in their meeting point.

The optical path traveled in a medium = the geometric path multiplied with the refractive index of the medium [x] = x•n

$$(E_1)_P = E_{1m} \cdot \sin(\omega \cdot t - \varphi_1)$$
$$(E_2)_P = E_{2m} \cdot \sin(\omega \cdot t - \varphi_2)$$

$$(E)_m \cdot \sin(\omega \cdot t - \varphi) = E_{1m} \cdot \sin(\omega \cdot t - \varphi_1) + E_{2m} \cdot \sin(\omega \cdot t - \varphi_2)$$

$$Pour\ t_a = 0: \quad (E)_m \cdot \sin\varphi = E_{1m} \cdot \sin\varphi_1 + E_{2m} \cdot \sin\varphi_2$$

$$Pour\ t_b = \frac{\pi}{2 \cdot \omega}:$$

$$(E)_m \cdot \sin\left(\omega \cdot \frac{\pi}{2 \cdot \omega} - \varphi\right) = E_{1m} \cdot \sin\left(\omega \cdot \frac{\pi}{2 \cdot \omega} - \varphi_1\right) + E_{2m} \cdot \sin\left(\omega \cdot \frac{\pi}{2 \cdot \omega} - \varphi_2\right)$$

$$(E)_m \cdot \cos\varphi = E_{1m} \cdot \cos\varphi_1 + E_{2m} \cdot \cos\varphi_2$$

$$(E)_m \cdot \sin\varphi = E_{1m} \cdot \sin\varphi_1 + E_{2m} \cdot \sin\varphi_2$$

$$(:) \quad (*)$$

$$(E)_m \cdot \cos\varphi = E_{1m} \cdot \cos\varphi_1 + E_{2m} \cdot \cos\varphi_2$$

$$tg\varphi = \frac{E_{1m} \cdot \sin\varphi_1 + E_{2m} \cdot \sin\varphi_2}{E_{1m} \cdot \cos\varphi_1 + E_{2m} \cdot \cos\varphi_2}$$

Squaring the relations (*):

$$(E)_m^2 \cdot \sin^2\varphi = E_{1m}^2 \cdot \sin^2\varphi_1 + E_{2m}^2 \cdot \sin^2\varphi_2 + 2 \cdot E_{1m}E_{2m} \cdot \sin\varphi_1 \cdot \sin\varphi_2$$

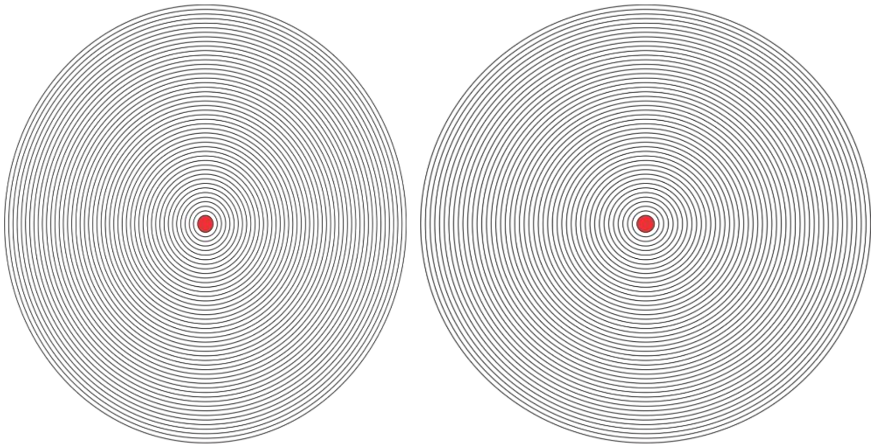
$$(E)_m^2 \cdot \cos^2\varphi = E_{1m}^2 \cdot \cos^2\varphi_1 + E_{2m}^2 \cdot \cos^2\varphi_2 + 2 \cdot E_{1m}E_{2m} \cdot \cos\varphi_1 \cdot \cos\varphi_2$$

$$(E)_m^2 \cdot \underbrace{\left(\sin^2\varphi + \cos^2\varphi\right)}_{=1} = E_{1m}^2 \cdot \underbrace{\left(\sin^2\varphi_1 + \cos^2\varphi_1\right)}_{=1} + E_{2m}^2 \cdot \underbrace{\left(\sin^2\varphi_2 + \cos^2\varphi_2\right)}_{=1} +$$

$$+ 2 \cdot E_{1m}E_{2m} \cdot \underbrace{\left(\sin\varphi_1 \cdot \sin\varphi_2 + \cos\varphi_1 \cdot \cos\varphi_2\right)}_{\cos(\varphi_2 - \varphi_1) = \cos\Delta\varphi}$$

$$(E)_m^2 = E_{1m}^2 + E_{2m}^2 + 2 \cdot E_{1m}E_{2m} \cdot \cos(\varphi_2 - \varphi_1)$$

The interference of two light waves



When the two waves overlap, two cases arise:

- in certain directions their energies are "constructively" composed (the resulting force is greater than the sum of the energies without superposition);
- in other directions their energies are "destructively" composed (the resulting force is less than the sum of the energies without superposition).

To form the interference picture (interference fringes), the emission from two sources must be "coherent".

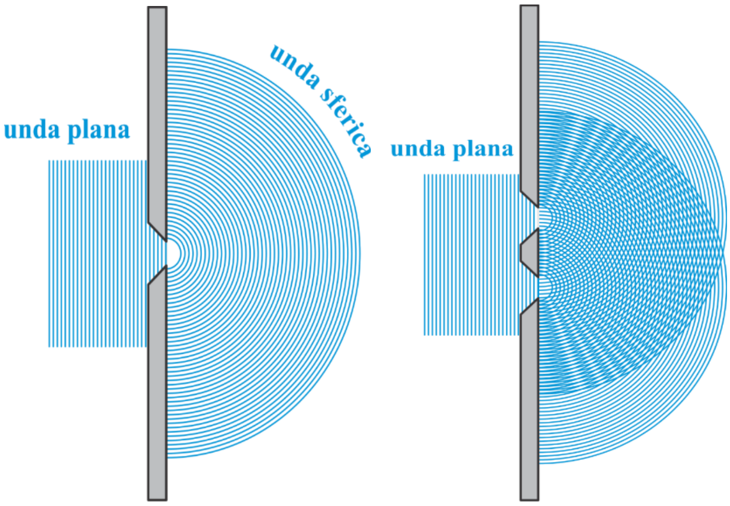
In the case illustrated, this condition is the simultaneity of the emission of the two sources.

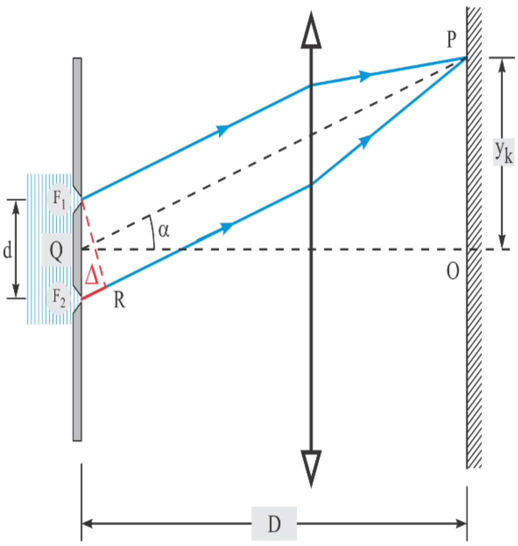
Depending on the direction of observation, we see “favoured” directions (high intensity) and “disadvantaged” directions (low intensity).

EXPERIMENTAL EVIDENCE OF INTERFERENCE. INTERFEROMETERS

Young experience

Two narrow, parallel and very close slits, illuminated by a common source, are two quasi-punctiform sources of the light wave.





