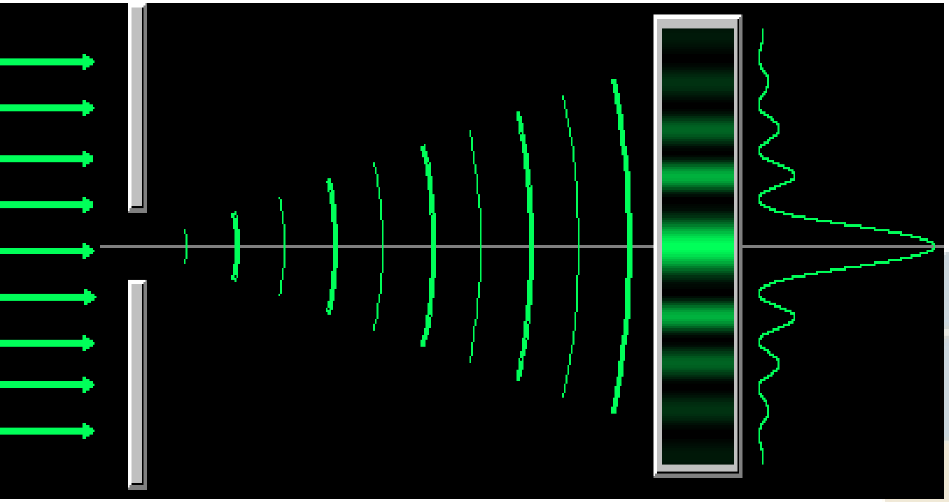
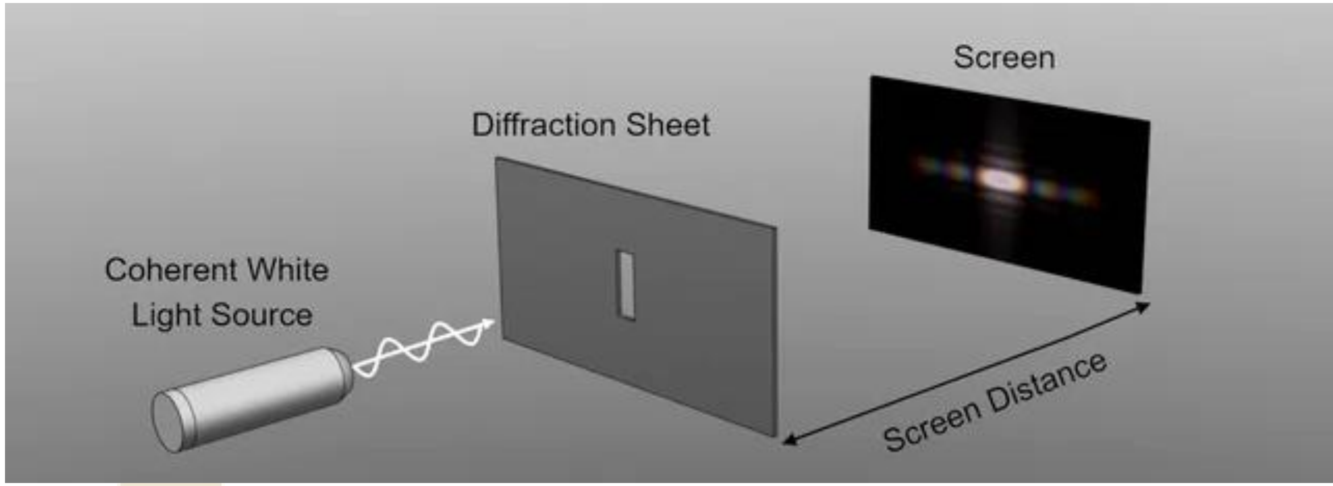




