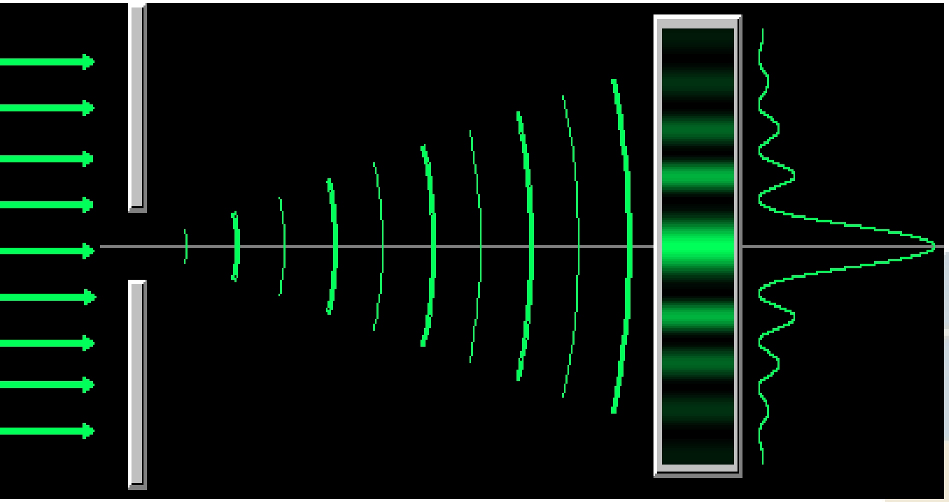
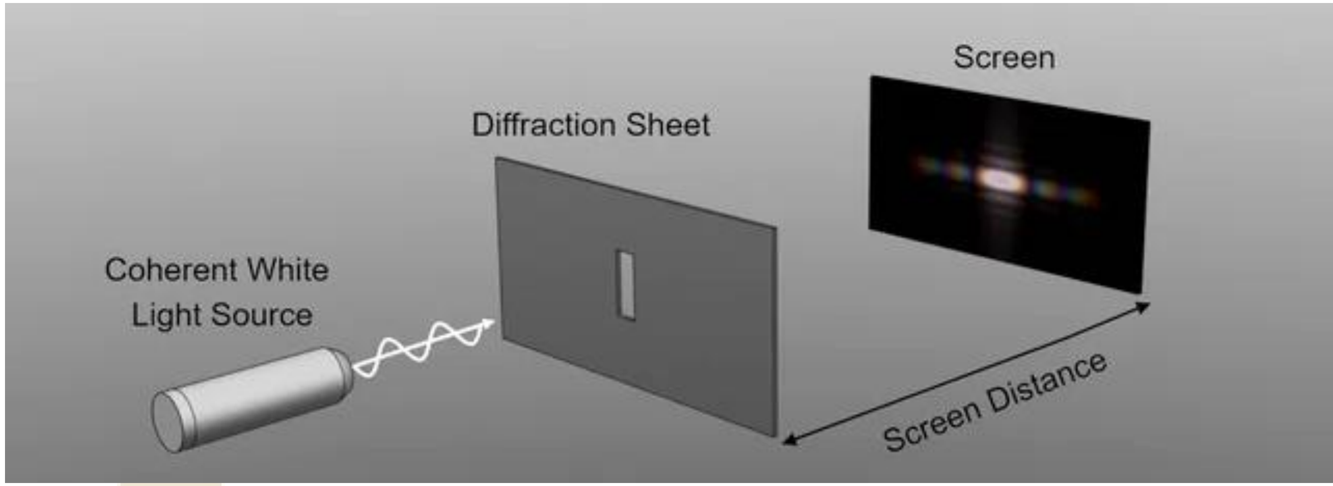