The optical path difference between the two directions D

From the triangle $F_1 F_2 R$: $\Delta = d \cdot \sin\alpha$

Condition of maximum illumination at point P:

$\Delta = d \cdot \sin\alpha = k \cdot \lambda$ and $tg\alpha = \dfrac{y_k}{D}$

From triangle OPQ: $y_k = D \cdot tg\alpha$

If a < 3 ^{o}, then $tg\alpha \approx \sin\alpha$

We have : $y_k = D \cdot \dfrac{k \cdot \lambda}{d}$

y_k is the "y" axis of maximum illumination of order "k"

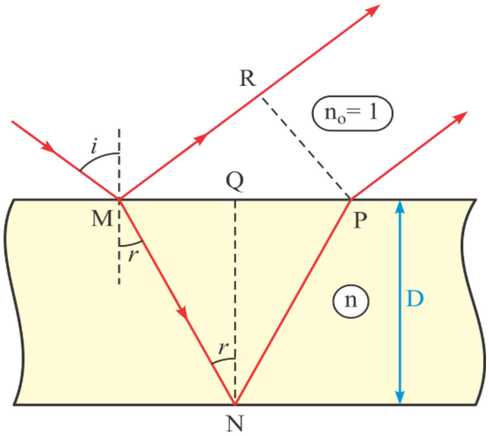
The distance between two consecutive maximum values:

"interfringe, i = $y_{k+1} - y_k$

$$i = y_{k+1} - y_k = D \cdot \frac{\lambda \cdot (k+1)}{d} - D \cdot \frac{\lambda \cdot k}{d}$$

$$i = D \cdot \frac{\lambda}{d}$$

INTERFERENCE ON THE PLANE-PARALLEL PLATE



- The Geometric Path (MN) corresponds to the optical path [MN] = n•(MN)
- The Geometric Path (NP) corresponds to the optical path [NP] = n•(NP)
- The Geometric Path (MR) corresponds to the optical path $[MR] = (MR) - \frac{\lambda}{2}$

The optical path difference, Δ, is: $\Delta = n \cdot (MN + NP) - \left(MR - \frac{\lambda}{2}\right)$

$$\Delta = \frac{2 \cdot n \cdot D}{\cos r} - 2 \cdot D \cdot tgr \cdot \sin i + \frac{\lambda}{2}$$

But $\sin i = n \cdot \sin r$ then:

$$\Delta = \frac{2 \cdot n \cdot D}{\cos r} - 2 \cdot D \cdot \frac{\sin r}{\cos r} \cdot \sin i + \frac{\lambda}{2}$$

$$\Delta = \frac{2 \cdot n \cdot D}{\cos r} - 2 \cdot D \cdot \frac{\sin r}{\cos r} \cdot n \cdot \sin r + \frac{\lambda}{2}$$

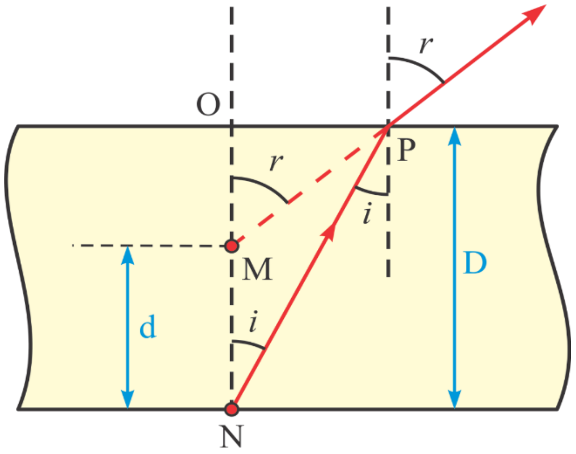
$$\Delta = \frac{2 \cdot n \cdot D}{\cos r} \cdot \left(1 - \sin^2 r\right) + \frac{\lambda}{2}$$

$$\Delta = \frac{2 \cdot n \cdot D}{\cos r} \cdot \cos^2 r + \frac{\lambda}{2}$$

$$\Delta = 2 \cdot n \cdot D \cdot \cos r + \frac{\lambda}{2}$$

Condition for maximum interference: $2 \cdot n \cdot D \cdot \cos r + \frac{\lambda}{2} = k \cdot \lambda$

CHAULNES METHOD: MEASUREMENT OF THE REFRACTIVE INDEX OF TRANSPARENT PLATES WITH PARALLEL FACES



d = D - OM

$$Din\ \ \Delta MOP \Rightarrow\ OM = \frac{OP}{tg\,r} \ \Rightarrow\ d = D - D\cdot\frac{tg\,i}{tg\,r} = D\cdot\left(1-\frac{tg\,i}{tg\,r}\right)$$

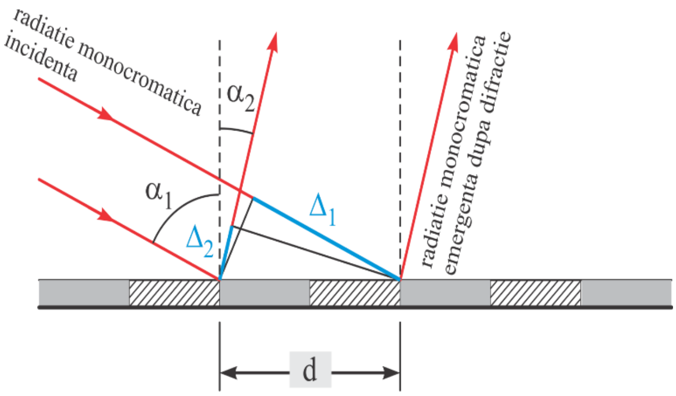
$$Din\ \ \Delta NOP \Rightarrow\ OP = D\cdot tg\,i$$

If the direction of observation is closer to the normal surface (ON), then we have: $\frac{tg\,i}{tg\,r} \approx \frac{\sin i}{\sin r} = \frac{1}{n}$

$$d = D\cdot\left(1-\frac{1}{n}\right)$$

The refractive index of the plate is calculated with the formula: $n = \frac{D}{D-d}$

Interference ("diffraction") produced by an optical grating (special reflection)



The diffraction grating in reflection: the reflective and opaque parts are alternated.

d = lattice constant

The optical path difference, "D", between two waves incident at points at distance "d" from each other is:

$$\Delta = \Delta_1 - \Delta_2 = d \cdot (\sin \alpha_1 - \sin \alpha_2)$$

The condition for maximum interference in the direction of emergence is:

$$\Delta = k \cdot \lambda$$

$$d \cdot (\sin \alpha_1 - \sin \alpha_2) = k \cdot \lambda$$

$$(k = \ldots, -2, -1, 0, 1, 2, \ldots)$$

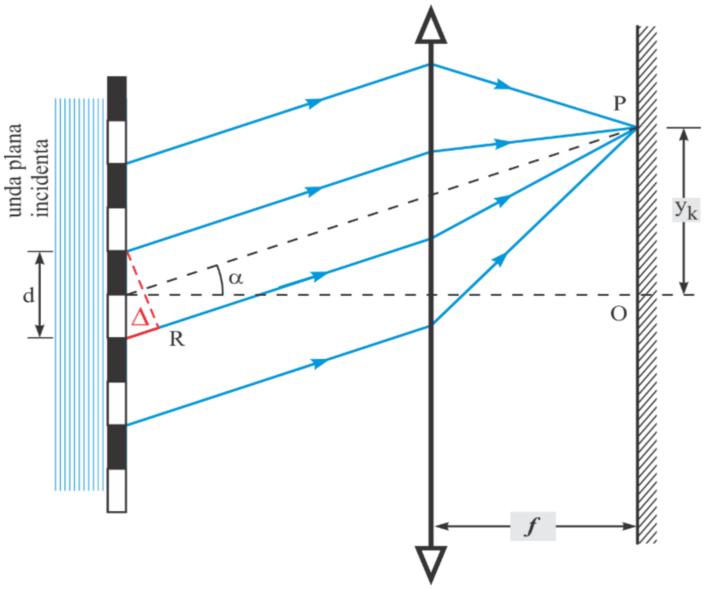
Or

k = 0: maximum of zero order

k = 1: maximum of order 1

- - - - -- - - etc - - - - -

The diffraction grating as a transparent medium



The condition that the maximum interference value of order "k" at point "P" of the screen is displayed is: $\Delta = k \cdot \lambda$

$$\sin \alpha = \frac{\Delta}{d} = \frac{y_k}{D}$$

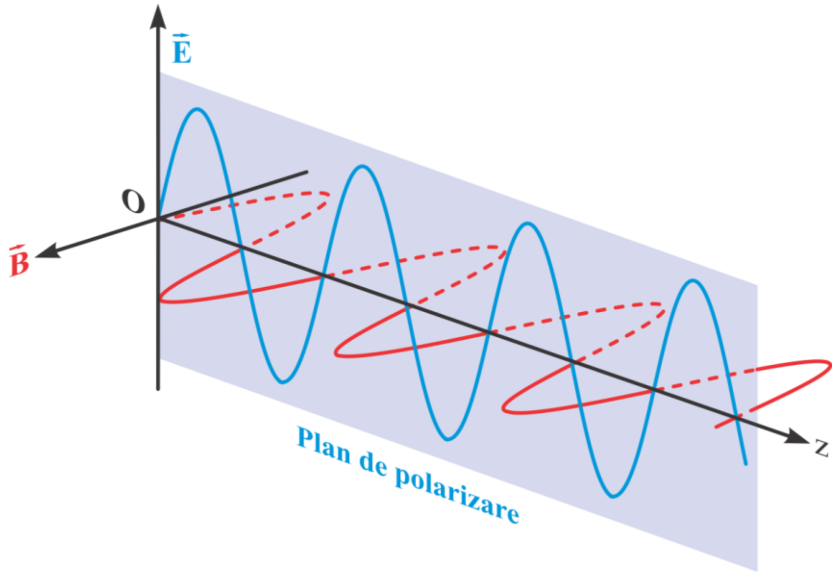
$$y_k = k \cdot \lambda \cdot \frac{D}{d}$$

"D" represents the distance between the grating and the screen (if the lens is very close to the grating, then D ≈ f)

The interfranje "i" is y_{k+1} - y_k : $i = (k+1) \cdot \lambda \cdot \frac{D}{d} - k \cdot \lambda \cdot \frac{D}{d} = \lambda \cdot \frac{D}{d}$

For all wavelengths an interference maximum (maximum of zero order) forms in the middle of the screen ($y_k = 0$).

