Exercise 1

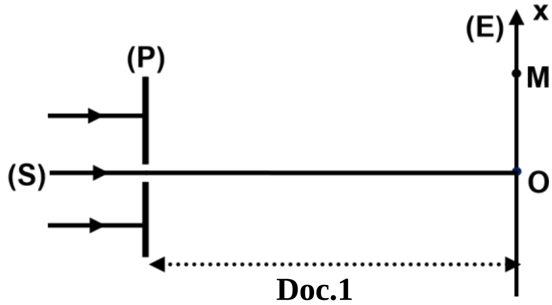
Consider a dichromatic light source (S) emitting two monochromatic lights (A) and (B) of wavelengths in air λ_1 and λ_2 respectively. The color of the light beam emitted from (S) appears magenta. The aim of this exercise is to determine λ_1 and λ_2.

Given: The range of wavelength of visible light in air: $400\ nm \le \lambda \le 800\ nm$; $\lambda_1 < \lambda_2$.

1) Diffraction of light

(S) illuminates in air, at normal incidence, a vertical thin slit, of width $a = 0.2\ mm$, which is cut in an opaque plane (P). We observe a diffraction pattern on a screen (E) placed parallel to (P) at a distance $D = 2\ m$ away from it. A point M on the screen belongs to the obtained diffraction pattern, and it has a position $x = \overline{OM}$ relative to the center O of the central bright fringe (Doc. 1).

The diffraction angles of the fringes in the following questions are small.



Doc.1

1-1) A filter is placed in front of source (S). It transmits light (B) only of wavelength $\lambda = \lambda_2$.

Let M be the center of a dark fringe of order n (n is integer)

1-1-1) Write in terms of a, n, and λ, the expression of the diffraction angle θ of M.

1-1-2) Prove that the abscissa of M is $x_n = \dfrac{n\lambda D}{a}$.

1-1-3) The central bright fringe obtained by the diffraction of a monochromatic light of wavelength λ separates the centers of two dark fringes. Deduce using part (1-1-2) that the width of the central bright fringe is $L = \dfrac{2\lambda D}{a}$

1-2) We remove the filter, so that the two lights (A) and (B) reach the screen.

1-2-1) Compare the width of the central bright fringe obtained by the diffraction of light (A) to that obtained by the diffraction of light (B).

1-2-2) We notice that the central fringe on the diffraction pattern appears magenta. The width of this fringe is 9.3 mm. Deduce that $\lambda_1 = 465\ nm$.

1-3) The two lights (A) and (B) still reaching the screen. The abscissa of a point Q in the diffraction pattern is $x = 27.9\ mm$. Q is the center of a dark fringe of order n_1 for light (A) and at the same time Q is the center of a dark fringe of order n_2 for light (B).

1-3-1) Determine the value of n_1.

1-3-2) Prove that $n_2 \times \lambda_2 = 2790 nm$.

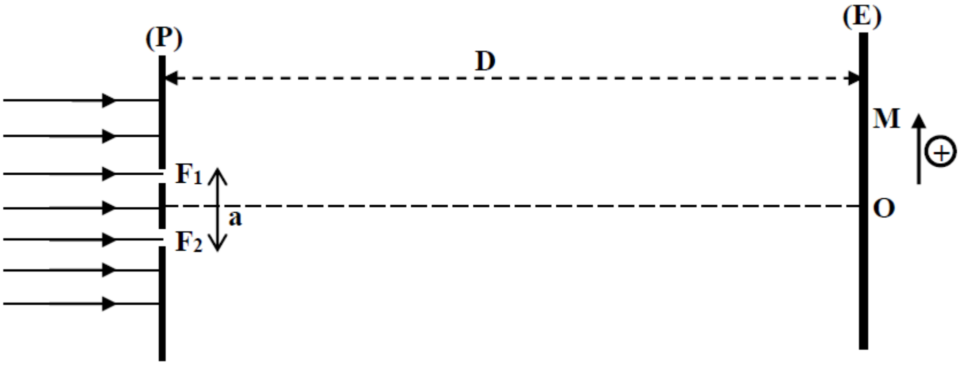
1-3-3) Prove that $4 \le n_2 < 6$.

1-3-4) Deduce that the possible values of λ_2 are 558 nm and 697.5 nm.

Exercise 2

Two horizontal slits F_1 and F_2, are illuminated normally with a laser source. Each slit, cut in an opaque screen (P), has a width $a_1 = 0.1$ mm and are situated at a distance $F_1F_2 = a = 1$ mm from each other. The wavelength of the laser light is $\lambda = 600$ nm. The distance between the plane (P) of the slits and the screen of observation (E) is $D = 2m$. (Figure below).

O is a point on the screen (E) and belongs to the perpendicular bisector of $[F_1F_2]$.



We cover the slit F_1 by an opaque sheet thus light is emitted only from F_2.