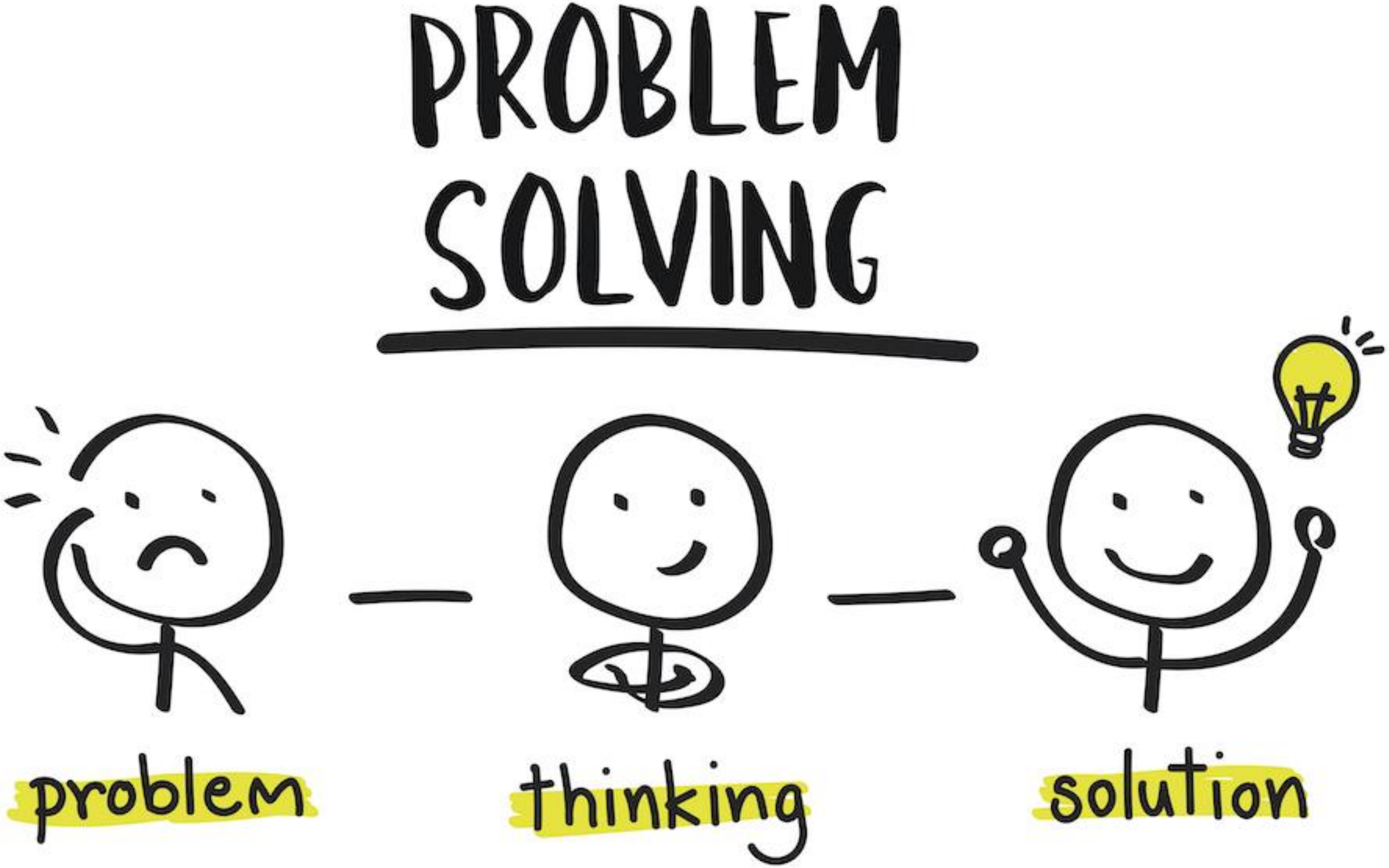


Unit III

Chapter 13

Wave Aspect of Light - Diffraction

Prepared and Presented by: Mr. Mohamad Seif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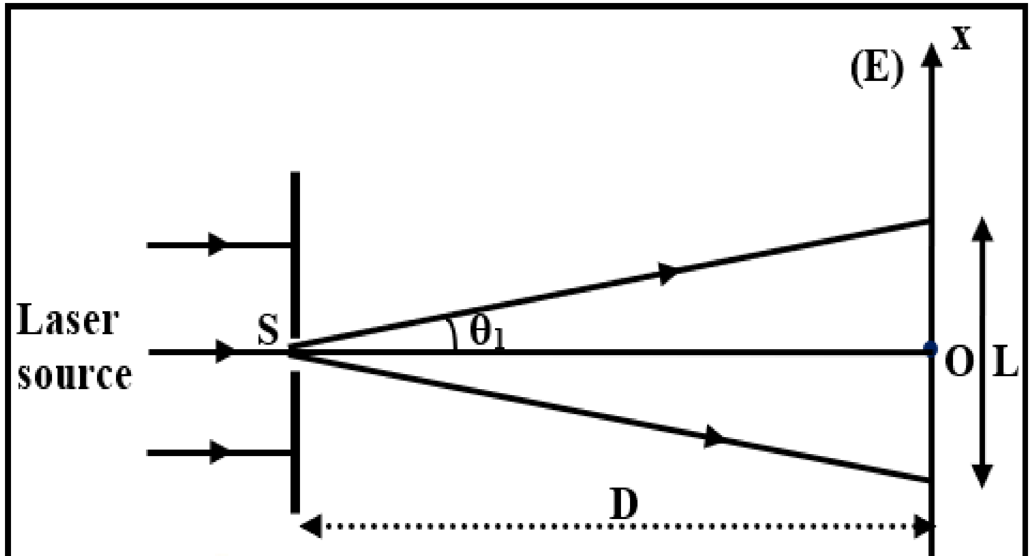
Exercise 1:

Consider a horizontal slit S of width $a_1 = 0.1mm$. O is the center of the central bright fringe and $\alpha = 2\theta_1$ where α is the angular width of the central bright fringe (θ_1 is a small angle) (Doc. 7).



Doc. 7

The screen (E) is placed parallel to the plane of the slits at a distance $D = 2m$. A laser source illuminates the slit by a monochromatic light of wavelength $\lambda = 600nm$ in air, under normal incidence.

Exercise 1:

1) **Name the phenomenon that takes place at the slit S.**
2) **Show that the width L of the central bright fringe is given by the expression:** $L = \frac{2\lambda D}{a_1}$**.**
3) **Deduce the distance d between O and the center of the first dark fringe.**
4) **This experiment show evidence of an aspect of light. Name this aspect.**

Exercise 1:

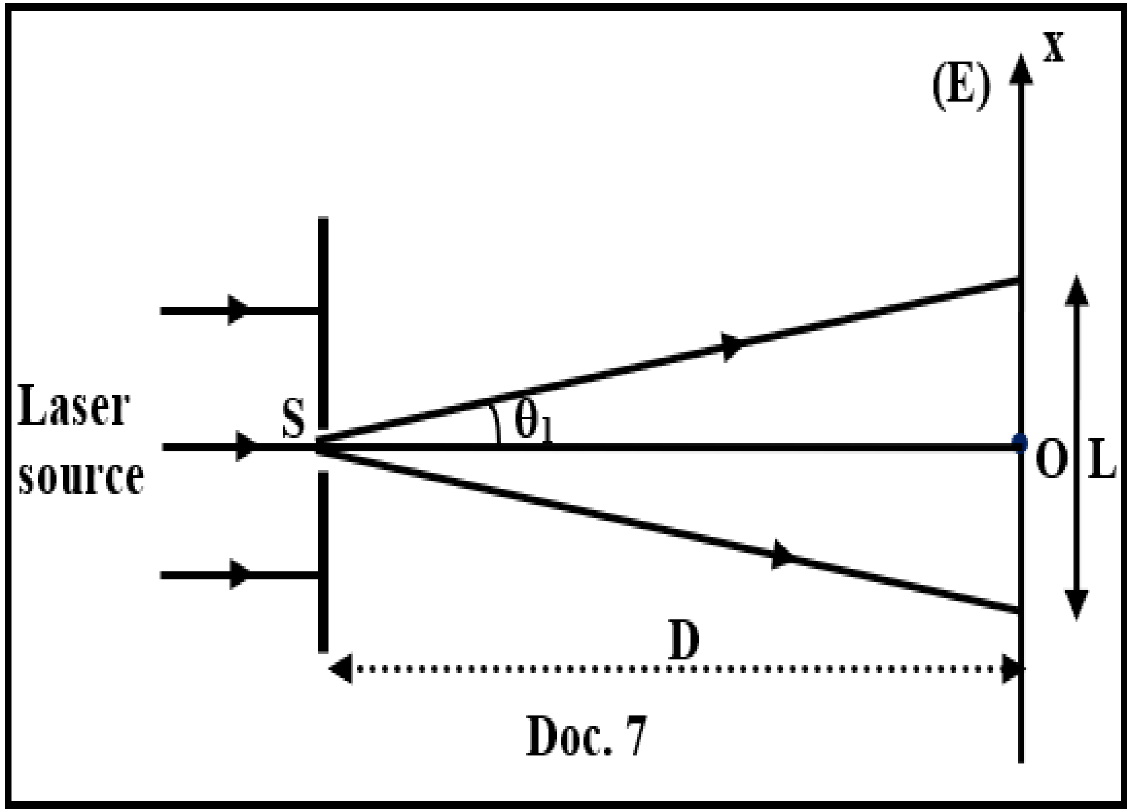
$a_1 = 0.1mm$; $\alpha = 2\theta_1$; (θ_1 is a small angle); $D = 2m$; $\lambda = 600nm$

1)Name the phenomenon that takes place at the slit S.

The phenomenon is Diffraction of light.

2)Show that the width L of the central bright fringe is given by the expression: $L = \frac{2\lambda D}{a_1}$.