THE STATE OF POLARIZATION OF THE LIGHT WAVE



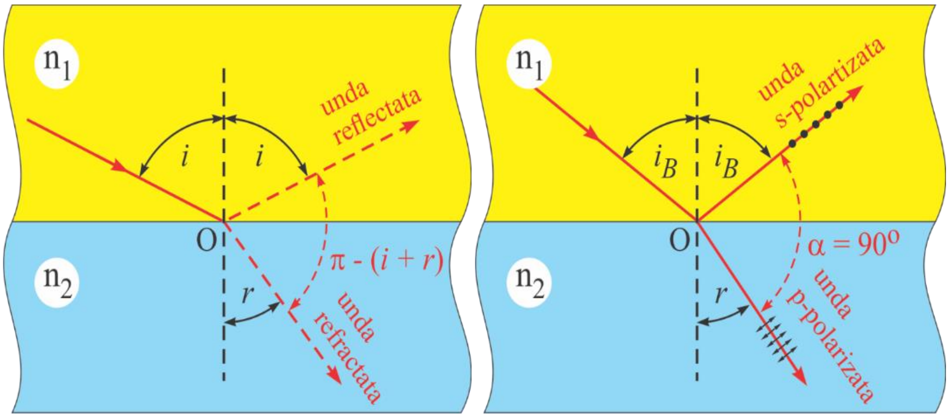
In general, a wave which propagates in a medium, can be associated with oscillations produced in the direction of propagation (longitudinal waves) or in the direction perpendicular to the direction of propagation (transverse waves).

In the case of electromagnetic waves (thus in the case of light waves too), the electric field and magnetic field vectors oscillate in directions perpendicular to the direction of propagation (the light wave is transverse).

The plane where the electric field vector oscillates defines the "plane of polarization" of the wave.

If during wave propagation the orientation of the plane of polarization does not change, then the light wave is linearly polarized (in the wave plane). In other circumstances, the light wave may be circularly polarized or elliptically polarized.

THE PLANE-POLARIZED OR LINEARLY POLARIZED LIGHT WAVE



The unpolarized light wave, incident at the surface of separation between two media, is partially reflected, partially refracted (with one exception: the condition of total reflection)

If reflection/refraction occurs at the surface of a dielectric medium and the angle of incidence has a special value (iB, Brewster's angle), then the directions of propagation of the reflected and refracted waves are perpendicular and both Emerging waves are linearly polarized (or in a plane).

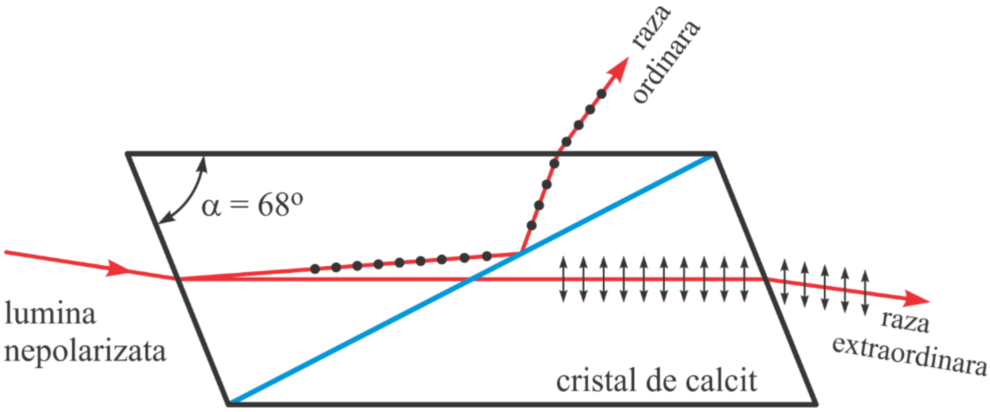
The polarization condition of the emerging waves: the direction of propagation of the reflected wave and the direction of propagation of the refracted wave are perpendicular to each other:

$$\frac{n_2}{n_1} = \frac{\sin i_B}{\sin\left(\frac{\pi}{2} - i_B\right)} = \frac{\sin i_B}{cos i_B} = tg i_B$$

The direction of oscillation of the electric field vector of the reflected wave is perpendicular to the plane defined by the directions of incidence and emergence (polarized wave S). The direction of oscillation of the electric field vector of the refracted wave is parallel to the plane defined by the directions of incidence and emergence (polarized wave p).

The S-polarized wave is totally polarized and the p-polarized wave is partially polarized.

The polarization of light using the *Nicol prism* (*William Nicol* – 1828)



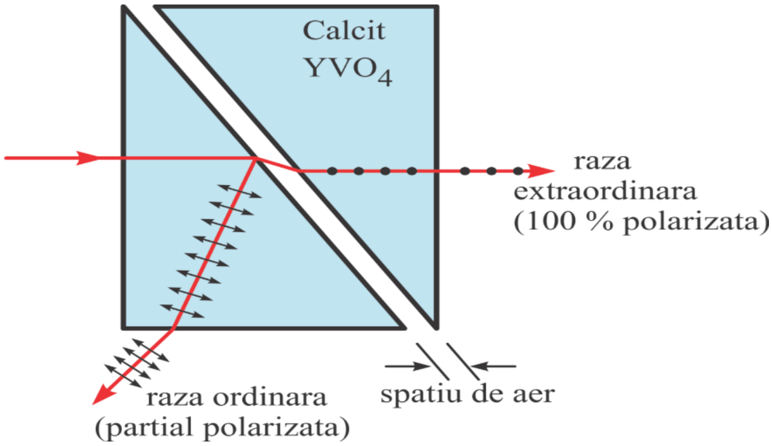
Calcite crystal (A variety of $CaCO3$) indicates the phenomenon of birefringence

The incident ray, non-polarized, splits inside the crystal into two components (the ordinary ray and the extraordinary ray); they follow two different paths. At the crystal-Canada turpentine (Canada balsam or fir gum) interface (nbc = 1.55) the two components behave differently: the ordinary ray (n0 = 1.658) undergoes total reflection at the crystal- Canada turpentine, while the extraordinary ray (ne = 1.486) passes through the Canada balsam layer.

$n_o > n_{bc}$ (total reflection)

$n_e < n_{bc}$ (refraction)

THE POLARIZATION OF LIGHT USING THE *GLAN–FOUCAULT PRISM*



benefits:

- From the construction point of view, it is shorter than other devices;
- It can be used at high intensity radiation (lasers)

inconvenience:

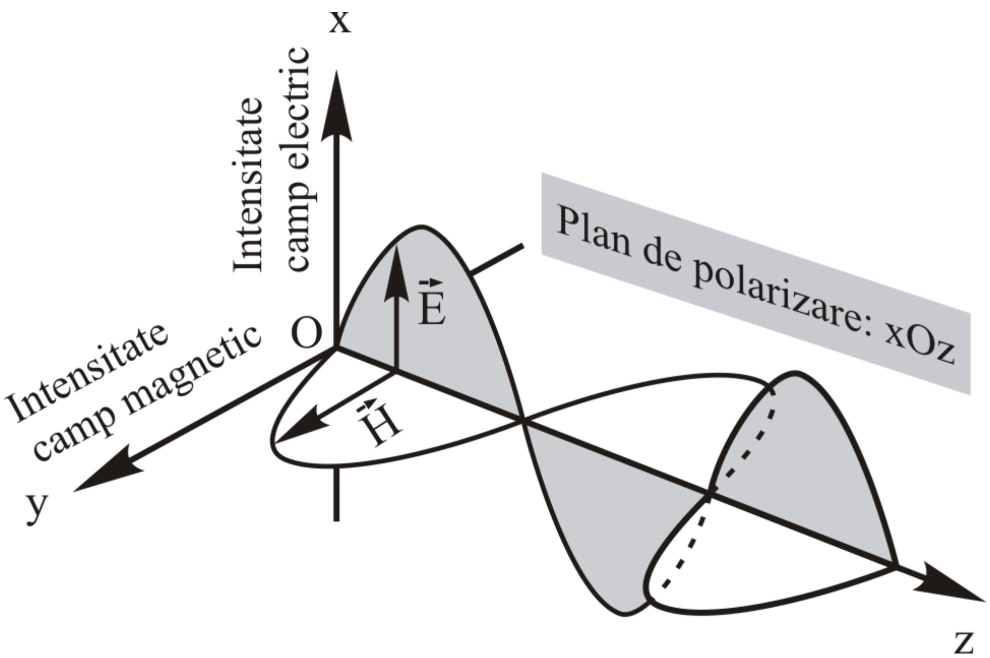
- Claims about the angle of incidence

The two calcite crystals are not glued with Canada balsam, but between them there is an air space. By this, it is more resistant to a high temperature, it is qualitatively superior and useful to assemblies with radiation of the laser type. It is more advantageous from the point of view of energy efficiency. A particularly advantageous (but expensive) material is the crystal of yttrium orthovanadate (YVO4).

