Diffraction of light :

prerequisites:

*The period T is the time needed to complete one oscillation. Its SI unit is the seconds.

*Frequency is the number of oscillations performed in one second. Its SI unit is the Hz.

*The wavelength λ is the distance covered by a wave during a period. So $\lambda = vT = \frac{V}{F}$.

*To each color of light, there corresponds a well determined frequency f independent of the medium of propagation and of a well determined wavelength $\lambda = \frac{v}{f}$. The frequency f is a characteristic of the source but the speed v is a characteristic of the medium of propagation. The speed v remains constant in the same medium.

*A monochromatic light is formed of one color like the laser while a polychromatic light is formed of many colors like a torch light or sunlight.

*Domain of visible radiations: 400 nm (λ_{violet}) $\leq \lambda \leq$ 750nm (λ_{red})
Ultraviolet: $\lambda <$ 400 nm; Infrared: $\lambda >$750nm.

*Visible radiations constitute a part of the electromagnetic spectrum.

*The phenomena of diffraction, interference, reflection and refraction are an important proof of the wave nature of light.

***Remark:** $In\ vacuum\ \lambda = \frac{c}{F}$ $(c : speed\ of\ light\ in\ vacuum)$ $index\ of\ refraction\ is\ n = \frac{c}{v}$

$In\ a\ certain\ transparent\ medium\ \lambda' = \frac{v}{F} (v : speed\ of\ light\ in\ medium)$

$$\frac{\lambda}{\lambda'} = \frac{\frac{c}{F}}{\frac{v}{F}} = \frac{c}{v} = n \quad so \quad \lambda' = \frac{\lambda}{n} \quad but \quad n \geq 1\ So\ the\ wavelength\ is\ longest\ in\ vacuum\ or\ air.$$

1- What is meant by diffraction of light?

The diffraction of light is the deviation that a light beam undergoes during its passage in the neighborhood of the edges of an obstacle or through a narrow(fine) slit.

2-Describe the diffraction pattern observed on the screen.

The diffraction pattern observed on the screen is formed of bright and dark fringes perpendicular to the plane of the slit with the width of the central fringe is double that of the other bright fringes and it is much more luminous than them.

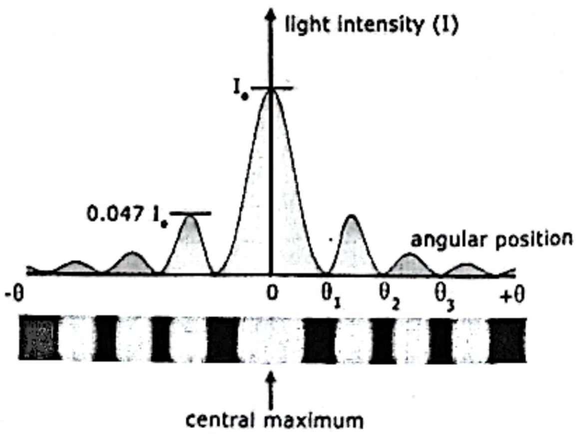
*The narrower is the slit the more important is the diffraction.

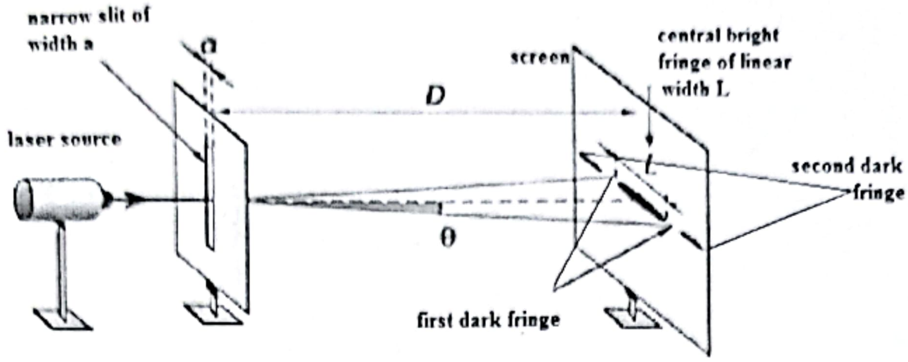
*If the width of the slit is a>>>λ diffraction cannot be observed.

*For diffraction of an electromagnetic radiation to take place the slit must be very narrow or fine (a <1mm).

3-It is impossible to isolate a luminous ray by reducing the size of the slit. Why?

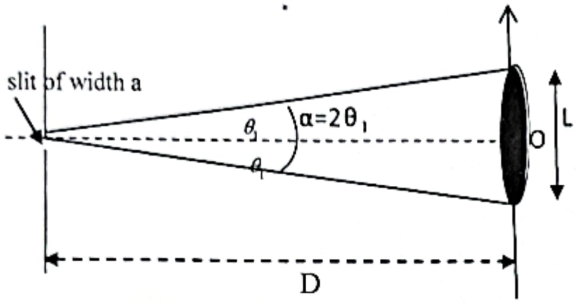
To isolate a ray of light a beam must pass through a tiny hole of very small diameter. Because of the diffraction of light, this beam diffracts and the ray is not isolated.





θ is the angle of diffraction in radians.

D is the distance between the slit and the screen.



θ_K: angular abscissa of the dark fringe of order k, it is given by the formula $\sin\theta_K=\frac{k\lambda}{a}$

So θ_K is the angle from the central axis to the k^{th} dark fringe.(K=….,-3,-2,-1,1,2,3…)

(λ is the wavelength of the monochromatic light in m; a is the width of the slit in m;

D is the distance between the plane of the slit and the screen in m)

For the 1^{st} dark fringe θ_1 is small so $\sin\theta_1=\theta_1$ in rad and $\tan\theta_1=\theta_1$ in rad.