1) The phenomenon of diffraction is observed on the screen (E). Justify.
2) Redraw the figure and trace the beam of light leaving the slit F_2.
3) Describe the pattern observed on the screen (E).
4) Write the expression of the angular width α (α is very small) ofthe central bright fringe in terms of λ and a_1.
5) a) Show that the linear width L ofthe central bright fringe is given by: $L = \frac{2\lambda D}{a_1}$.

   b) Calculate L.
6) The opaque sheet is moved to cover the slit F_2. The slit F_1 sends light now on the screen (E). The center of the new central bright fringe is at a distance d from the previous center of the central bright fringe. Specify the value of d .

Exercise 3

Wave aspect of light and its applications

The object of this exercise is to show evidence of exploiting an optical phenomenon in the measurement of small displacements.

A laser beam illuminates, under normal incidence, a straight slit F, of width a, cut in an opaque screen (P). The light through F is received on a screen (E), parallel to (P) and found at 3 m from (P) (Fig. 1).

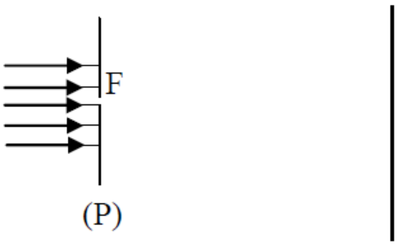


Fig.1

1) Describe what would be observed on (E) in the two (p) following cases:

   a) $a = a_1 = 1$ cm. Fig.1

   b) $a = a_2 = 0.5$ mm.
2) It is impossible to isolate a luminous ray by reducing the size of the slit. Why?
3) We use the slit of width $a_2 = 0.5$ mm. The width ofthe central fringe of diffraction observed on (E) is 7.2 mm. Show that the wavelength of the light used is $\lambda = 600$ nm.
4) We remove the screen (P). A hair of diameter d is stretched in the place of the slit F. We obtain on the screen a diffraction pattern. The measurement of the width of the central fringe of diffraction gives 12 mm. Determine the value of d.

Exercise 4

A source of monochromatic radiation of wavelength λ in air illuminates under normal incidence a horizontal slit F of adjustable width acut in an opaque screen (P). A screen of observation (E) is placed parallel to (P) at a distance D = 5 m (Fig.1).

1) For λ= 0.5 µm, show on a diagram the shape of the luminous beam emerging from the slit in each of the two following cases :

- width of the slit a = 2 cm.
- width of the slit a = 0.4 mm.

2) The width of the slit is now kept at 0.4 mm and the radiation used belongs to the visible spectrum. (wavelength of the visible spectrum : 0.4 µm □λ □0.8 µm)

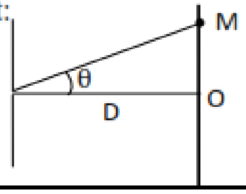
a)Write , in this case, the expression giving the angular width of the central bright fringe in terms of λ and a.

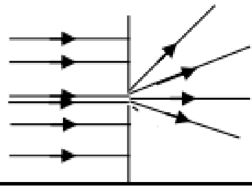
b)Show that the linear width of this central fringe is given by : $L = \frac{2D\lambda}{a}$.

c) Calculate the linear widths L_{red} and L_{violet}, when using successively a red radiation (λ_{red} = 0.8 µm) and a violet radiation (λ_{violet} = 0.4 µm).