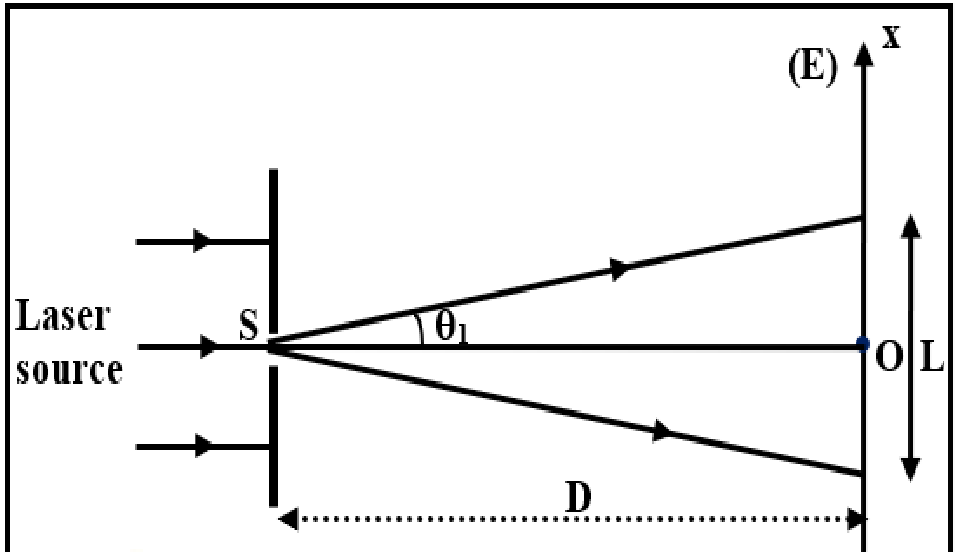
From the figure $tan[\theta_1] = \frac{L/2}{D}$



Exercise 1:

$\theta_1 \ll$ then: $\tan\theta_1 = \theta_1$

$$\theta_1 = \frac{L/2}{D} \Rightarrow \theta_1 = \frac{L}{2D}$$



Doc. 7

But $\theta_1 = \frac{\lambda}{a_1}$

$$\theta_1 = \theta_1$$

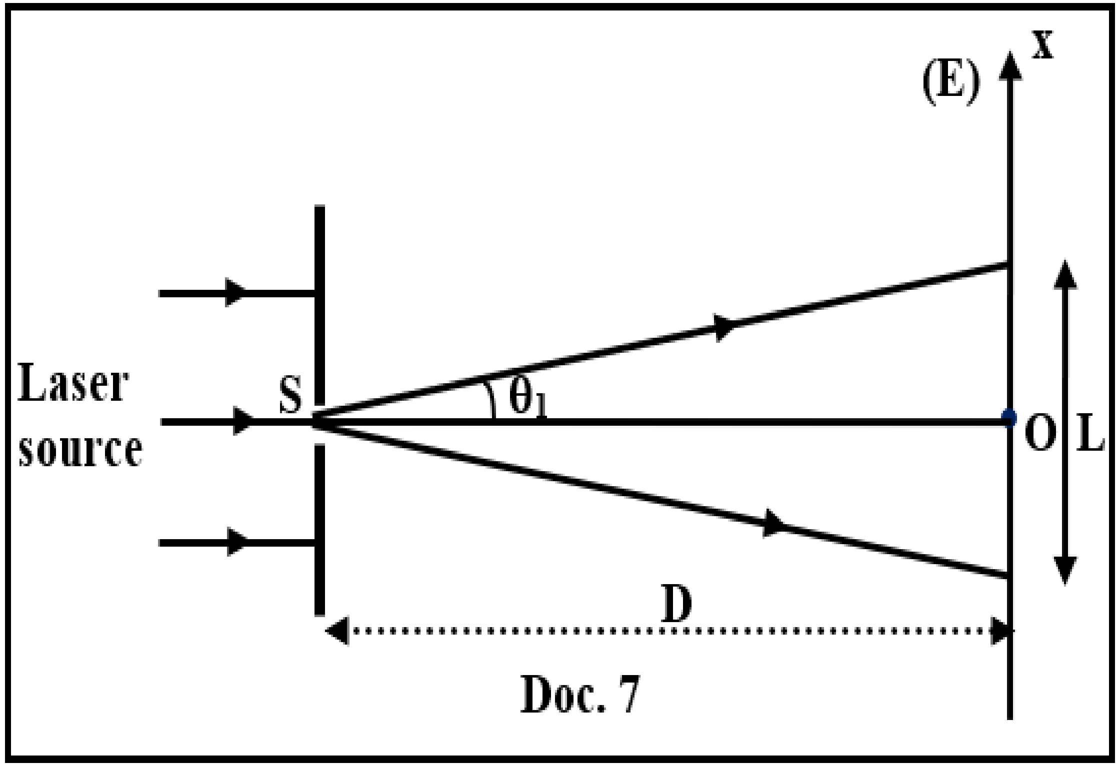
$$\frac{L}{2D} = \frac{\lambda}{a_1} \Rightarrow L = \frac{2\lambda D}{a_1}$$

Exercise 1:

$a_1 = 0.1mm;\ \alpha = 2\theta_1;\ (\theta_1 \ll);\ D = 2m;\ \lambda = 600nm$

3)Deduce the distance d between O and the center of the first dark fringe.

$$d = \frac{L}{2} \text{ where } L = \frac{2\lambda D}{a_1}$$



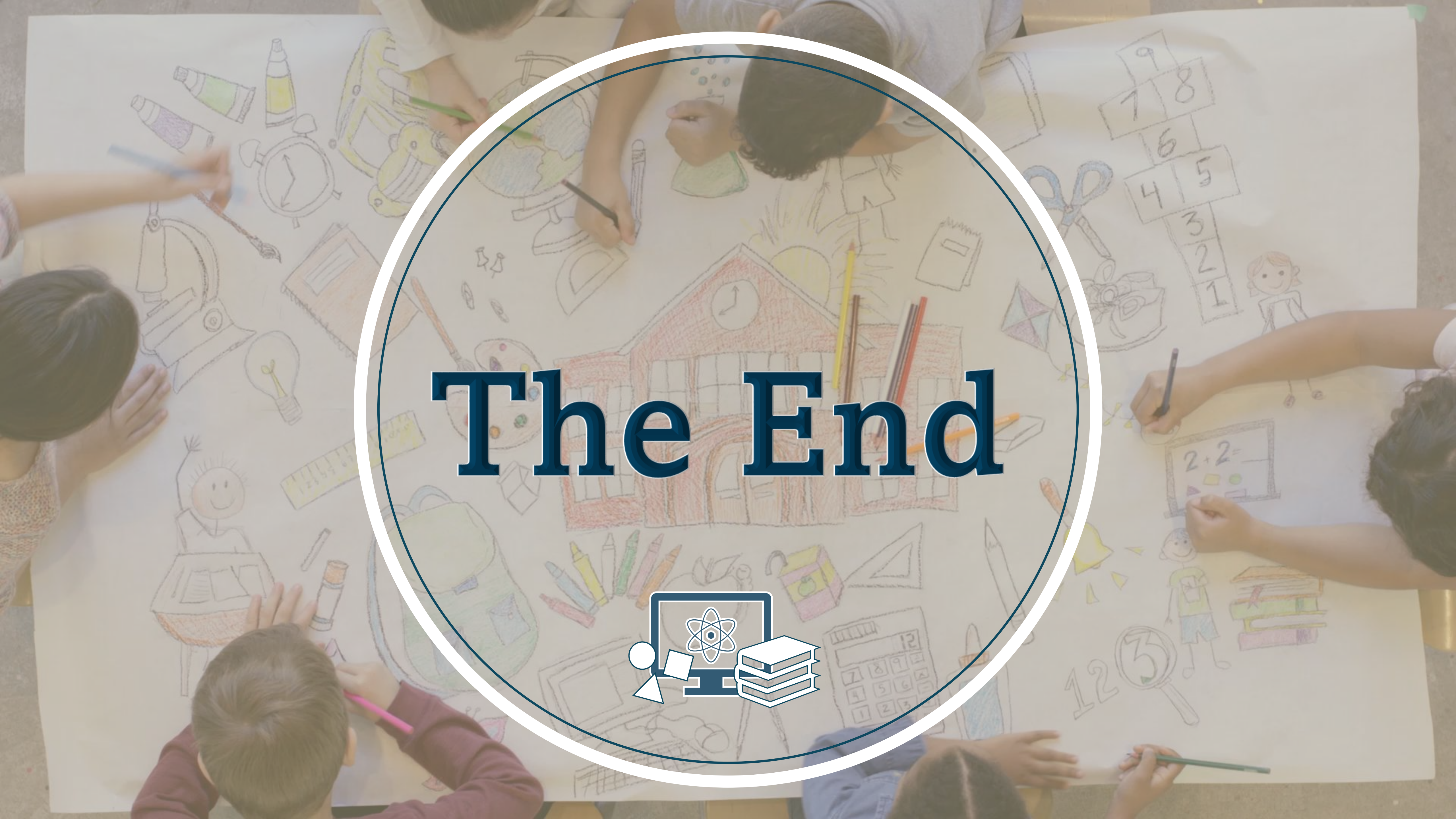
$$d = \frac{2\lambda D}{2a_1} \Rightarrow d = \frac{\lambda D}{a_1}$$