Unit III

Chapter 13

Wave Aspect of Light - Diffraction

Prepared and Presented by: Mr. Mohamad Seif

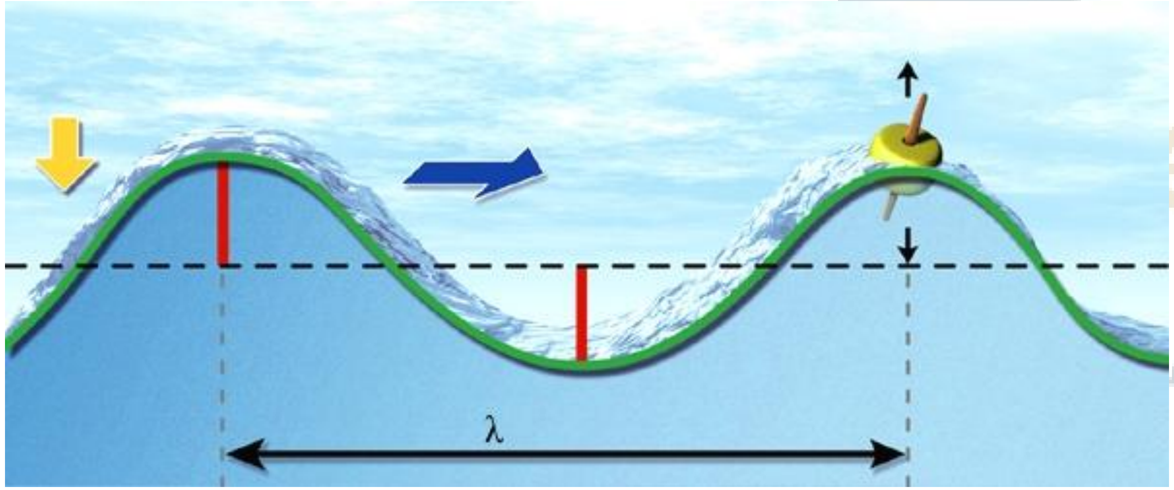
OBJECTIVES

1	**Revision about waves**
2	**Properties of Visible Light**

Revision about waves

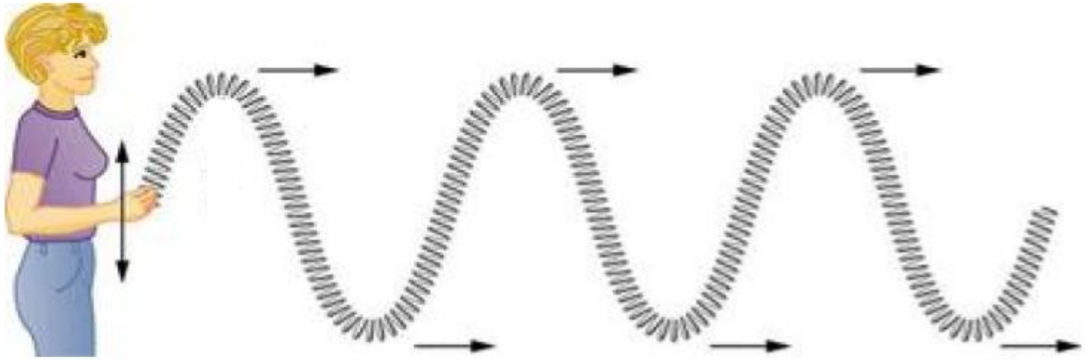
What is a wave?

A wave is a moving vibration. (It is the propagation of a vibration).



Remark:

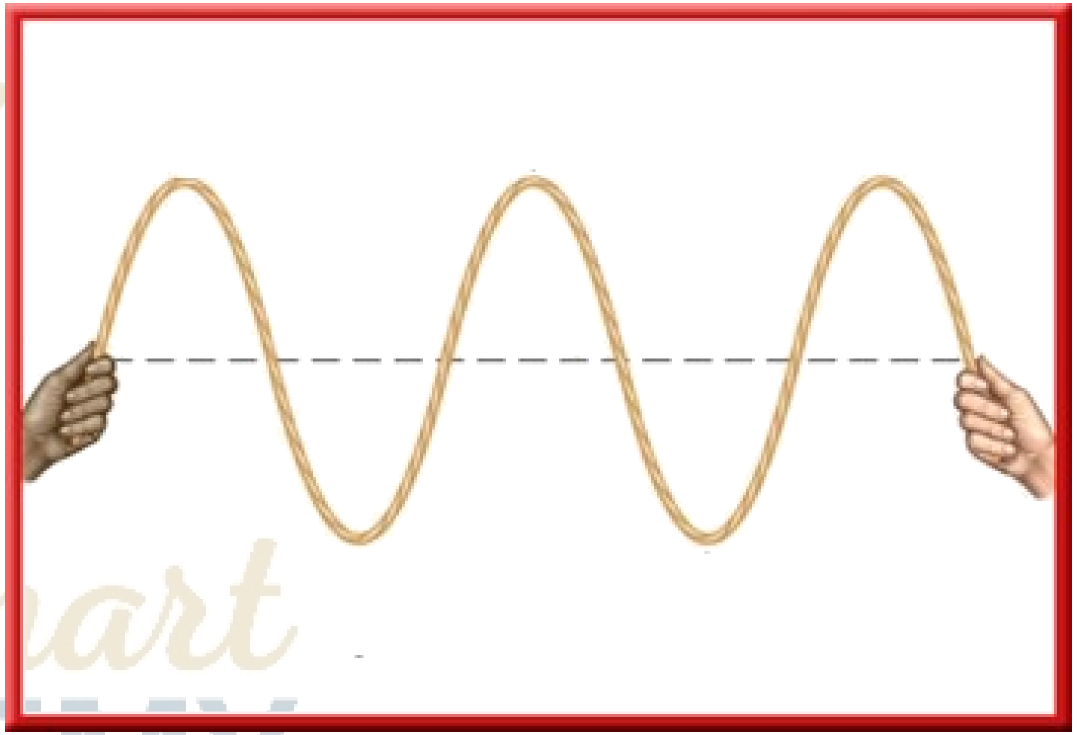
Waves transport energy and does not transport matter



Revision about waves

A wave is a moving vibration, so it has the same characteristics of a vibration:

