

### Third exercise: (7 ½ points)

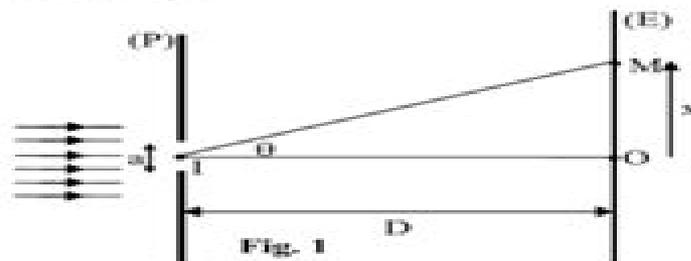
#### Diffraction and interference of light

A laser source emits a monochromatic cylindrical beam of light of wavelength  $\lambda = 640 \text{ nm}$  in air.

##### A – Diffraction

This beam falls normally on a vertical screen (P) having a horizontal slit  $F_1$  of width  $a$ . The phenomenon of diffraction is observed on a screen (E) parallel to (P) and situated at a distance  $D = 4 \text{ m}$  from (P).

Consider on (E) a point M so that M coincides with the second dark fringe counted from O, the center of the central bright fringe.  $\text{OIM} = \theta$  ( $\theta$  is very small) is the angle of diffraction corresponding to the second dark fringe (Fig. 1).



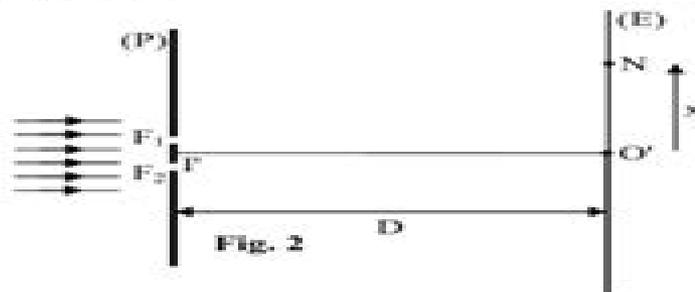
- 1) Write the expression of  $\theta$  in terms of  $a$  and  $\lambda$ .
- 2) Determine the expression of  $\text{OM} = x$  in terms of  $a$ ,  $D$  and  $\lambda$ .
- 3) Determine the value of  $a$  if  $\text{OM} = 1.28 \text{ cm}$ .
- 4) We replace the slit  $F_1$  by another slit  $F_1'$  of width 100 times larger than that of  $F_1$ . What do we observe on the screen (E)?

##### B – Interference

We cut in (P) another slit  $F_2$  identical and parallel to  $F_1$  so that the distance  $F_1F_2 = a' = 1 \text{ mm}$ . The laser beam falls normally on the two slits  $F_1$  and  $F_2$ . We observe on (E) a system of interference fringes.

$O'$  is the orthogonal projection of the midpoint  $I'$  of  $F_1F_2$  on (E) (Fig. 2).

- 1) a) Due to what is the phenomenon of interference?  
b) Describe the fringes observed on (E).
- 2) Consider a point N on (E) so that  $\text{O'N} = x$ .  
a) Write the expression of the optical path difference  $\delta = F_2N - F_1N$  in terms of  $a'$ ,  $x$  and  $D$ .  
b) If N is the center of a dark fringe of order  $k$ , write the expression of the optical path difference  $\delta$  at N in terms of  $\lambda$  and  $k$ .  
c) Deduce the expression of  $x$  in terms of  $a'$ ,  $D$ ,  $k$  and  $\lambda$ .  
d) Knowing that the interfringe distance  $i$  is the distance between the centers of two consecutive dark fringes, deduce then the expression of  $i$  in terms of  $\lambda$ ,  $D$  and  $a'$ .



- 3) The whole set up of figure 2 is immersed in water of index of refraction  $n$ .

- a) i) The interfringe distance  $i$  varies and becomes  $i'$ . Why?  
ii) Show that  $i' = \frac{i}{n}$ .
- b) We move (E) parallel to (P) and away from it by a distance  $d = \frac{4}{3} \text{ m}$ . We notice that the interfringe distance takes again the initial value  $i$ . Deduce then the value of  $n$ .

# 31 Diffraction And Interference Exercise Answers

**Mike Jess**



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