Applications of polarized light

- In chemistry: in the study of aspects of stereochemistry, in the characterization of molecules of chiral drugs; in the study of chiral substances in circularly polarized light (circular dichroism spectroscopy)
- In technique: as a method of visualizing mechanical stresses and optical inhomogeneities in the structure of transparent materials; liquid crystal displays.
- In crystallography: in the study of crystals using the microscope in polarized light.
- In certain three-dimensional visualization techniques.
- In the photographic technique: shaping the quality of the images obtained.
- In geology: identify certain types of minerals.

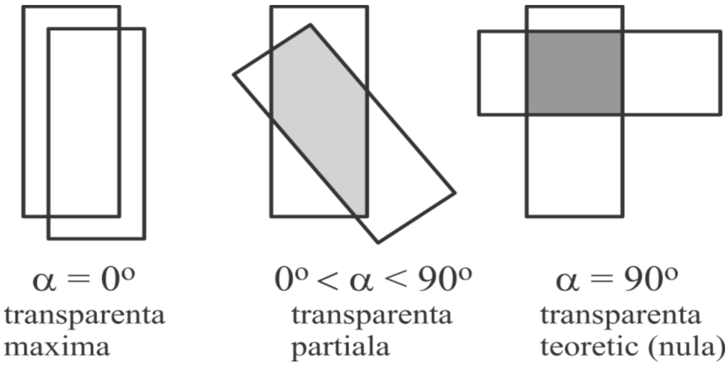
Special use of polarized light in the field of pharmaceutical chemistry – polarimetry



The set of vectors: magnetic field strength and electric field strength is “chiral“.

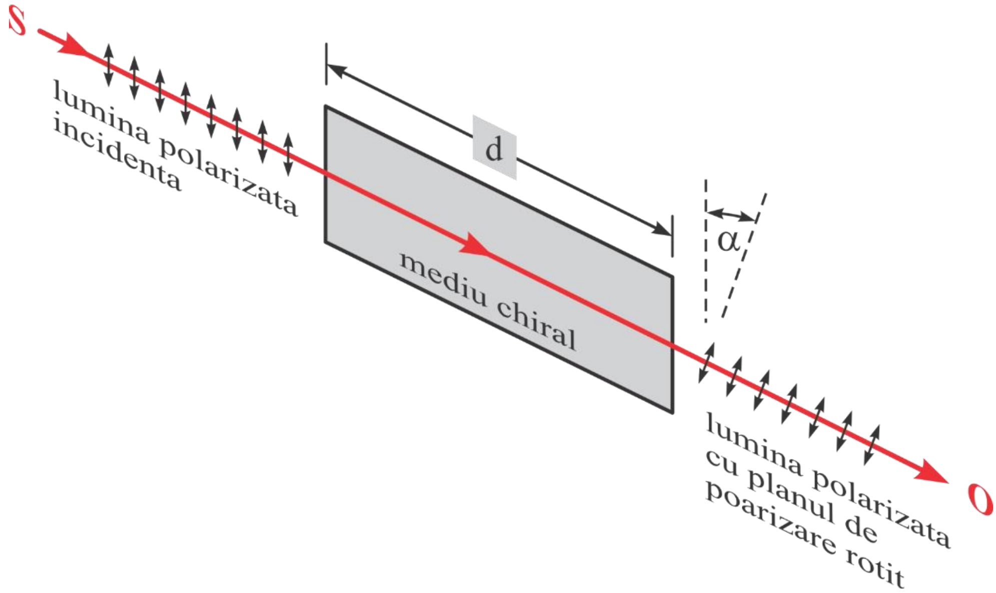
Optical activity: the rotation of the plane of oscillation of the vector E around the direction of propagation (the z axis).

Special use of polarized light in the field of pharmaceutical chemistry – polarimetry



Pour solutions : $\alpha = [\alpha]_D^{20} \cdot c \cdot d$

Pour liquides : $\alpha = [\alpha]_D^{20} \cdot \rho \cdot d$



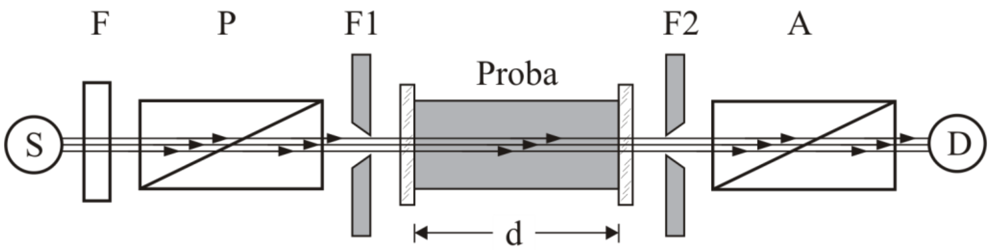
The angle of rotation is variable according to:

-the wavelength of the incident light (I)

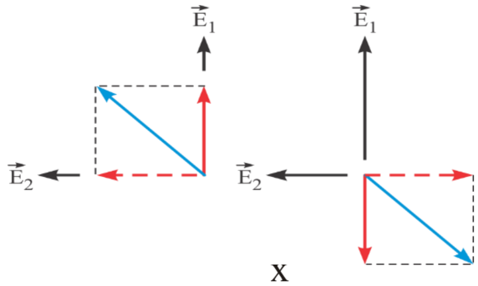
- The nature of the chiral substance (its own power of rotation, also called "specific rotational power" [a]).

- The thickness of the chiral material (d), crossed by the polarized light.

- The temperature of the chiral material.

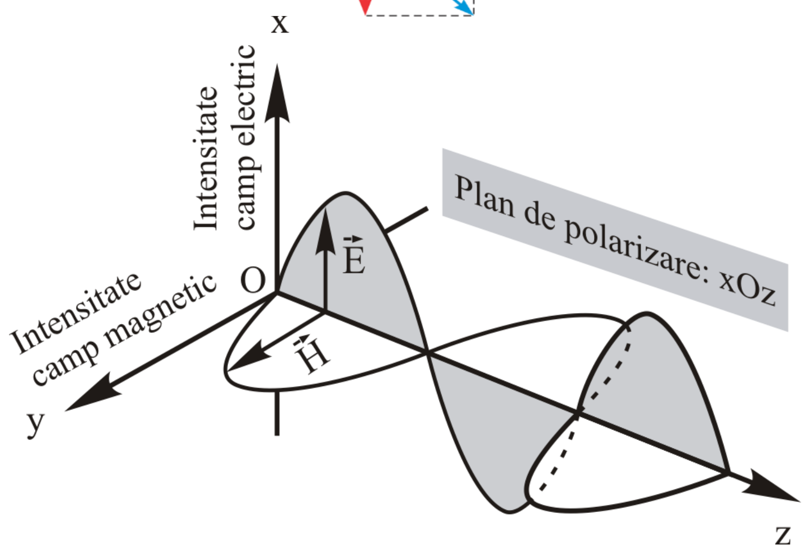


Details for the construction of a conventional polarimeter (l): the resonance radiation of Na vapors - 589.3 nm



The transformation of linearly polarized light into circularly polarized light

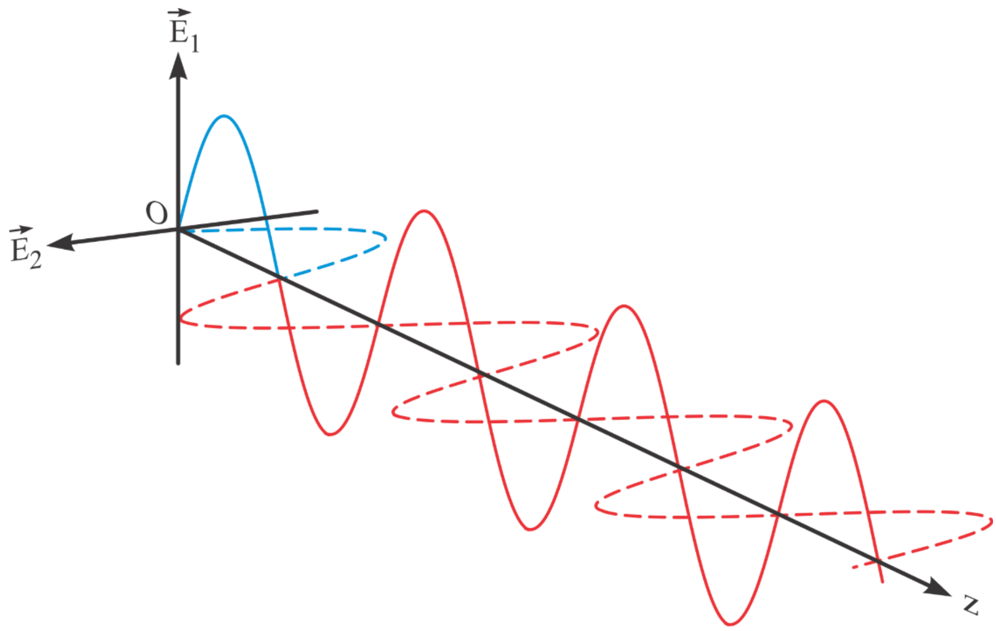
The set of vectors: magnetic field strength and electric field strength is “chiral“.