$$d = \frac{600 \times 10^{-9} \times 2}{0.1 \times 10^{-3}} = 0.012m$$

Exercise 1:

4) This experiment show evidence of an aspect of light. Name this aspect.

The aspect of light shown by the experiment is wave aspect pf light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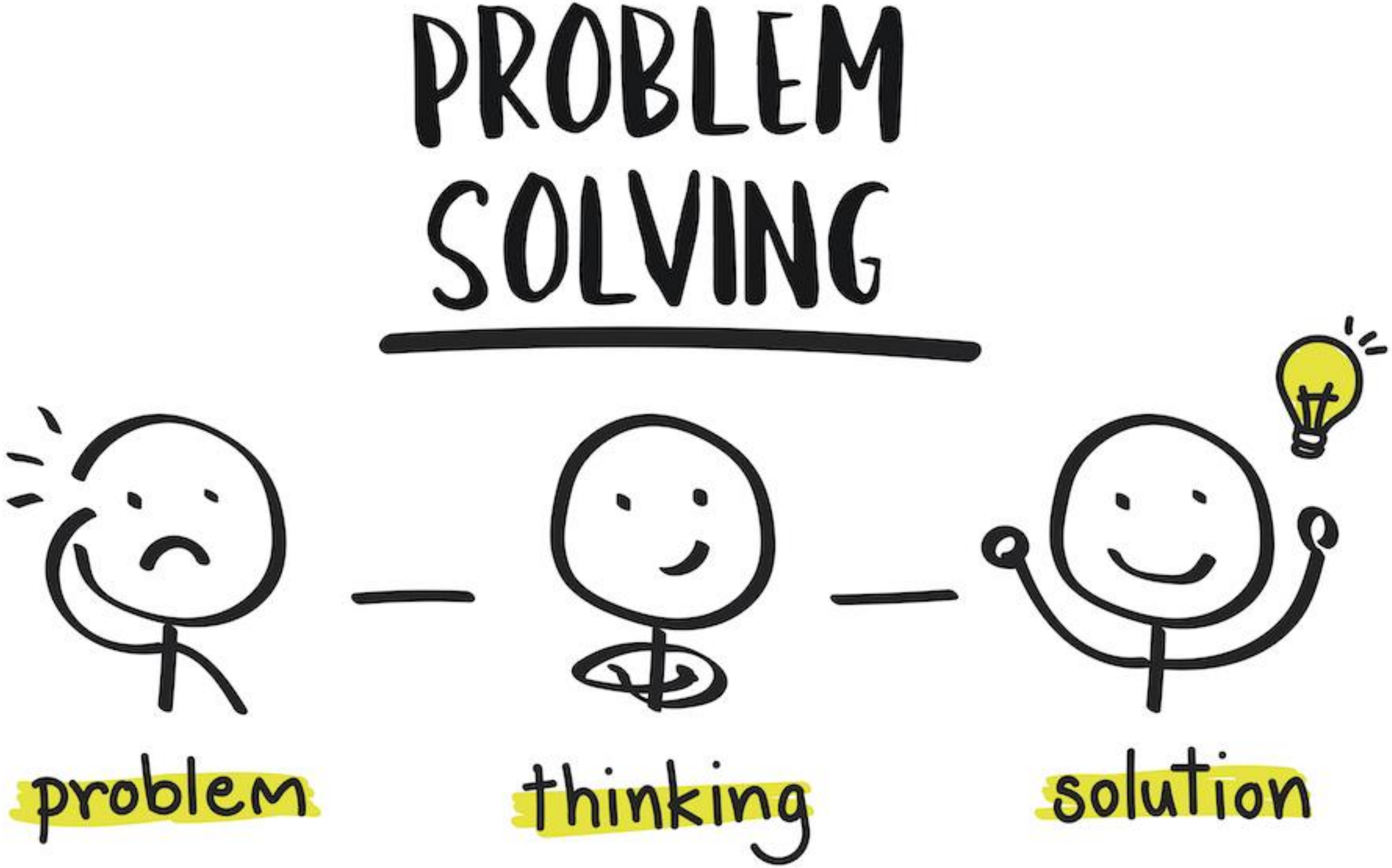
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Exercise 2:

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

This beam falls normally on a vertical screen (P) having a horizontal slit F_1 of width a.

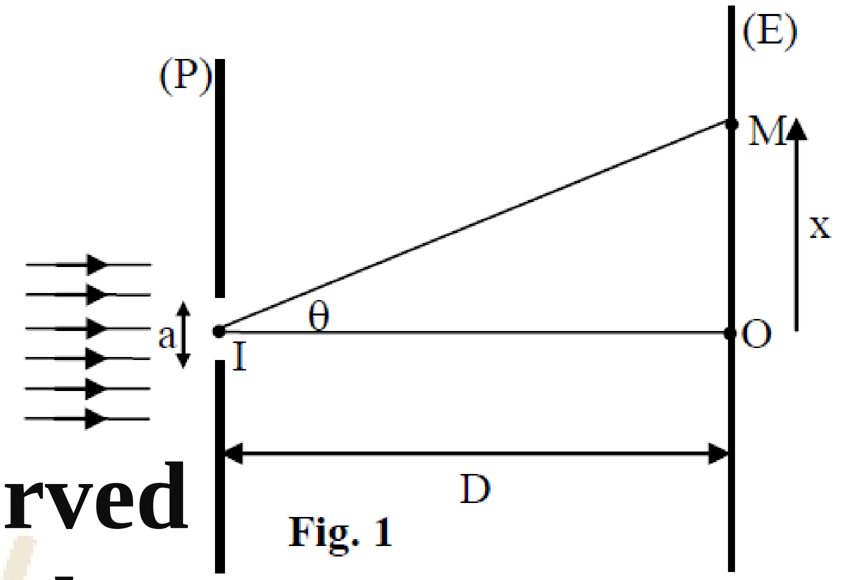


Fig. 1

The phenomenon of diffraction is observed on a screen (E) parallel to (P) and situated at a distance $D = 4$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.

Exercise 2:

$\widehat{OIM} = \theta$ (θ is very small) is the angle of diffraction corresponding to the second dark fringe (Fig. 1).