$\sin\theta_1=\frac{\lambda}{a}=\theta_1$ in rad and $\tan\theta_1=\frac{L/2}{D}=\frac{L}{2D}=\theta_1$ in rad (θ_1 is small) so $\frac{L}{2D}=\frac{\lambda}{a}$ so $L=\frac{2\lambda D}{a}$

The angular width of the central bright fringe is $\alpha=2\theta_1=2\frac{\lambda}{a}$ so $L=\alpha D$.

The position of the k^{th} dark fringe w.r.t O is $x_K=\frac{k\lambda D}{a}$ $(K=......-2,-1,1,2,.....)$

The position of the center of the k^{th} bright fringe is $x_K=\pm\frac{\lambda D}{a}(k+\frac{1}{2})$ $(K=1,2,3....)$

5-We illuminate the slit with white light. We observe over the linear width L_{violet} white light. Justify.

The linear width L of the central fringe is such that: $L_{violet}\leq L\leq L_{red}$. All the central bright fringes superpose within L_{violet}, so as a result we obtain a white fringe over L_{violet}.

6- Statement of Huygen's Principle:

Light propagates step by step in space .Each of the points receiving a light wave beam behave in its turn as a secondary wave source.

7- Diffraction of visible light by a circular hole:

The diameter « d » of the hole must be less than 1mm and the diffraction pattern is formed of a circular bright fringe larger than « d » surrounded by concentric alternating bright and dark rings

Formula: $\alpha=2\theta_1$, $\theta_1=\frac{1.22\,\lambda}{d}$, $\theta_2=\frac{2.23\,\lambda}{d}$, $\theta_3=\frac{3.24\,\lambda}{d}$

Photoelectric effect:

A) The photoelectric effect was discovered by Hertz on 1887. The experiment represented in figure 1 may show evidence of this effect. A zinc plate is fixed on the conducting rod of an electroscope. The whole set-up is charged negatively. If we illuminate the plate by a lamp emitting white light rich with ultraviolet radiations (U.V), the leaves F and F' of the electroscope approach each other rapidly.

Due to what is the approaching of the leaves?

The plate has excess of electrons; so when the plate is exposed toU-V radiations electrons are extracted ,which explains the discharge of the electroscope.

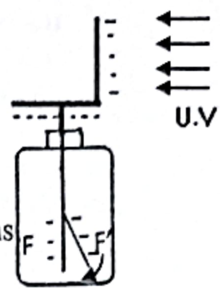


Fig.1

1- Define photoelectric effect.

It is the emission of the electrons (photoelectrons) from the surface of a metal when exposed to a suitable electromagnetic radiation.

2-Indicate the aspect of light that the photoelectric effect shows evidence of.

It is an evidence of the corpuscular aspect of light while diffraction and interference are evidences of the wave nature of light.

3- Define a photon

A radiation of frequency υ is made up of small bundles of energy called "photons". A photon is a non-charged particle of zero mass. It moves in vacuum at the speed of light c.

Remark:

According to the classical wave theory of light, when an incident radiation of any frequency is incident on the surface of a metal , energy is given progressively and continuously to its surface .When the energy received by an electron on the surface of the metal becomes greater than the work function $W_0$of that of the metal, the electron is liberated from its surface .**BUT THAT DOES NOT HAPPEN. SO THE WAVE THEORY FAILS TO EXPLAIN THE PHENOMENON OF PHOTOELECTRIC EFFECT.**

4-Give the characteristics of a photon:

a- No mass ;

b- No charge;

c- Moves at the speed of light in vacuum ;

d-Carries a well determined value or we can say that its energy is quantized.

This energy is given by the expression:

$E=h\upsilon=\frac{hc}{\lambda}$ where h:Planck's constant; c:speed of light in vacuum;

λ:wavelength in m ; υ: frequency in Hz

5- Define the work function of a metal W_o.

It is the minimum energy necessary to extract an electron from the metal .This energy is a characteristic of the metal.

6- Define threshold frequency υ_o of a metal.

The threshold frequency of a metal is the minimum frequency necessary to extract an electron from the metal.

7- Define threshold wavelength λ_o of a metal.

The threshold wavelength of a metal is the maximum wavelength necessary to extract an electron from the metal.

8-Three cases to be known:

a- A radiation is capable of extracting an electron from a metal; if a photon has energy E is larger or equal to the energy of extraction W_o of the metal.
If E $> W_o$, then the electron is liberated with maximum K.E such that $K.E_{max}=E-W_o$

So **Einstein's Formula:** $\frac{m_e v^2_{max}}{2}=h\upsilon-W_o$ where $W_o=h\upsilon_o=\frac{hc}{\lambda_o}$

b- If $E = W_o$ then the electron is liberated from the metal without speed.

c- If $E < W_o$, then the electron remains attached to the metal.

9-A monochromatic beam of light, of frequency υ carries during a duration t a number N of photons. The power of the beam is: $p=\frac{E}{t}=\frac{Nh\upsilon}{t}$

The quantum efficiency of a photocell is $\eta=\frac{n}{N}$ where n: number of effective photons (nb. of electrons extracted) and N: number of photons received by the photocell.

The intensity then of the electric current is $I=\frac{ne}{t}$ (e: elementary charge $=1.6\times10^{-19}$C)

$N=\frac{pt}{h\upsilon}$

The number of the incident photons and consequently the number of the liberated electrons increases if:

a- The power of the incident radiation increases.

b- The exposure time of the metal to the incident radiation increases.

c- The radiation of power P is replaced by another one of same power but of lower frequency provided that $\upsilon \geq \upsilon_0$

10-The interaction is strictly photon –electron. An effective photon is one that extract an electron. The number of effective photons=number of extracted electrons. An infinite nb of ineffective photons cannot provoke in any case photoelectric emission.