Optical activity: the rotation of the plane of oscillation of the vector E around the direction of propagation (axis z).

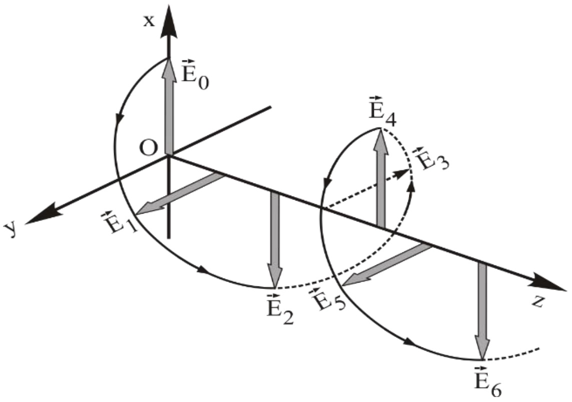
Two light waves at the same wavelength, in the same phase, have perpendicular planes of polarization.

Only the trajectories of the extremity of the electric field vectors are represented there.



The vector sum of the intensities of the electric fields is, in each moment, a wave always linearly polarized (result: a linearly polarized wave).

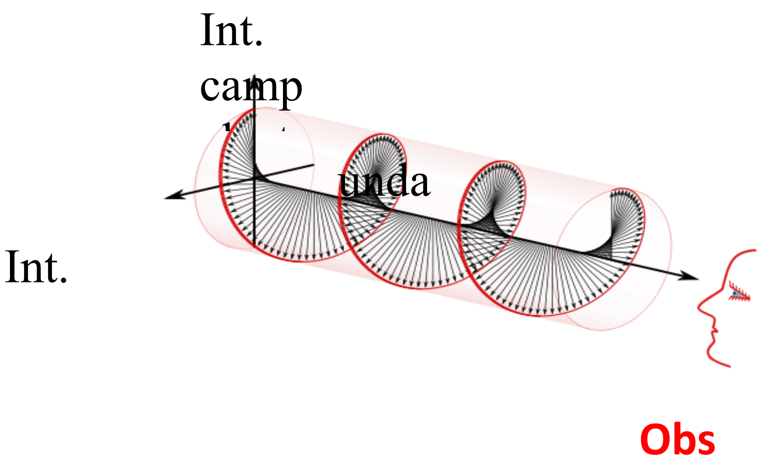
Two light waves, at the same wavelength, but at a phase difference of a quarter wave, have perpendicular planes of polarization. The vector sum of the electric fields at each moment generates a rotation vector whose extremity describes a helical path (result: the circularly polarized wave).



Circularly polarized radiation is chiral.

- Two rays polarized in a plane, at perpendicular planes of polarization
- A radiation is delayed by a quarter of the wavelength
- The superposition of two radiations generates a circularly polarized radiation.

The circularly polarized wave can have two directions of rotation: the dextrorotatory direction and the levorotatory direction.



The circularly polarized wave can have two directions of rotation: the dextrorotatory direction and the levorotatory direction.

OPTICAL ABSORPTION SPECTROMETRY

ABSORPTION SPECTROPHOTOMETRY IN THE ULTRAVIOLET RANGE AND IN THE VISIBLE RANGE

Basic methods:

The measurement of the energy variables of monochromatic radiation as it passes through a sample layer, as a function of a wave variable of the radiation.

Wave Variables:

the wavelength (l) (nm)

the wave number (n ~) (cm-1)

Frequency (f) (Hz)

propagation speed (v)

Energy Variables:

energy flow (F)

radiation intensity (I)

transmission (T) (transmission factor)

transmission (transmittance) in percentage (T%)

absorbance (A)

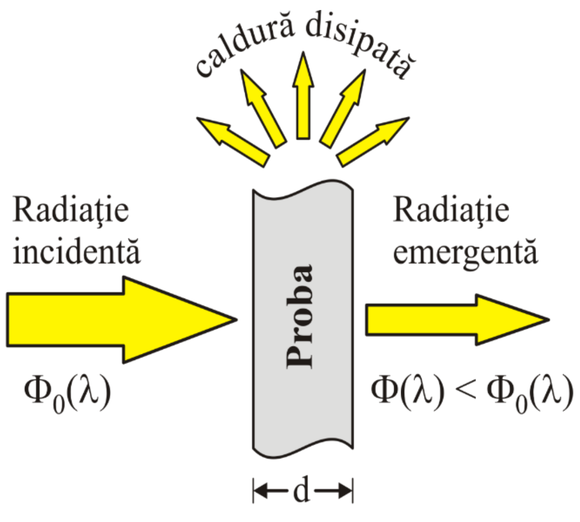
Relationship between wave variables:

$$v = \lambda \cdot f \quad ; \quad \tilde{v} = \frac{1}{\lambda}$$

Spectral domains of analytical interest

Conventional name	Domain limits (under a vacuum)		Molecular (atomic) level event involved in interaction with radiation
	n ~ (cm -1)	l(nm)	
Vacuum Ultraviolet (UV)	> 52600	< 190	Electronic transitions in molecules (atoms)
Ultraviolet (UV)	52600 – 26300	190 – 380	
Visible (VIS)	26000 – 13300	380 – 750	
near infrared (NIR)	13000 – 4000	750 – 2500	Molecular vibrational transitions, crystal lattice vibrational or rotational molecular transitions
mid-infrared(IR)	4000 – 200	2500 – 50000	
Infrared removed(FIR)	< 200	> 50000	

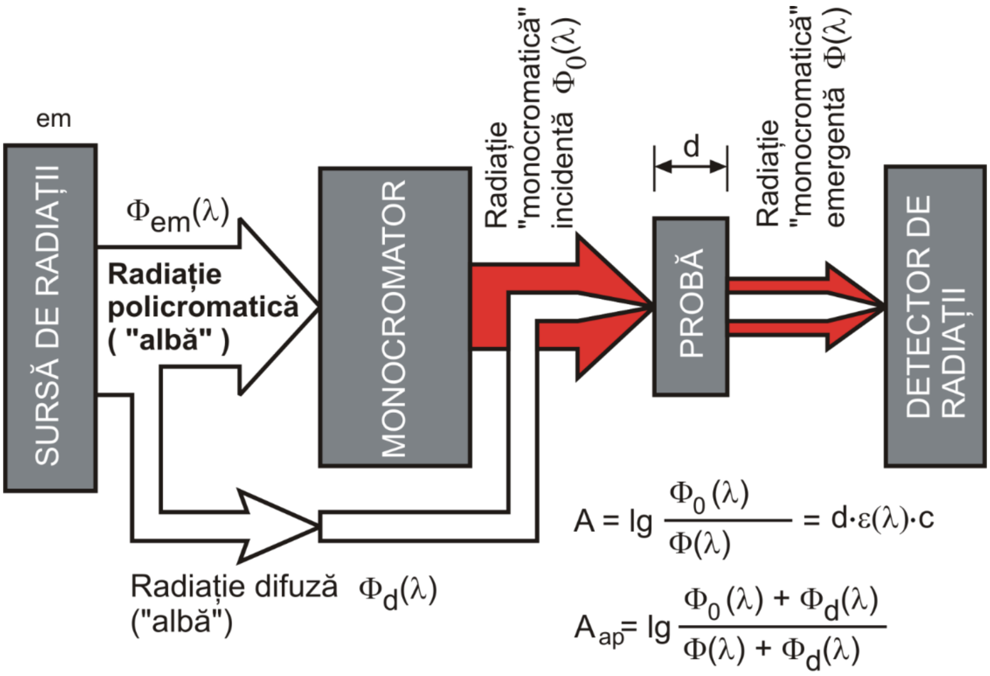
Definition of energy values (variables) characteristic of optical absorption



$$T(\lambda)=\frac{\Phi(\lambda)}{\Phi_0(\lambda)} \quad ; \quad T\%(\lambda)=\frac{\Phi(\lambda)}{\Phi_0(\lambda)}\cdot 100 \quad ; \quad A(\lambda)=\lg\frac{\Phi_0(\lambda)}{\Phi(\lambda)}$$