1) Write the expression of θ in terms of a and λ.

2) Determine the expression of OM = x in terms of a, D and λ.

3) Determine the value of «a» if OM = 1.28cm.

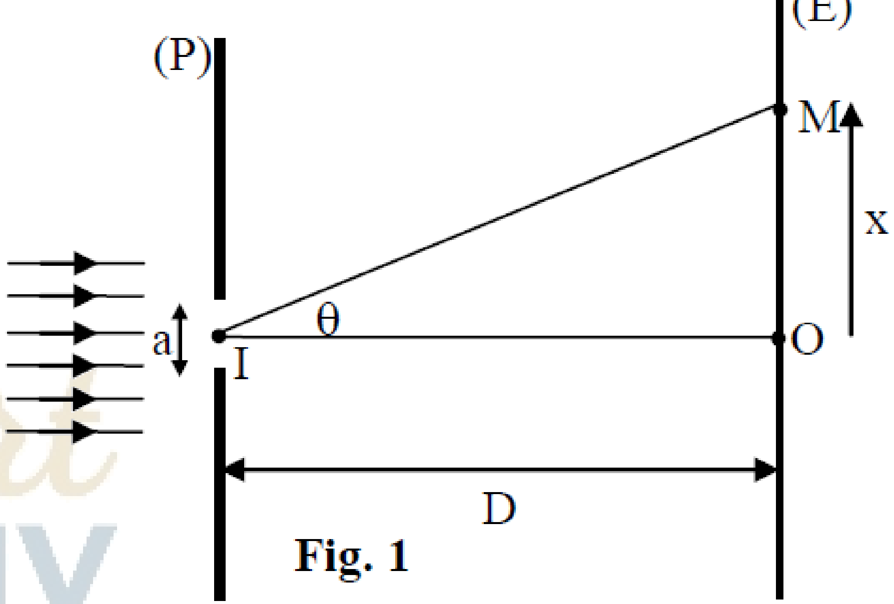


Fig. 1

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)?

Exercise 2:

$\lambda = 640nm$; $D = 4m$; M coincides with 2nd D.F

1)Write the expression of θ in terms of a and λ.

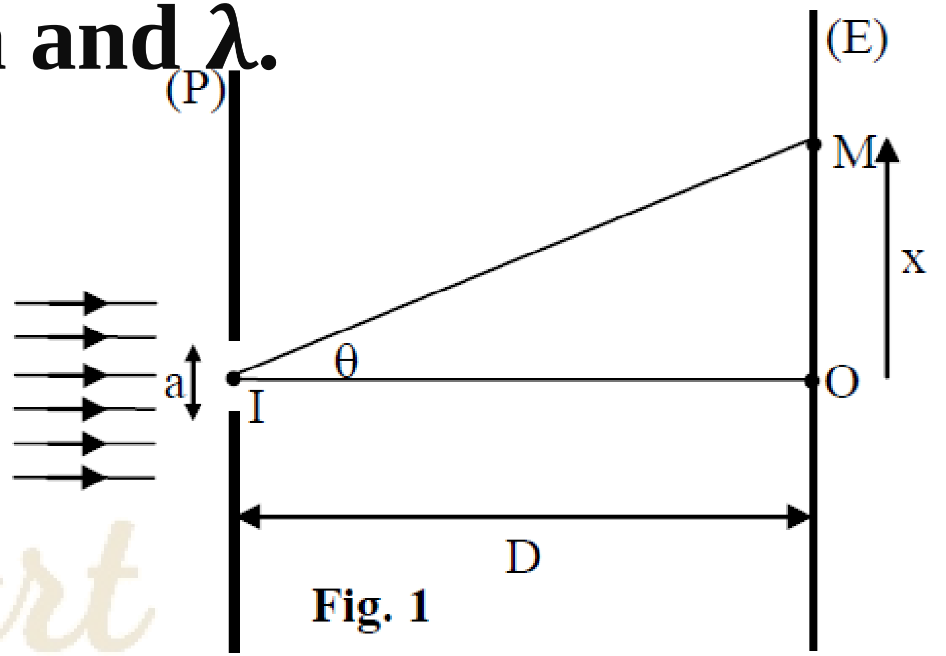


Fig. 1

The angle is small, and M coincides with 2nd D.F then:

$$\sin\theta_n \approx \theta_n = \frac{n\lambda}{a} \Rightarrow \theta = \frac{2\lambda}{a}$$

2)Determine the expression of OM = x in terms of a, D and λ.

$$\tan\theta = \frac{opp}{hyp} = \frac{OM}{D} = \frac{x}{D}$$

The angle $\theta \ll$ is then:

$$\theta = \frac{x}{D}$$

Exercise 2:

$\lambda = 640\text{nm}$; $D = 4\text{m}$; M coincides with 2^{nd} D.F

$$\theta = \frac{2\lambda}{a}$$

And

$$\theta = \frac{x}{D}$$

$$\theta = \theta$$

$$\frac{2\lambda}{a} = \frac{x}{D}$$

$$x = \frac{2\lambda D}{a}$$

Exercise 2:

$\lambda = 640nm$; $D = 4m$; M coincides with 2nd D.F

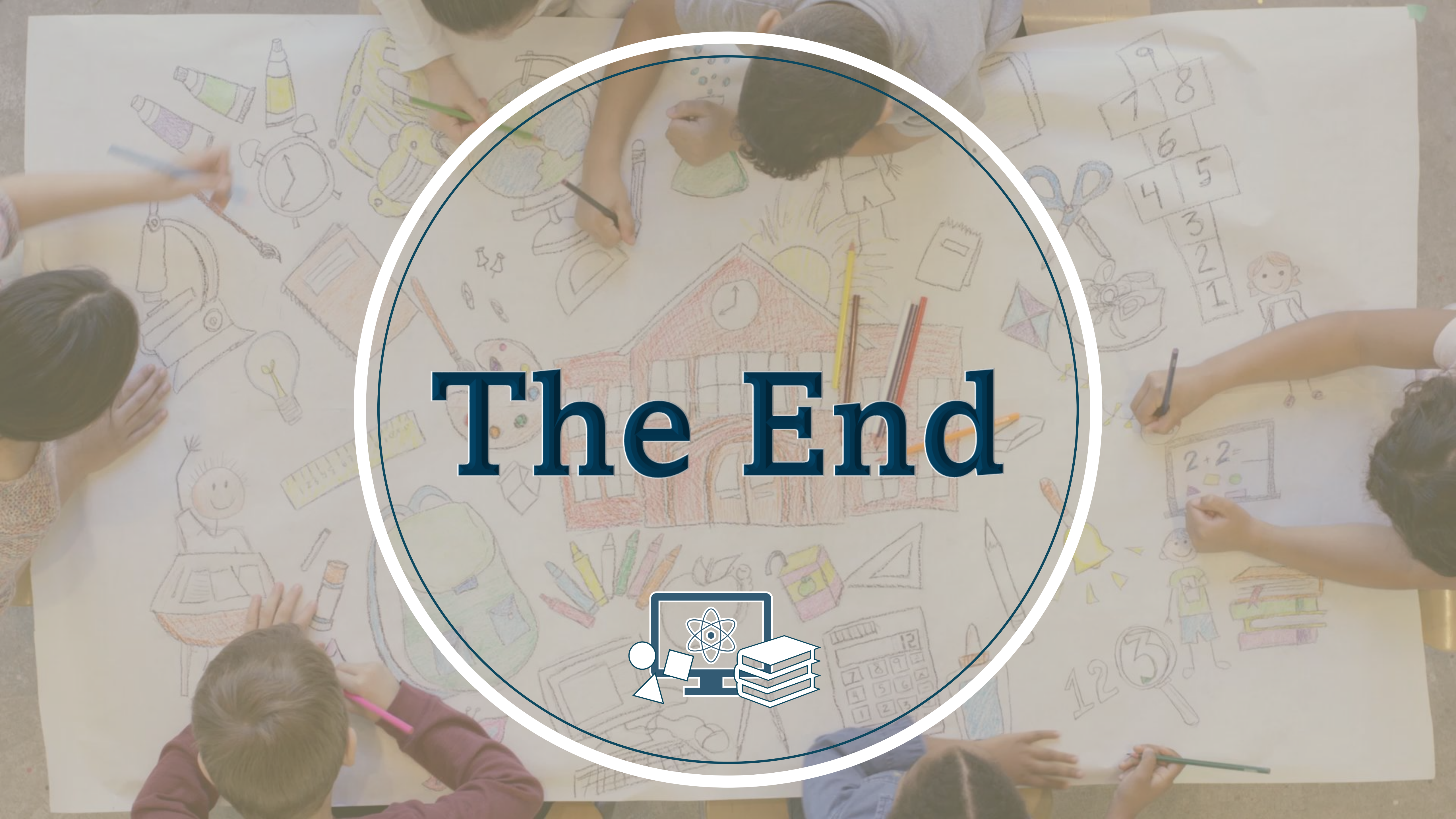
3)Determine the value of «a» if $OM = 1.28cm$.