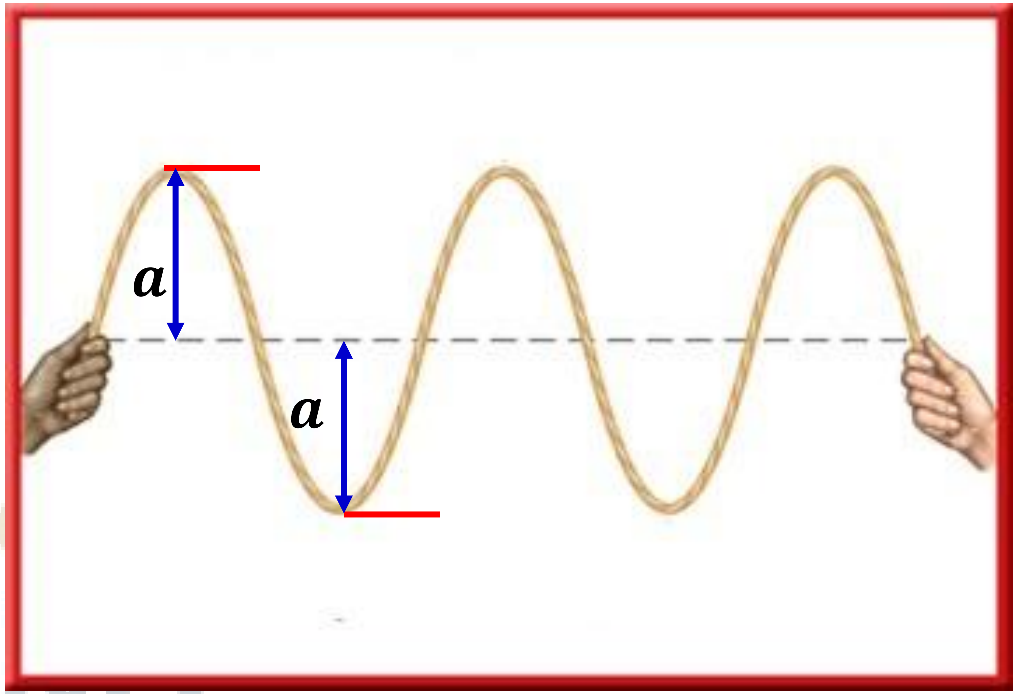
- **Amplitude:**
- **Period:**
- **Frequency:**
- **Wavelength: A wave move, this means it covers a certain distance called wavelength (λ).**
- **Speed of wave.**



Revision about waves

1.Amplitude (a):

Amplitude is the distance between axis and maximum (crest) or minimum point (trough).



2. Period (T):

Period is the time for one wave, in seconds.

3. Frequency (f):

Frequency is the number of waves per time. For one wave.

$$f = \frac{1}{T}$$

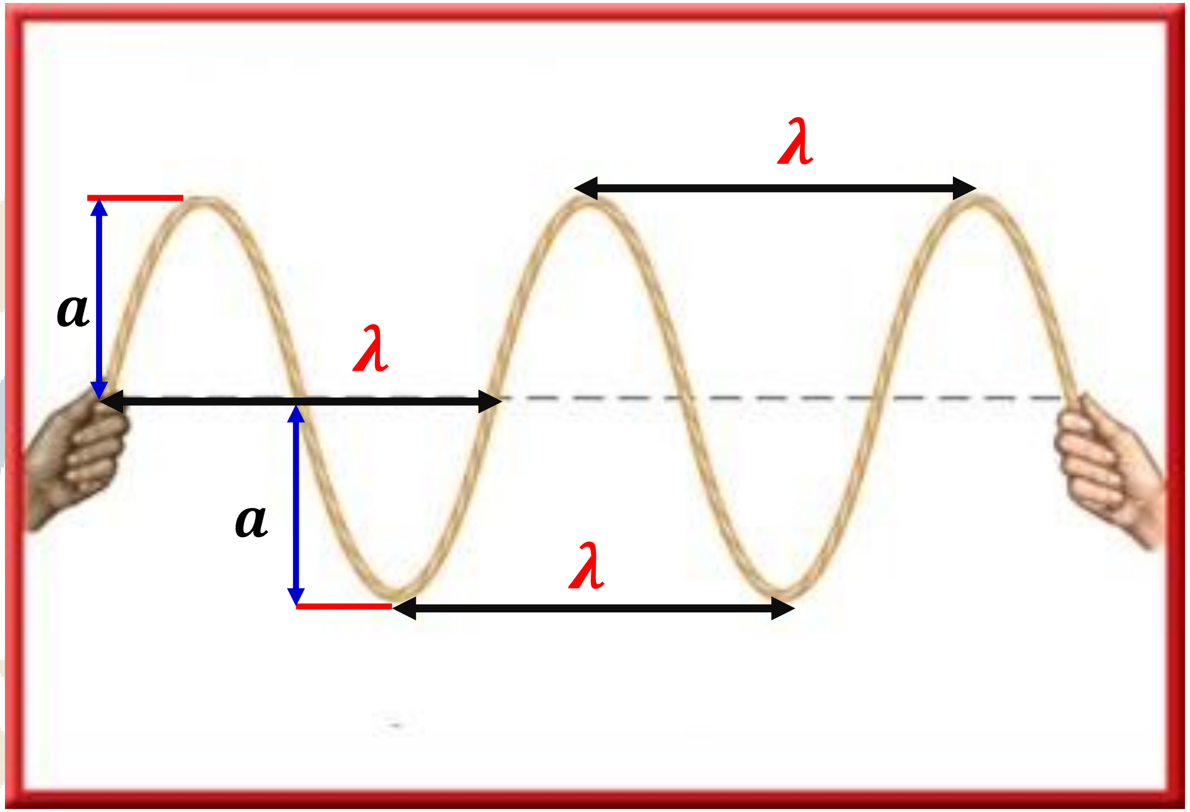
Revision about waves

4. Wavelength (λ):

Wavelength is the distance traveled.