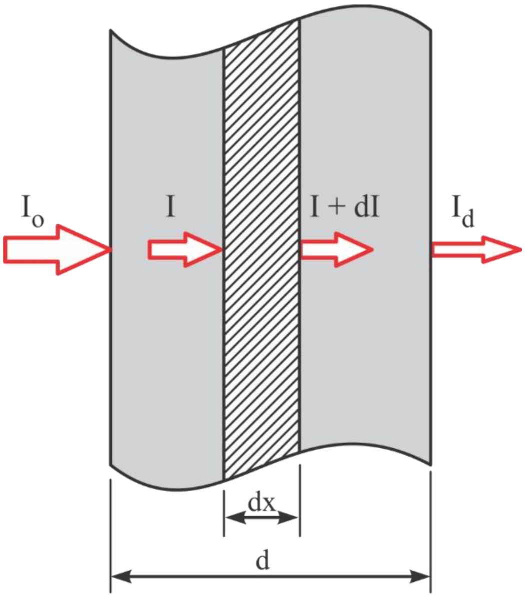
$$A(\lambda)=-\lg T(\lambda)=2-\lg T\%(\lambda)$$

Aspects concerning the construction and particularities of operation of an absorption spectrophotometer (single beam)



light absorption

– *Lambert–Beer relationship*



$$dI = -k \cdot I \cdot dx$$

k: absorbance constanta

$$\frac{dI}{I} = -k \cdot dx$$

$$\int_{I_0}^{I} \frac{dI}{I} = -k \cdot \int_0^d dx$$

$$\ln I - \ln I_o = -k \cdot d$$

$$\ln \frac{I}{I_o} = -k \cdot d$$

$$\frac{I}{I_o} = e^{-k \cdot d}$$

$$I = I_o \cdot e^{-k \cdot d}$$

$$\ln \frac{I_o}{I} = k \cdot d$$

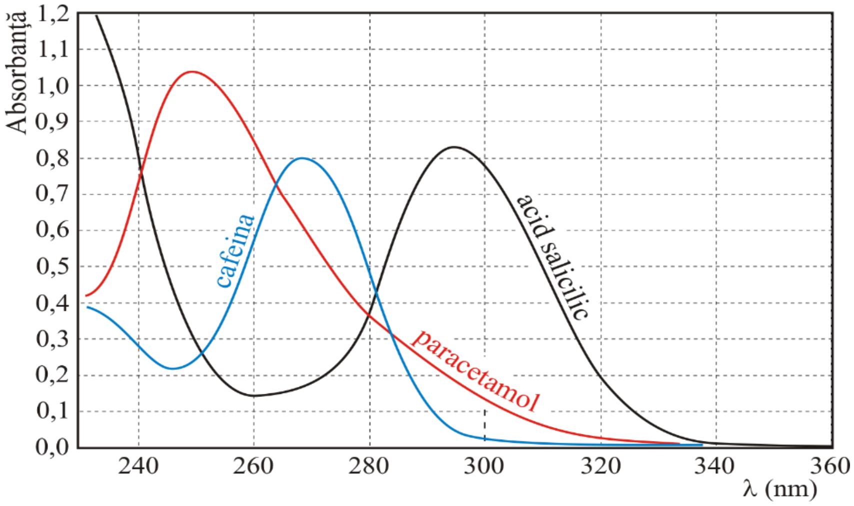
$$A = \log \frac{I_o}{I} = k' \cdot d$$

The Absorbance is directly proportional to the thickness of the medium crossed. *(Bouguer–Lambert–Beer law*)

Characterization of chemical solutions using the absorption spectrum

Examples:

Absorption spectra in the ultraviolet range of caffeine, paracetamol and salicylic acid in aqueous solution.



13.MODEL OF QUESTIONS FOR THE EXAM

1. Which of the following statements regarding continuous current intensity are true?

Amperage. . .

To). . . is equal to the amount of electric charge carried by the diameter per unit time.

b). . . is equal to the amount of electric charge carried by the unit section of the conductor per unit time.

vs). . . is expressed in the International System of Units (SI) in Coulomb/second

d). . . is expressed in the International System of Units (SI) in amperes (A).

e). . . is a vector quantity.

Answer: a),c), d)

2. Which of the following statements regarding the electrostatic lines of an electric charge are true?

a) two different field lines intersect in at least two points.

b) the field lines from a positive point of charge make sense to the electric charge.

c) field lines from a positive point of charge make sense to the electric charge.

d) the electrostatic field lines are closed loops.

e) electrostatic field lines are not closed loops

Answer: c), e)

3. Explain the semnifications of Kirchoff's laws made for a DC circuit?

a) Kirchhoff's first law expresses the relationship between the current in the circuit branches that respond to a node.

b) Kirchoff's second law expresses the relationship between the current in the circuit branches which respond to a node.

c) Kirchhoff's first law refers to the algebraic sum of the voltages in an eye (loop) circuit.

d) Kirchoff's second law relates to the algebraic sum of the voltages in an eye (loop) circuit.

e) Kirchhoff's first law refers to the power dissipated in a circuit resistance.

Answer: a), d)

4. Express Faraday's law of electrolysis of an electrolyte?

a) The mass of the substance transported to the cathode is equal to the mass of the materials transported to the anode.

b) The mass of matter transported to the cathode is directly proportional to the electric current.

c) at constant current intensity, the mass of the substance transported to the cathode is directly proportional to the duration of the electrolysis.

d) At a constant current intensity, the mass of the substance transported to the cathode during electrolysis is inversely proportional.

e) At a constant current intensity, the mass of the substance transported to the electrolysis of the cathode is proportional to the square of the length.

Answer: b), c).

5. The magnetic induction inside the solenoid depends on . .

To). . .the intensity of the electric current through the coils.

b). . . the density of the interior of the solenoid.

vs). . . Number of magnetic coils.

d). . . wound length of the coil.

e). . . the permeability of the environment in the solenoid.

Answer: a),c), d), e).

6. The Lorentz force acting on a crossed linear DC conductor depends on . .

To). . . the density of the material it is made of wire.

b). . . the cross-sectional area of the conductor.

vs). . . the length of the linear conductor located in the magnetic induction.

d). . . the intensity of the electric current in the field

e). . . the angle between the linear conductor and the magnetic field lines.

Answer: c), d), e).

7. Which of the following statements are true?

a) the magnetic flux through a surface is a scalar.

b) The direction of the self-induced current in a solenoid at the circuit break is opposite to the current from the solenoid which passed through the solenoid before breaking the circuit.

c) the energy of the magnetic field generated in the solenoid depends on the density of the material inside the solenoid.

d) The energy of the magnetic field generated in a solenoid is directly proportional to the logarithm of the intensity of the current of the solenoid.

e) ratio between the actual intensity and the maximum intensity of the alternating current is 0.707

Answer: a), b), e).

8. Which theories explain electrical phenomena?

a) the theory of action at a distance

b) contiguous action theory

c) the relativistic theory of electromagnetic phenomena

d) archimedes theory

e) load theory

answer: a), b), c)

9. Which of the following statements regarding distributions of electric charges are true?

a) Coulomb is a quantity with fundamental unit of measurement in SI

b) Linear distribution $\lambda$of electric charge is the distributed charge per unit length

c) Distribution superficial σ of the electric charge is the charge distributed per unit area

d) Volume ρdistribution electric charge is the charge distributed per unit volume

e) In Coulomb's law it is not about the interaction of the punctiform charge

Answer: b) , c), d).

10. Which of the following statements regarding **Coulomb's law** are true?

a) $dq = \lambda dl$

b) $dq = \rho dV$

c) $\vec{F} = \frac{q_0}{4\pi\varepsilon_0}\int \lambda \frac{dl}{r^2}\vec{n}$

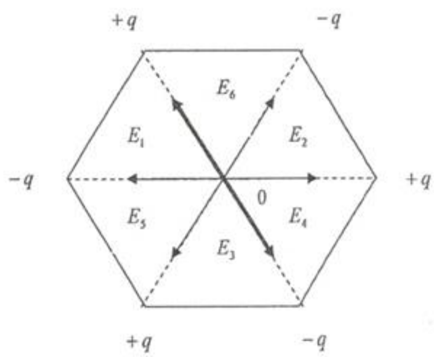
d) $\vec{F} = \frac{q_0}{4\pi\varepsilon_0}\int \sigma \frac{dS}{r^2}\vec{n}$

e) $\vec{F} = \frac{q_0}{4\pi\varepsilon_0}\int \rho \frac{dV}{r^2}\vec{n}$

Answer: c), d), e).

11. In the peaks of a regular hexagon of side l = 30 cm are placed in the air, in different ways, three identical positive charges and three identical negative charges q = 4pC. Find the electric field strength in the center of the hexagon.

a) $\vec{E} = 0$



b) $\vec{E} = 2\vec{i} + 3\vec{j} + 5\vec{k}$

c) $\vec{E} = 20\vec{i} + 30\vec{j} + 50\vec{k}$

d) $\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \vec{E}_4 + \vec{E}_5 + \vec{E}_6$

e) $\vec{E} = 8\vec{i} + 9\vec{j} + 10\vec{k}$

Answer:a), d).