$$OM = x = \frac{2\lambda D}{a} \Rightarrow a = \frac{2\lambda D}{x} \Rightarrow a = \frac{2 \times 640 \times 10^{-9} \times 4}{1.28 \times 10^{-2}}$$

$$a = 0.4 \times 10^{-3} m$$

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)?

We observe a spot of light.



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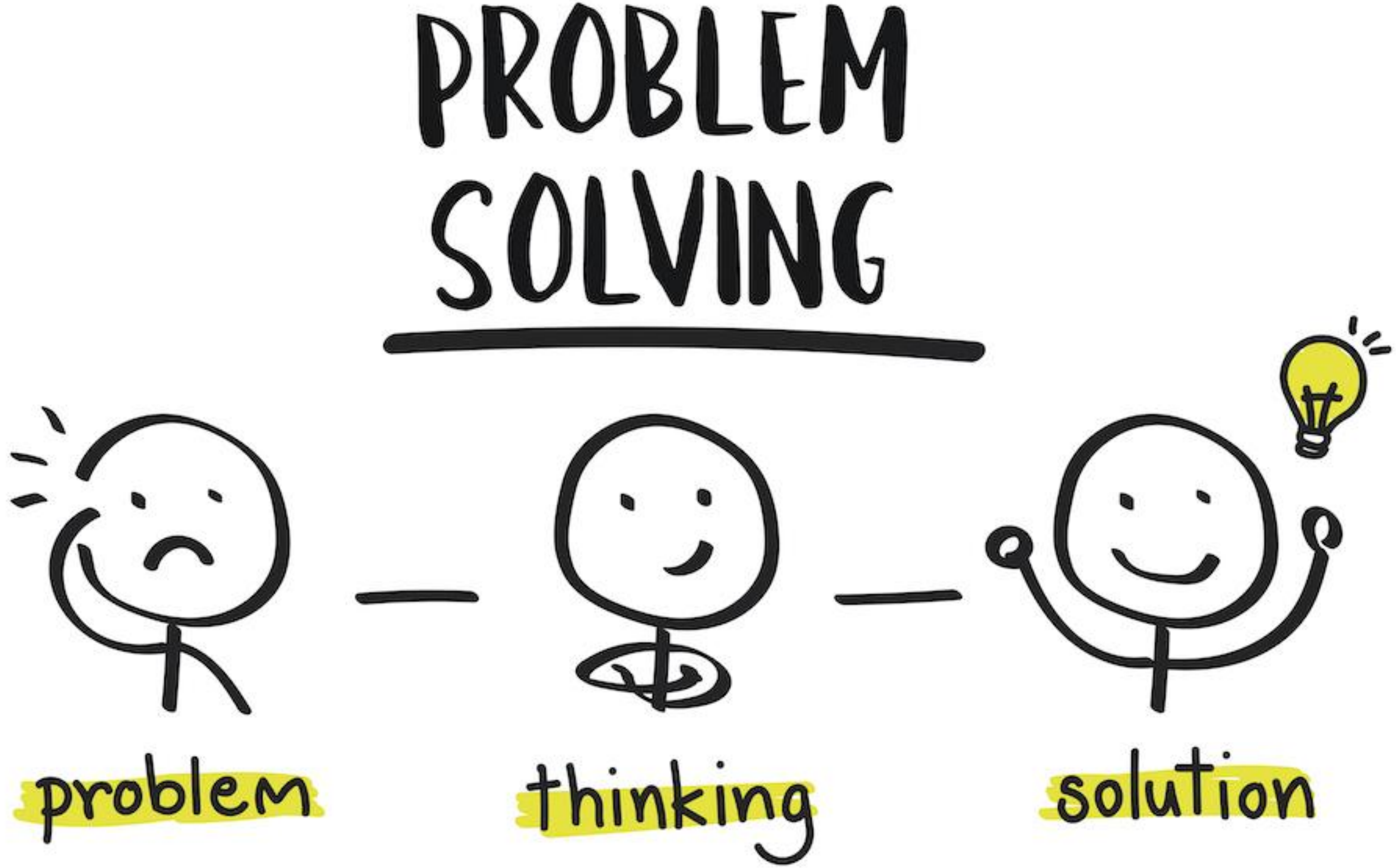
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Exercise 3:

Part A: Measurement of the width of a slit

A laser beam of light, of wavelength in vacuum $\lambda = 632.8nm$, falls normally on a vertical slit of width "a".

The diffraction pattern is observed on a screen placed perpendicular to the leaser beam at a distance $D = 1.5m$ from the slit.

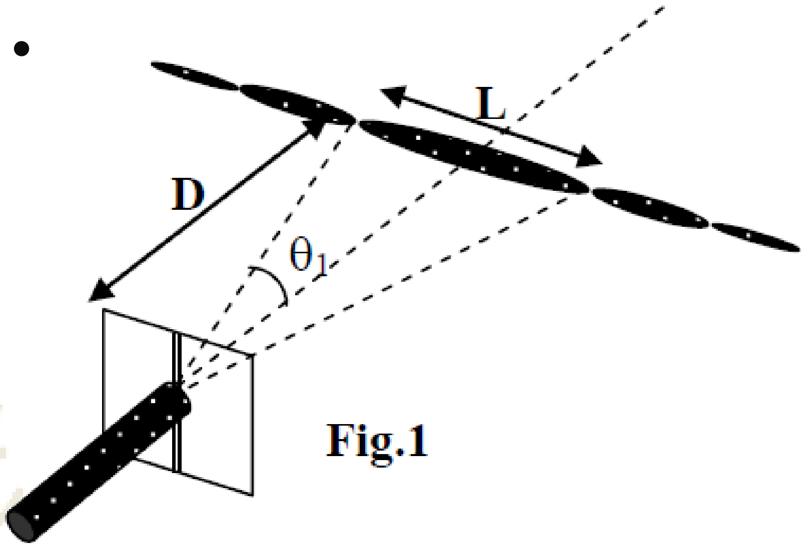


Fig.1

The angle of diffraction θ corresponding to a dark fringe of order n is given by $\sin\theta = \frac{n\lambda}{a}$ where $n = \pm1, \pm2, \pm3 \ldots$ For small angles, take $\tan\theta \approx \sin\theta \approx \theta$ in radian.