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

Exercise 1

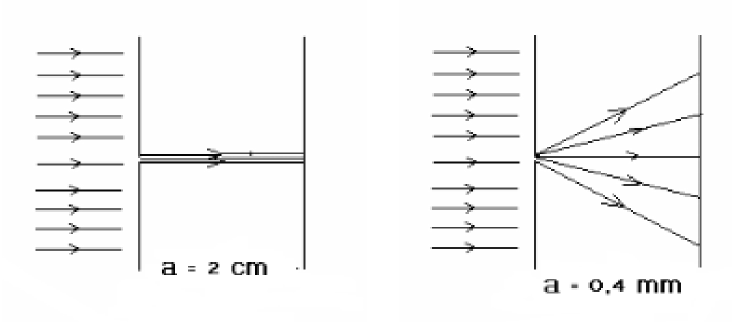
Third Exercise			Solution	7.5 pts
1	1	1	$\sin\theta = \frac{n\lambda}{a}$, since the angles are small then $\sin\theta \cong \theta$, then $\boldsymbol{\theta = \frac{n\lambda}{a}}$	0.5
		2	Consider the right triangle formed by O, M, and the center of the slit; $\tan\theta \cong \theta = \frac{x}{D}$, then $x = \theta D = \frac{n\lambda D}{a}$ 	1
		3	The first dark fringes situated on both sides of the central bright fringe, then $L = x_1 - x_{-1} = \frac{\lambda D}{a} - \frac{-\lambda D}{a} = \frac{2\lambda D}{a}$	1
	2	1	Since $\lambda_1 < \lambda_2$, then $L_1 < L_2$ Therefore, the width of the central bright fringe of (B) is longer than that of (A). The width of the central bright fringe of (B) is longer than that of (A) The color appears magenta in the common area of the central fringes of (A) and (B). Therefore, the 0.2 mm represents the **width of the central bright fringe of light (A)**	0.25 0.5
		2	$L_1 = \frac{2\lambda_1 D}{a}$, then $\lambda_1 = \frac{a L_1}{2D} = \frac{0.2\times10^{-3}\times9.3\times10^{-3}}{2\times2} = 4.65\times10^{-7}$ m = **465 nm**	0.5
	3	1	$x = \frac{n_1\lambda_1 D}{a}$, then $n_1 = \frac{a\,x}{D\,\lambda_1} = \frac{0.2\times10^{-3}\times27.9\times10^{-3}}{2\times465\times10^{-9}} = \mathbf{6}$	0.5
		2	$x = \frac{n_2\lambda_2 D}{a}$, then $n_2\lambda_2 = \frac{a\,x}{D} = \frac{0.2\times10^{-3}\times27.9\times10^{-3}}{2}$, hence $\mathbf{n_2\lambda_2 = 2.79\times10^{-6}}$ **m** Or: $\mathbf{n_2\lambda_2 = 2790}$ **nm**	0.75
		3	$n_2 = \frac{2790}{\lambda_2}$ and $465\text{ nm} < \lambda_2 \leq 800\text{ nm}$ $n_2 \geq \frac{2790}{800}$, so $n_2 \geq 3.49$ but $n \in N$; therefore, $n_2 \geq 4$ $n_2 < \frac{2790}{400}$; therefore $\mathbf{n_2 < 6}$ or $n_2\lambda_2 = n_1\lambda_1$, but $\lambda_2 > \lambda_1$, then $n_2 < n_1$; therefore $\mathbf{n_2 < 6}$	1
		4	$\lambda_2 = \frac{a.x}{n_2 D}$ if $n_2 = 4$ then $\lambda_2 =$ **697,5 nm** if $n_2 = 5$ then $\lambda_2 =$ **558 nm**	0.75
2			Photoelectrons takes place if $\lambda_2 \leq \lambda_o$, but we have no emission of electrons, then $\lambda_2 > \lambda_o$; therefore, $\boldsymbol{\lambda_2 = 697.5}$ **nm**	0.75

Part of the Q	Answer	Mark
A.1	The width of the slit a_1 is of the order of mm (or λ has to be of the same order of $a_1 (a_1 = 10^3 \lambda)$.	0.50
A.2.	Aspect of the emerging beam. 	0.50
A.3	We observe : • Alternate bright and dark fringes. • The direction of the diffraction pattern is perpendicular to that of the slit. • The width of the central bright fringe is twice as broad as others.	0.75
A.4	$\sin\alpha = \frac{2\lambda}{a_1}$ and in case of small angles $\sin\alpha \approx \alpha_{rd} \Rightarrow \alpha = \frac{2\lambda}{a_1}$	0.50
A.5.a	Figure $\tan\frac{\alpha}{2} = \frac{L}{2D}$ and case of small angles $\tan\alpha \approx \alpha_{rd} \Rightarrow \quad L = \alpha \times D = \frac{2\lambda D}{a_1}$.	0.75
A.5.b	$L = \frac{2 \times 0.633 \times 10^{-3} \times 2 \times 10^3}{0.1} \text{mm} = 25 \text{ mm}$.	0.50
A.6.	The displacement of 1 mm is due to the distance a =1 mm between the two slits	0.50

Part of the Q	Answer	Mark
A.1	M is a dark fringe if $\sin\theta = n\frac{\lambda}{a} = \theta$, the second fringe: n =2 then $\theta = 2\frac{\lambda}{a}$	**1**
A.2	$\tan\theta = \theta = \frac{OM}{D} = \frac{x}{D}$ then $\mathbf{x} = OM = D \times \theta = \frac{2D\lambda}{a}$	**¾**
A.3	$a = \frac{2\lambda D}{x} = 0.4\text{mm}$	**¾**
A.4	We observe a spot of light.	**½**

<u>Third exercise :</u> (7 pts)

A- 1) (½ pt)



2) a) $\alpha = \frac{2\lambda}{a}$. **(½ pt)**

b) $\alpha = \frac{2\lambda}{a} = \frac{L}{D}$ (Figure) $\Rightarrow L = \frac{2D\lambda}{a}$. **(¾ pt)**

c) $L_{Red} = \frac{2D\lambda_{Red}}{a} = 2$ cm ; $\lambda_{Red} = 2\,\lambda_{Violet}$

$\Rightarrow L_{Red} = 2\,L_{Violet} \Rightarrow L_{Violett} = 1$ cm **(½ pt)**

d) The linear width L of the central fringe is: $1\text{cm} \le L \le 2$ cm.

All the central bright fringes superposed within 1 cm:

We obtain white fringe. **(¾ pt)**