12. **The equivalent electrical capacitance of a set of capacitors is:**

a) For capacitors connected in series: $U = U_1 + U_2 + U_3 + \cdots$

b) For capacitors connected in parallel: $C_P = C_1 + C_2 + C_3 + \cdots$

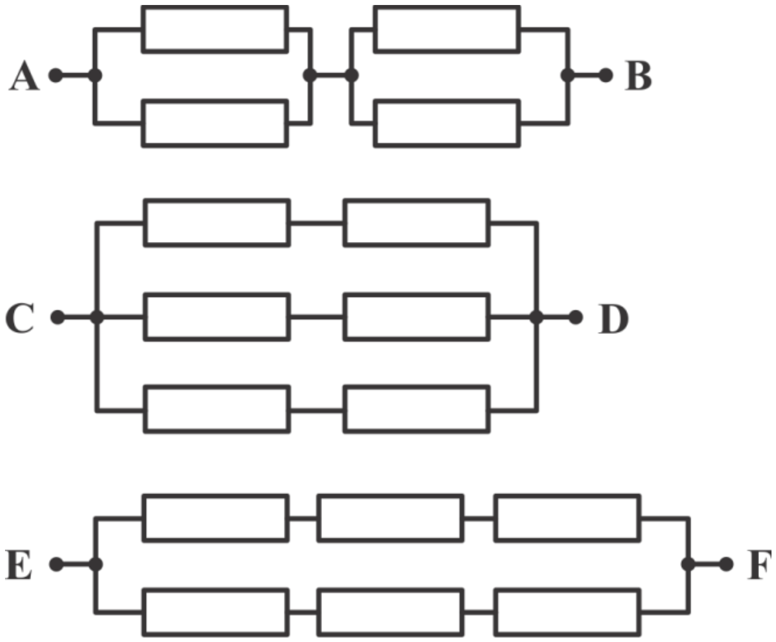
c) For capacitors connected in series: $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$

d) For capacitors connected in parallel: $Q = Q_1 + Q_2 + Q_3 + \cdots$

e) For capacitors connected in parallel: $C_P \cdot U = C_1 \cdot U + C_2 \cdot U + \cdots$

Answer: b), c)

3. In the figures below are the identical resistors grouped into three configurations. The equivalent resistor configurations are: RAB, RCD and REF. What is the decreasing order of these equivalent resistances?



a) $R_{AB} > R_{CD} > R_{EF}$

b) $R_{EF} > R_{CD} > R_{AB}$

c) $R_{CD} > R_{AB} > R_{EF}$

d) $R_{EF} > R_{AB} > R_{CD}$

e) $R_{AB} > R_{EF} > R_{CD}$

Answer: d)

14. **the electrical capacitance of a capacitor is:**

a) $C = \varepsilon_0 \cdot \varepsilon_r \cdot \frac{S}{d}$

b) $C = \frac{Q}{U_{1,2}}$

c) $U_{1,2} = V_1 - V_2$

d) $V_1 = \frac{Q}{4 \cdot \pi \cdot \varepsilon \cdot r_1}$;

e) $V_2 = \frac{Q}{4 \cdot \pi \cdot \varepsilon \cdot r_2}$

Answer: a), b)

15. The Resistance equivalent to a set of resistors is:

a) For resistors in series: $R_s = \sum_{i=1}^{n} R_i$

b) For resistors in parallel: $\frac{1}{R_p} = \sum_{i=1}^{n} \frac{1}{R_i}$

c) $U_{AB} = I \cdot R = I_A \cdot (R + R_A)$

d) $I = I_A \cdot \left(1 + \frac{R_A}{R}\right)$

e) $C = \frac{Q}{U_{1,2}}$

Answer: a),b)

16*. Write **Ohm's law for the entire circuit :**

a) $I = \frac{E}{R+r}$; b) $I_0 = \frac{E}{r}$; c) $I = \frac{U_{AB}}{R}$; d) $I = U_V \cdot \left(\frac{1}{R} + \frac{1}{R_V}\right)$; d) $I = I_A \cdot \left(1 + \frac{R_A}{R}\right)$

Answer: a),

17. Which of the following statements are true?

a) The heat dissipation (Q_R) on R of external resistance in time t: Q=UIt

b) The power dissipated (P_R) on the external resistance R: $P_R = I^2$

c) The power dissipated (P_{R+r}) on the complete circuit: $P_{R+r} = \frac{Q_{R+r}}{t} = E \cdot I = \frac{E^2}{R+r}$

d) The power dissipated (P_{R+r}) on the complete circuit: $P_{R+r} = \frac{Q_{R+r}}{t} = E \cdot I = \frac{E^2}{R+r}$

e) The power dissipated (P_R) on the external resistance R: $P_R = U^2$

Answer: a), c), d).

18. Write the formula for **the Lorentz force:**

a) The vector form: $\vec{f} = q\vec{v}x\vec{B}$

b) The scalar form: F=qvB

c) $T = \frac{2\pi}{\omega}$

d) $\omega = \frac{qB}{m}$

e) $T = \frac{2\pi}{\omega} = \frac{2\pi}{q.B} m$

Answer: a), b).

19. Which of the following statements are true?

a) the magnetic induction in the center of a circular conductor (of radius R): $B = \mu_0 \cdot \mu_r \cdot \frac{I}{2 \cdot R}$

b) Magnetic induction inside a solenoid: $B = \mu_0 \cdot \mu_r \cdot \frac{I \cdot N}{l}$

c) the Lorentz force is : $\frac{m \cdot v^2}{R}$

d) the centrifugal force is: qvB

e) In a magnetic field, the forces are: $\frac{m \cdot v^2}{R} = q \cdot v \cdot B$

Answer: a), b), e).

20*. Write down Ohm's law for an entire circuit:

A. $I = \frac{E}{R + r}$;

B. $I_0 = \frac{E}{r}$;

C. $I = \frac{U_{AB}}{R}$;

D. $I = U_V \cdot \left(\frac{1}{R} + \frac{1}{R_V} \right)$;

E. $I = I_A \cdot \left(1 + \frac{R_A}{R} \right)$

Answer:**A.**

21*. The following statements are true:

A. The determination of viscosity is done by the Stokes' law procedure

B. The viscosity of many lyophilic colloids obeys Archimedes' law

C. When a solid, spherical particle of radius r advances with velocity v in a liquid of viscosity η, a force F of resistance (internal friction), opposite to the force of the liquid, is produced, having the magnitude: F=6mη

D. The viscosity of the cytoplasm does not vary during cell division

E. The cytoplasm is formed from non-fibrillar molecules of the oncoplasmic reticulum in which a sol is located.

Answer:: A)

22*. The following statements are true:

A.The sound level Ns of a sound is defined by : $N_s = \log \frac{I}{I_m}$

B.The sound level Ns of a sound is defined by Ns= p/pm

C.The lower hearing threshold decreases with age,

D.The lower hearing threshold decreases when the ear is exposed to noise for a long time.

E.The energy corresponding to ordinary sounds is very high.

Answer: A

23*. The thin lens approximation is written :

A. $\frac{1}{f} = (n-1) \cdot \left[\frac{1}{R_1} - \frac{1}{R_2} - \frac{(n-1) \cdot d}{n \cdot R_1 \cdot R_2} \right]$

B. $\frac{1}{f} \approx (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2} \right)$

C. $\frac{1}{f} = \frac{1}{x_i} - \frac{1}{x_o}$

D. $f = \frac{R}{2}$

E. $\frac{1}{x_F} = \frac{2}{R} \cdot \frac{\cos i}{2 \cdot \cos i - 1} \approx \frac{2}{R}$

Answer B

24*.In the case of the Doppler effect studied in sounds it can be said that if the source is at rest with respect to the medium, the observer approaches the source with velocity "v" with respect to the medium, the propagation velocity in the medium of the wave emitted by the source is "c", the frequency f recorded by the observer approaching the source with velocity v, the source has its own emission frequency fo, is :

A. $f = f_0 \left(1 + \frac{v}{c}\right)$

B. $f = f_0 \left(1 - \frac{v}{c}\right)$

C. $T = T_0 \left(1 + \frac{v}{c}\right)$

D. $T = T_0 \left(1 - \frac{v}{c}\right)$

E. $T = T_o \cdot \frac{v}{c} \cdot T$

Answer:A.