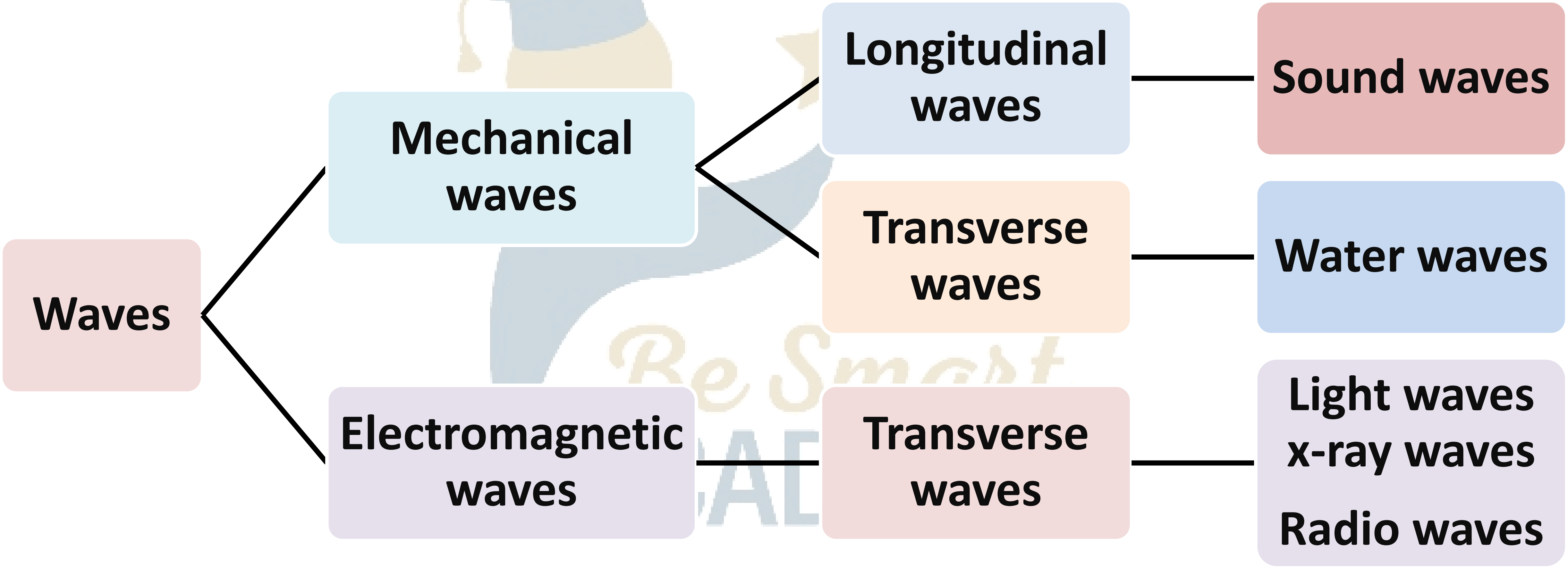
5. Speed (V):

Speed is the distance covered by the wave per unit of time. It is in m/s



$$V = \frac{d}{t}$$ **For one wave** $$V = \frac{\lambda}{T} \Rightarrow V = \lambda . f$$