Exercise 3:

1) **Describe the aspect of the diffraction pattern observed on the screen.**

2) **Write the relation among a, θ_1 and λ.**

3) **Establish the relation among a, λ, L and D.**

4) **Knowing that $L = 6.3$ mm, calculate the width "a" of the used slit**

Exercise 3:

1)Describe the aspect of the diffraction pattern observed on the screen.

- **Alternating bright and dark fringes.**
- **The size of the central bright fringe is double that of any other bright fringe.**
- **The direction of the pattern of fringes is perpendicular to that of the slit.**
- **Central bright fringe id of maximum intensity.**

Exercise 3:

$\lambda = 632.8nm; D = 1.5m;$

2)Write the relation among a, θ_1 and λ.

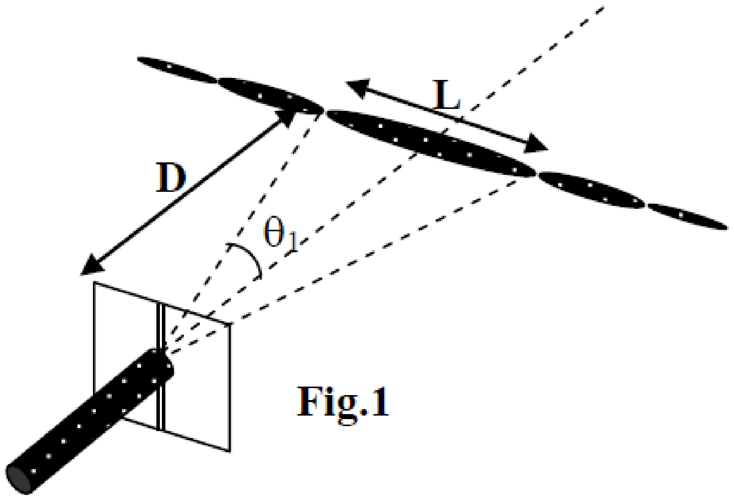


Fig.1

$$sin\theta_n \approx \theta_n = \frac{n\lambda}{a} \Rightarrow \theta_1 = \frac{\lambda}{a}$$

3)Establish the relation among a, λ, L and D.

$$tan\theta_1 = \frac{L}{2D}$$

$\theta \ll$ then: $tan\theta_1 = \theta_1$

$$\theta_1 = \frac{L}{2D}$$

$$\theta_1 = \theta_1$$

$$\frac{\lambda}{a} = \frac{L}{2D}$$

Exercise 3:

$\lambda = 632.8\text{nm};\ D = 1.5\text{m};$

4) Knowing that $L = 6.3$ mm, calculate the width "a" of the used slit

$$\frac{\lambda}{a} = \frac{L}{2D}$$

$$a = \frac{2\lambda D}{L}$$

$$a = \frac{2 \times 632.8 \times 10^{-9} \times 1.5}{6.3 \times 10^{-3}}$$

$$a = 3 \times 10^{-4} m$$

Exercise 3:

Part B: Controlling the thickness of thin wire

A manufacturer of thin wires wishes to control the diameter of his product.

He uses the same set-up mentioned in part (A) but he replaces the slit by a thin vertical wire. He observes on the screen the phenomenon of diffraction (fig. 2).

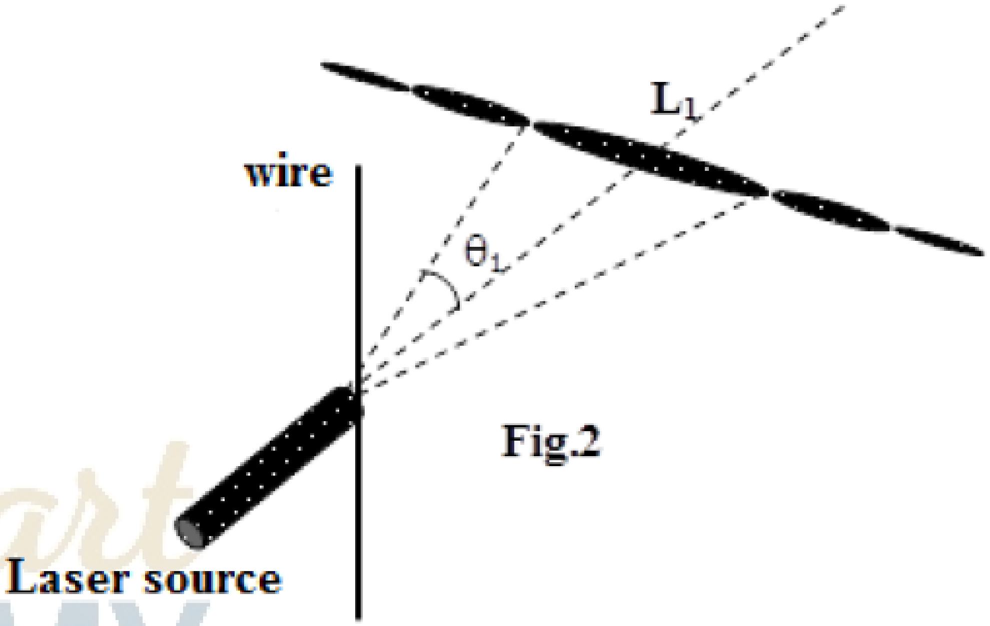


Fig.2

For $D = 2.60m$, he obtains a central fringe of constant linear width $L_1 = 3.4mm$.

Exercise 3:

1) Calculate the value of the diameter "a_1" of the wire at the illuminated point.

2) The manufacturer illuminates the wire at different positions under the same precedent conditions.

Specify the indicator that permits the manufacturer to check that the diameter of the wire is constant.

Exercise 3:

$D = 2.60m, L_1 = 3.4mm$ mm.