25*.The following questions about radiopharmaceuticals are true:
A. Radiopharmaceuticals or radiocompounds are a group of drugs that contain radioactive isotopes
B. Radiopharmaceuticals cannot be used as diagnostic and therapeutic agents.
C. Radiotracers cannot be used for the diagnosis of dysfunction in body tissues.
D. All medical isotopes are radioactive,
E. Radiopharmaceuticals are recently introduced to the market

Answer:A

26. Equivalent resistance when connected to resistors is:

A. $R_s = \sum_{i=1}^{n} R_i$

B. $\frac{1}{R_p} = \sum_{i=1}^{n} \frac{1}{R_i}$

C. $U_{AB} = I \cdot R = I_A \cdot (R + R_A)$

D. $I = I_A \cdot \left(1 + \frac{R_A}{R}\right)$

E. $C = \frac{Q}{U_{1,2}}$

Answer **: A,B.**

27. Which of the following statements are true?

A. $\Delta S = S_2 - S_1 = k \ln \frac{I_2}{I_1}$

B. The frequency of mechanical waves capable of impressing the human ear are between 16 and 20 000 Hz.
C. Vibrations with frequencies below 20 000 Hz are called ultrasound.
D. Ultrasound can be emitted and propagates like light rays in the form of beams, unlike ordinary sound which scatters in all directions.
E. Of the sound vibrations which go beyond the audible range of the human ear, of great interest from a practical point of view are ultrasounds, i.e. sounds whose frequency is higher than 20 000 Hz.
Answer: A,B,D,E.

28. Which of the following statements are true?
A. Sound is a mechanical oscillation capable of impressing the auditory organ (receiver).
B. Sound waves are transverse waves that propagate in solids, liquids and gases.
C. To be perceived by the ear, sound waves must not be produced by a sound source.
D. To be perceived by the ear, sound waves must not have an elastic propagation medium between the sound source and the receiver.
E. In order to be perceived by the ear, sound waves must not be within a range of frequencies.
Answer: A,B.

29. Which of the following statements are true?
A. Ultrasounds are obtained with the help of certain crystals called piezoelectric crystals (piezocrystals) which manifest the phenomenon of electrostriction.
B. The practical importance of ultrasound is related to its short wavelength
C. Ultrasound is strongly absorbed in gases and weakly absorbed in liquids and solids.
D. ultrasound cannot be emitted as light beams
E. ultrasound does not propagate like light rays in the form of beams
Answer: A,B,C.

30.. Which of the following statements are true?
A. Hearing is the result of vibratory mechanical stimulation of a certain frequency, intensity and pitch, called sound.
B. The frequency of mechanical waves capable of impressing the human ear is between 16 and 20,000 Hz.
C. Vibrations outside these limits cannot be detected by other sense organs.
D. At frequencies lower than sound frequencies, vibrations with an amplitude much greater than that of sound are perceived by touch.
E. Simple sound or tone, such as that given by a vibrating tuning fork, exerts a periodically oscillating sound pressure p
Answer A,B,D,E.

31. Three different models have been proposed to explain orientation by polarized light
A. the Brewster-Fresnel model
B. the dichroic filter model made in bees
C. the model of the intensity of light reflected or scattered by the medium being greater in the direction perpendicular to the plane of polarization
D. the Lenz model
E. the Archimedes model
Answer: A,B,C

32. Which of the following statements are true?
A. Incident radius, refracted radius and normal to the separating surface are not coplanar
B. The law of refraction is written : $\frac{\sin r}{\sin i} = \frac{n_1}{n_2}$
C. $\frac{1}{\sin i_l} = \frac{n_1}{n_2}$ when n1<n2
D. The refractive index of vacuum is no = 10.
E. $-\frac{n_1}{f_1} = \frac{n_2 - n_1}{R}$ for spherical diopter
Answer: B,C.

33.. If the refractive index (n) of the lens material is greater than the refractive index of the medium, then
A. In a lens the (real) image is not formed at the intersection of the real rays, in image space
B. The real image is not distorted compared to the position of the object for one diopter
C. a lens thicker in the middle and thinner at the edge is convergent
D. a lens thinner in the middle and thicker at the edge is divergent
E. The object-diopter distance is not greater than the distance corresponding to point F1 (object focus)
Answer: C,D.

34. The components of the microscope are :
A. Eyepiece
B. Objective
C. Condenser lens
D. Adjusting lens
E. Eyepiece table
Answer: A,B,C.

35. The refractive indices of the environments corresponding to the human eye are:
A. Cornea : n= 1,37
B. Aqueous humor: n= 1,33
C. Crystalline: n= 14,13
D. Vitreous body: n=133
E. Crystallin: n= 1,413 (1,375-1,473)
Answer: A,B,E
.
36. Which of the following are defects of vision?
A. Normal eye
B. Myopic eye
C. Hyperopic Eye
D. Supermetrop eye
E. Eye with astigmatism defects
Answer: B,E

37. Polarisation of light can be achieved with
A. Nicol prism
B. Glan - Foucault prism
C. Archimedes prism
D. Newton's lens
E. Young's device
A: A,B.

37. The photometric variables (wave variables) are :
A. wavelength (□) (nm)
B. wavenumber (n~) (cm-1)
C. frequency (f) (Hz)
D. propagation velocity (v)
E. Intensity (I) (A)
A: A,B,C,D.

38. The energy variables are:
A. energy flux (F)
B. intensity (I) (A)
C. transmission (x)
D. transmission (transmittance) percentage (T%)
E. absorbance (A)
R: A,D,E

39. Which of the following statements about the Doppler Effect are true?

A. The source is at rest relative to the medium and the Observer is approaching the source with velocity "v" relative to the medium. then the relationship is valid: $f = f_o \cdot \left(1 + \frac{v}{c}\right)$

B. The source is at rest relative to the medium and the Observer is approaching the source at velocity "v" relative to the medium. then the relationship is true: $T_o = T \cdot \left(1 + \frac{v}{c}\right)$

C. If the source is at rest relative to the medium and the observer is moving away from the source at velocity "v" relative to the medium then $f = f_o + \left(1 - \frac{v}{c}\right)$

D. If the source is at rest relative to the medium and the observer is moving away from the source at velocity "v" relative to the medium then $T = T_o . \frac{v}{c} \cdot T$

E. The source is at rest relative to the medium and the observer is approaching the source at velocity "v" relative to the medium. then the relationship is valid: $T_o = T \cdot \left(1 - \frac{v}{c}\right)$

Answer: A,B.

40. Which of the following statements about ultrasound are true:
A. Ultrasonophoresis represents the penetration of some pharmaceutical substances into the irradiated body
B. Ultrasound has the ability to favor the passage of the medicine through the skin and to help its action in the deep tissues.
C. Ultrasonophoresis is a therapeutic method that presents important therapeutic successes in various diseases such as: inflammatory rheumatic diseases (not exacerbation of inflammation), degenerative rheumatic diseases (coxarthrosis), tendinitis, traumatic and orthopedic diseases, scapulo-humeral periarthritis dislocations and contusions and sprains.
D. drugs that can be introduced into tissues by means of ultrasound: hydrocortisone, local anesthetics (procaine 2%)
E. drugs that can be introduced into tissues by means of ultrasound: paracetamol, algocalmin,
Answer, B, C, D.

41. Typical radiopharmaceuticals are:
A. Cobalt-58
B. Iodine-131
C. Gallium-68
D.Hydrogen-30
E. Indium-1011
Answer: A, B, C.

42. The following radiopharmaceuticals emit gamma radiation
A.Co57
B.Ca147
C.Cr151
D.Ga167
E.I131
Answer: A, E.

43. The following radiotracers are used in positron emission tomography (PET) in the neurological field.
A. [18F] Fallypride
B.[18F] Florbetaben
C.[18F] Flubatine
D.[18F] Fluspidine
E. [18F] Fluorodeoxysorbitol (FDS)
Answer: A, B, C, D.

44. The chemical synapse consists of:
A. The presynaptic portion containing: mitochondria, vesicles with chemical mediator and the presynaptic membrane
B. Synaptic cleft with dimensions of 200-500 A
C. The postsynaptic portion that includes chemically controlled ion channels
D. structures having electrical signals are transmitted directly –
E. ionic influxes - from the presynaptic to the postsynaptic cell
Answer: A, B, C.

45. The following statements regarding acetylcholine are true:
A. Acetylcholine was the first neurotransmitter identified in both the central nervous system and the peripheral nervous system.
B. Aceticolin was first identified in 2014 by Henry Hallett Dale, who discovers its action on heart muscle
C. Acetylcholine has no excitatory activity in the brain.
D. Acetylcholine binds to nicotinic receptors in brain fibers
E. Receptors for acetylcholine are nicotinic and muscarinic
Answer: Yes

46. The following statements regarding histamine are true:
A. Histamine is a biogenic amine.
B. It is found in the gynecological system and in the lens of the eye retina
C. In humans, histamine exists in the lungs, skin, gastrointestinal mucosa.
D. Histamine acts as a stimulant of hormone secretion.
E. Histamine is used to determine the acid secretory capacity of the stomach
Answer: A, C, E.

48. The following statements regarding serotonin are true:
A. Serotonin was the first neurotransmitter identified both in the central nervous system.
B. Serotonin is found in the lungs, skin, gastrointestinal mucosa.
C. Serotonin, a neurotransmitter present in various organs including the central nervous system,
D. Serotonin plays an important role in the development of depression and anxiety, due to the chemical disturbances it produces
E. Antidepressants generally act on the neurotransmitter serotonin
Answer: C, D, E

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