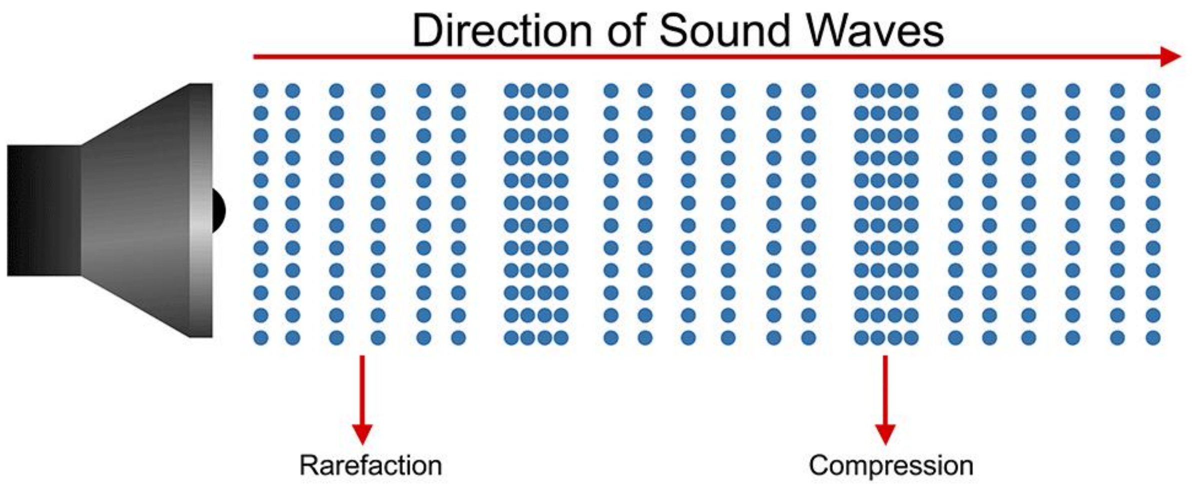
Revision about waves



Revision about waves

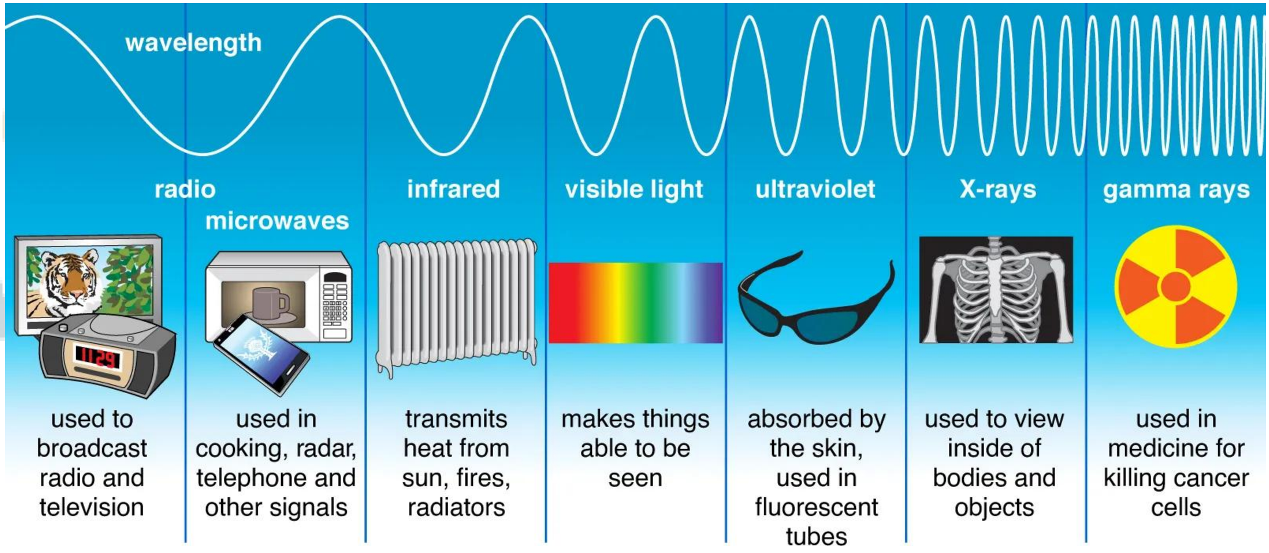
Mechanical waves:

It is a wave that <u>needs a medium to propagate,</u> so it can't propagate in vacuum, such as sound wave, water wave



Electromagnetic waves:

It is a wave that **doesn't require** medium to propagate. This wave can <u>propagate in medium or in vacuum, such as light waves</u>

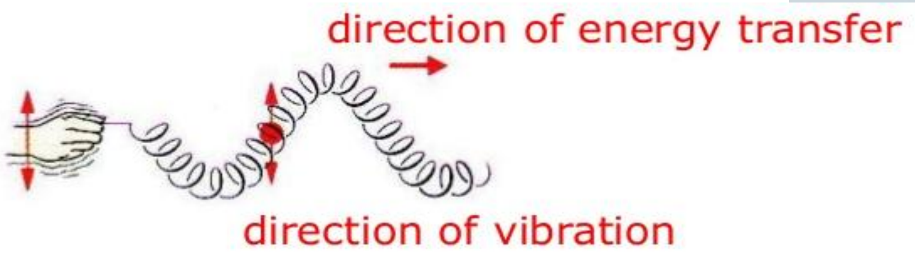


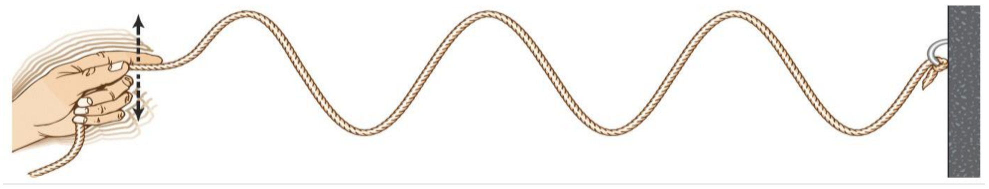
Revision about waves

Transverse wave :

Causes the particles of the medium vibrate ⊥ to the direction of the wave motion

water waves, light waves...