1)Calculate the value of the diameter "a_1" of the wire at the illuminated point.

$$a_1 = \frac{2\lambda D}{L_1}$$

$$a_1 = \frac{2 \times 632.8 \times 10^{-9} \times 2.6}{3.4 \times 10^{-3}}$$

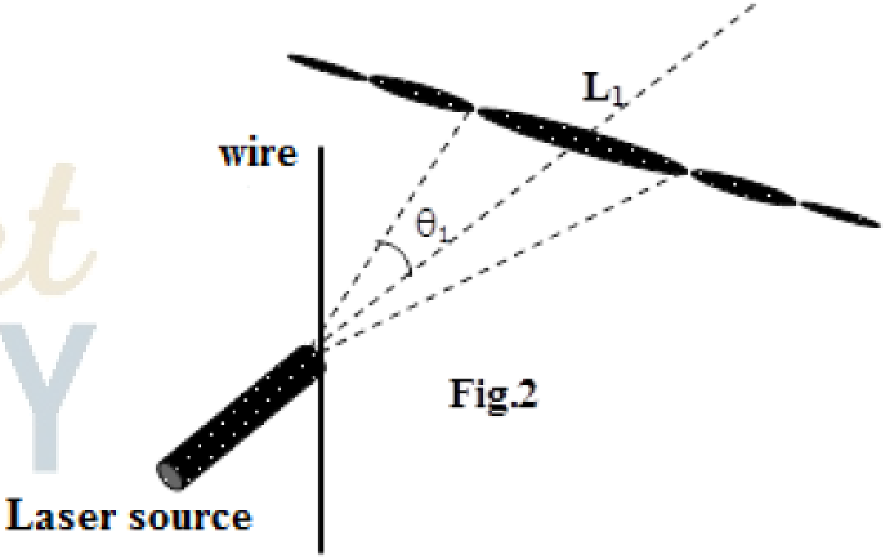
$$a_1 = 0.967 \times 10^{-4} m$$

Exercise 3:

$D = 2.60m, L_1 = 3.4mm$ mm.

2)The manufacturer illuminates the wire at different positions under the same precedent conditions. Specify the indicator that permits the manufacturer to check that the diameter of the wire is constant.

$$a_1 = \frac{2\lambda D}{L_1}$$



The linear width of the central fringe (L).

Because if L is constant then a is constant

Exercise 3:

Part C: Measurement of the index of water

We place the whole set-up of part (A) in water of index of refraction n_{water}. We obtain a new diffraction pattern.

We find that for $D = 1.5m$ and $a = 0.3mm$, the linear width of the central fringe is $L_2 = 4.7$mm.

1)Calculate the wavelength λ' of the laser light in water.

2) a) Determine the relation among λ, λ' and n_{water}.

b) Deduce the value of n_{water}.

Exercise 3:

$n_{water}; D = 1.5m; a = 0.3mm; L_2 = 4.7mm.$

1)Calculate the wavelength λ' of the laser light in water.

Apply the same relation we obtain:

$$\frac{\lambda'}{a} = \frac{L}{2D}$$

$$\lambda' = \frac{aL}{2D}$$

$$\lambda' = \frac{0.3 \times 10^{-3} \times 4.7 \times 10^{-3}}{2 \times 1.5}$$

$$\lambda' = 470 \times 10^{-9} m$$

$$\lambda' = 470nm$$

Exercise 3:

$n_{water}; D = 1.5m; a = 0.3mm; L_2 = 4.7mm.$

2) a) Determine the relation among λ, λ' and n_{water}.

$$\lambda' = \frac{V}{\nu}$$ And $$\lambda = \frac{C}{\nu}$$

$$\nu = \nu$$

$$\frac{V}{\lambda'} = \frac{C}{\lambda}$$

$$\frac{\lambda}{\lambda'} = \frac{C}{V}$$

$$\frac{\lambda}{\lambda'} = n_{water}$$

Exercise 3:

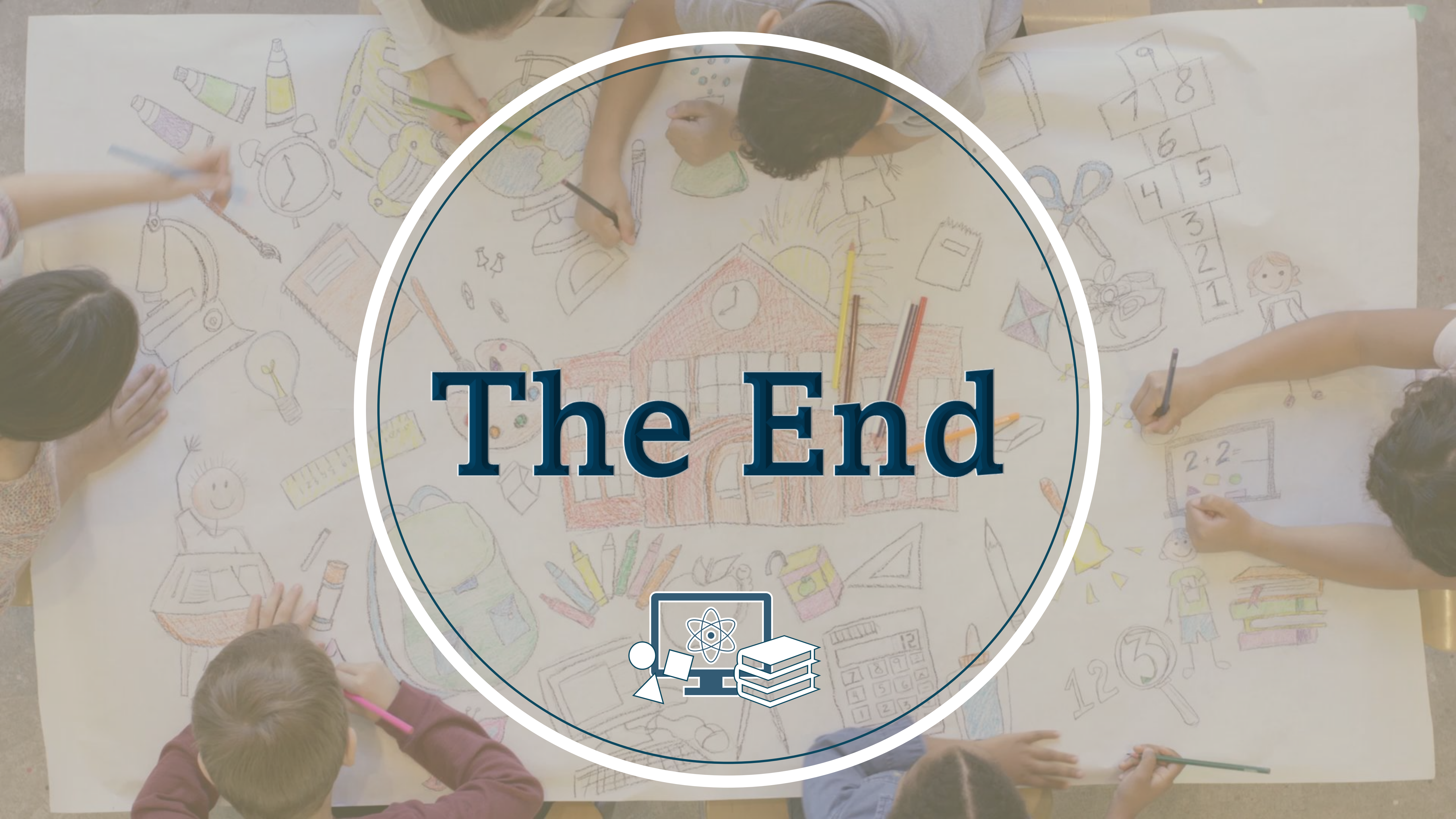
b) Deduce the value of n_{water}.

$$\frac{1}{n_{water}} = \frac{\lambda'}{\lambda}$$

$$\frac{1}{n_{water}} = \frac{470 \times 10^{-9} m}{632.8 \times 10^{-9} m}$$

$$n_{water} = \frac{632.8 \times 10^{-9} m}{470 \times 10^{-9} m}$$

$$n_{water} = 1.34$$



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