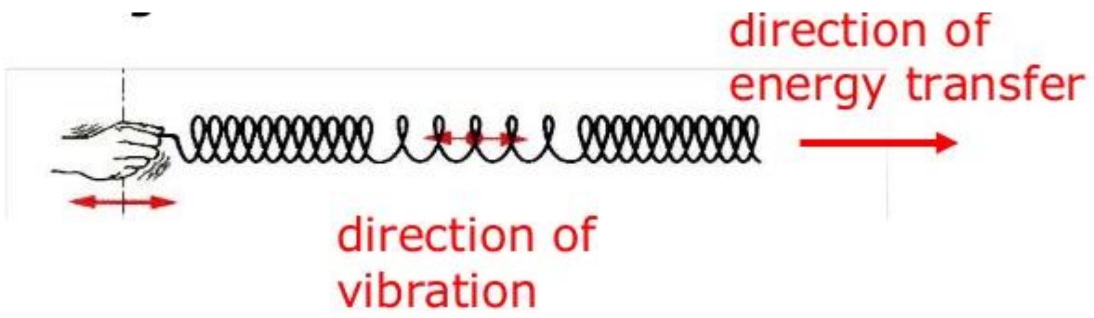


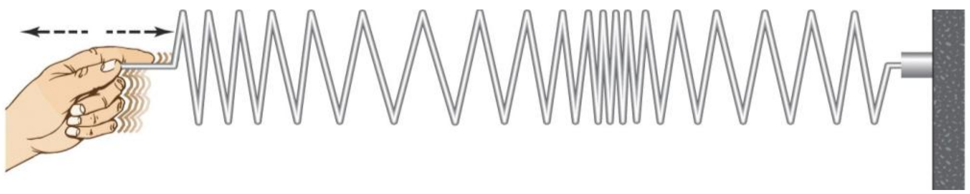


Longitudinal wave:

Causes the particles of the medium vibrate parallel to the direction of the wave motion.

Sound waves, spring…





Properties of visible light

Light undergoes many phenomena including:

1. **Reflection of light:** if light hits a mirror or any reflecting surface, it is reflected such that the angle of reflection is equal to the angle of incidence.
2. **Refraction of light:** if light moves from one transparent medium to another, it changes its direction.
3. **Rectilinear propagation of light:** in a homogeneous and transparent medium (air, water, glass…), light propagates in straight lines.
4. **Diffraction** of light, Interference of light and photo-electric effect are new phenomenon will be studied

Properties of visible light

- **Light is made up of oscillating electric and magnetic fields.**
- **Light is an electromagnetic radiation.**
- **A light radiation is sinusoidal transverse wave that propagates in a straight line in a homogenous medium.**
- **The speed of light is vacuum or still air is:**

$$C = 3 \times 10^{8} m/s$$

- **The wavelength of light of speed c and frequency ν in vacuum is:**

$$\lambda = \frac{C}{\nu}$$

Properties of visible light

The speed of light in a medium of index of refraction n is:

$$V = \frac{C}{n}$$

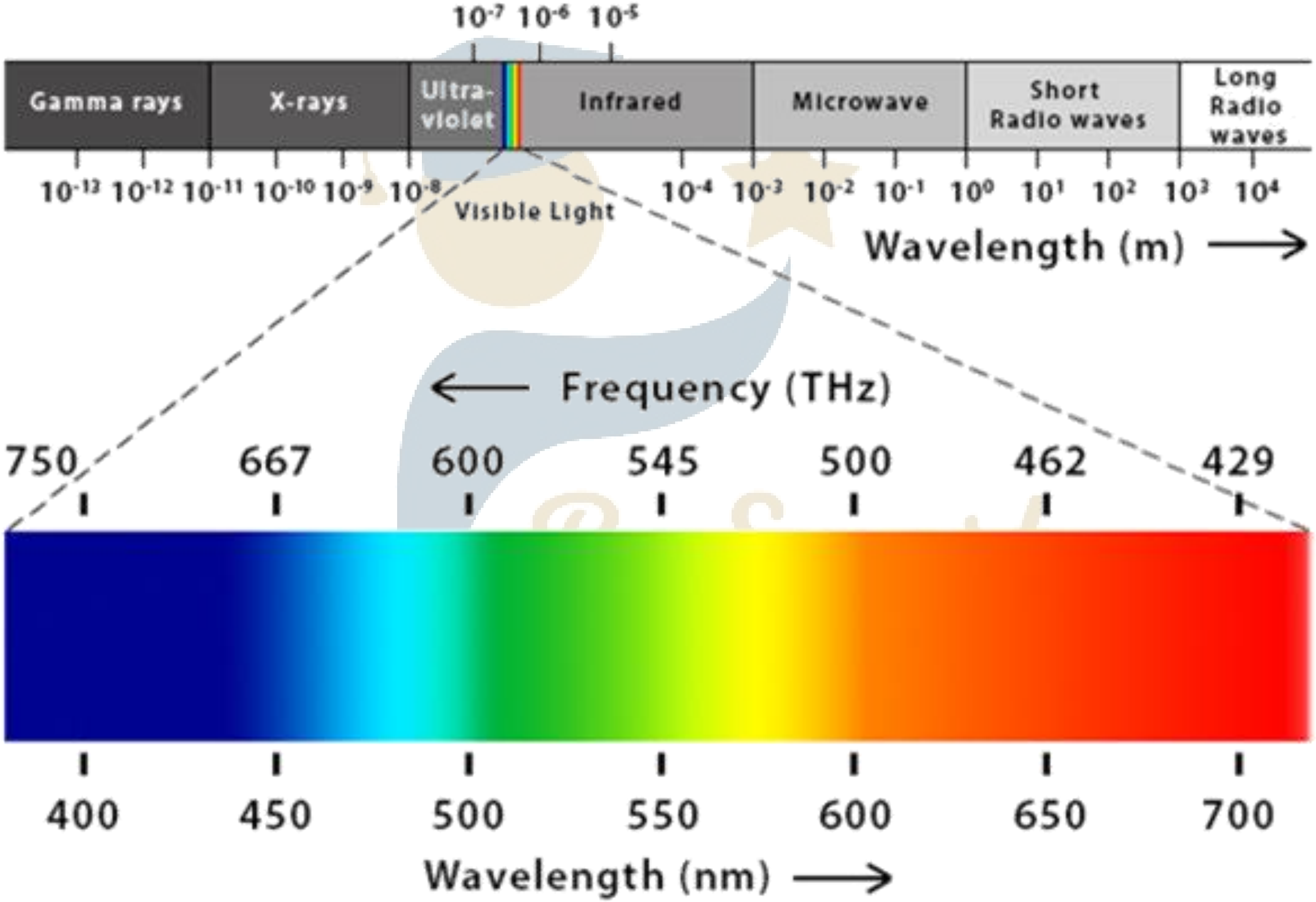
The wavelength of light of frequency ν' and speed V in a medium of index n is:

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

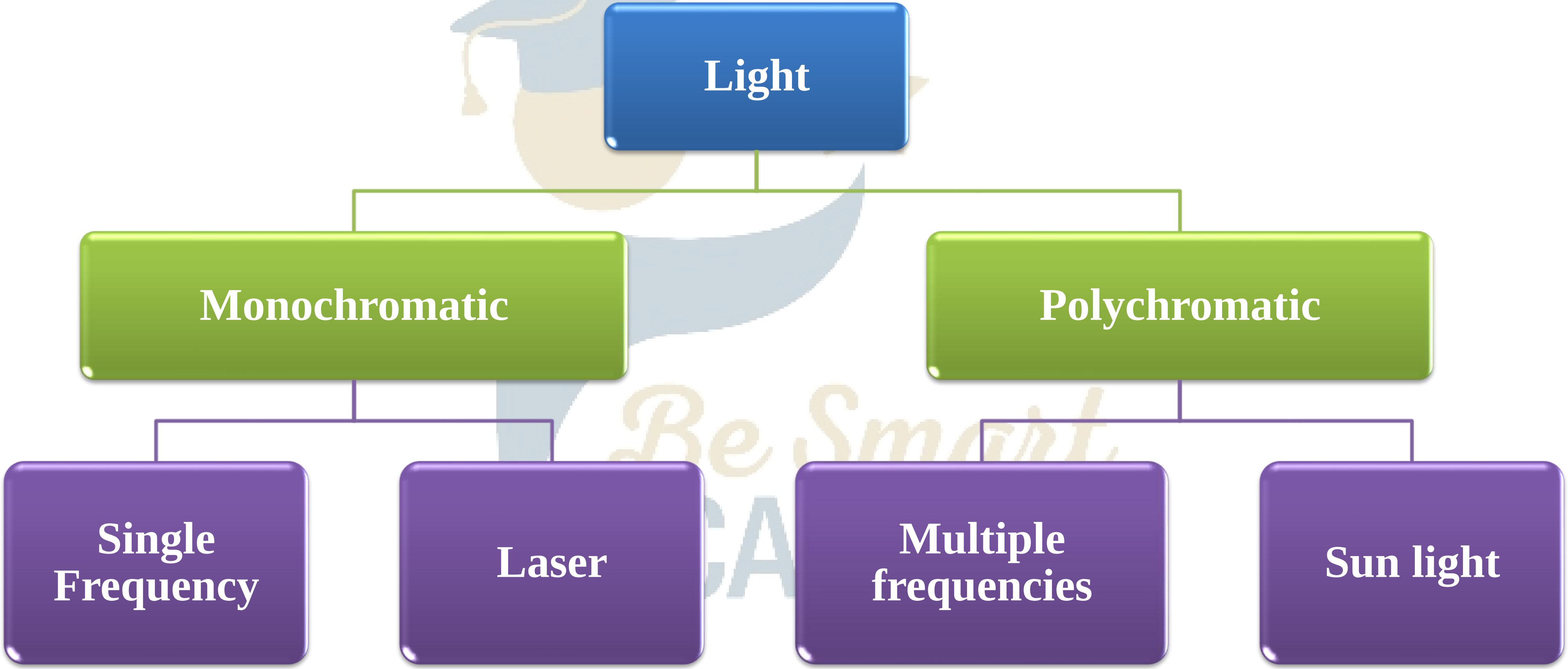
The wavelength range of visible light in vacuum is:

$$400\text{nm} \leq f_{visible} \leq 750nm$$

Properties of visible light



Properties of visible light



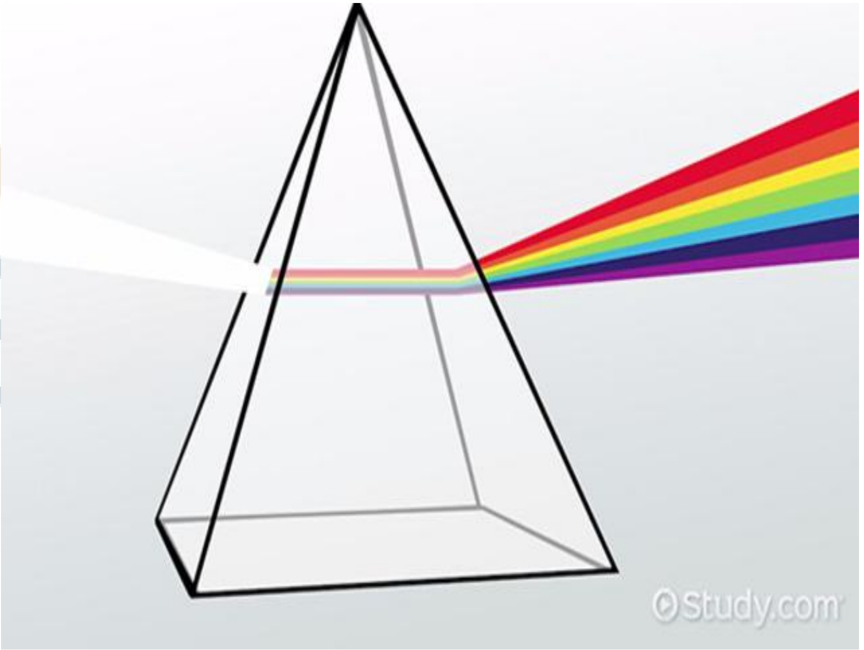
Properties of visible light

Monochromatic light:

Monochromatic light: is light consists of one radiation, one color, one wavelength and one frequency. Example: laser light.

Polychromatic light:

Polychromatic light: is a light consists of many radiations (colors) and many frequencies. Example while or sun light

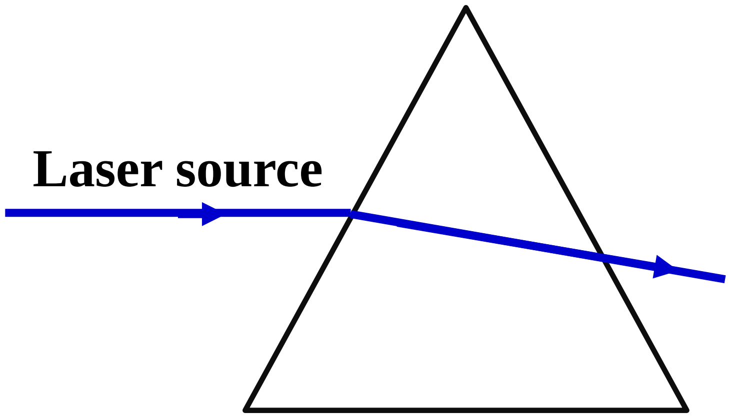


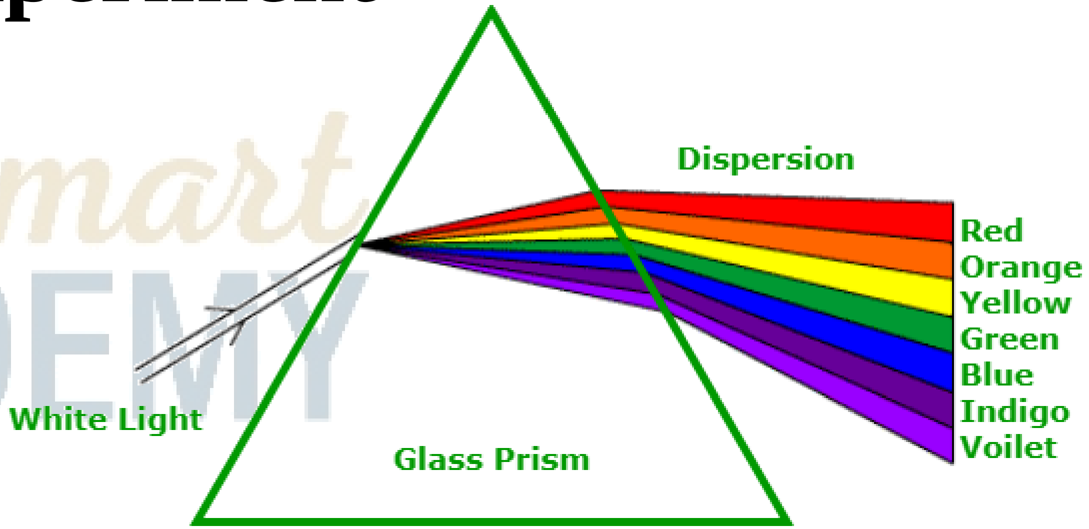
Properties of visible light

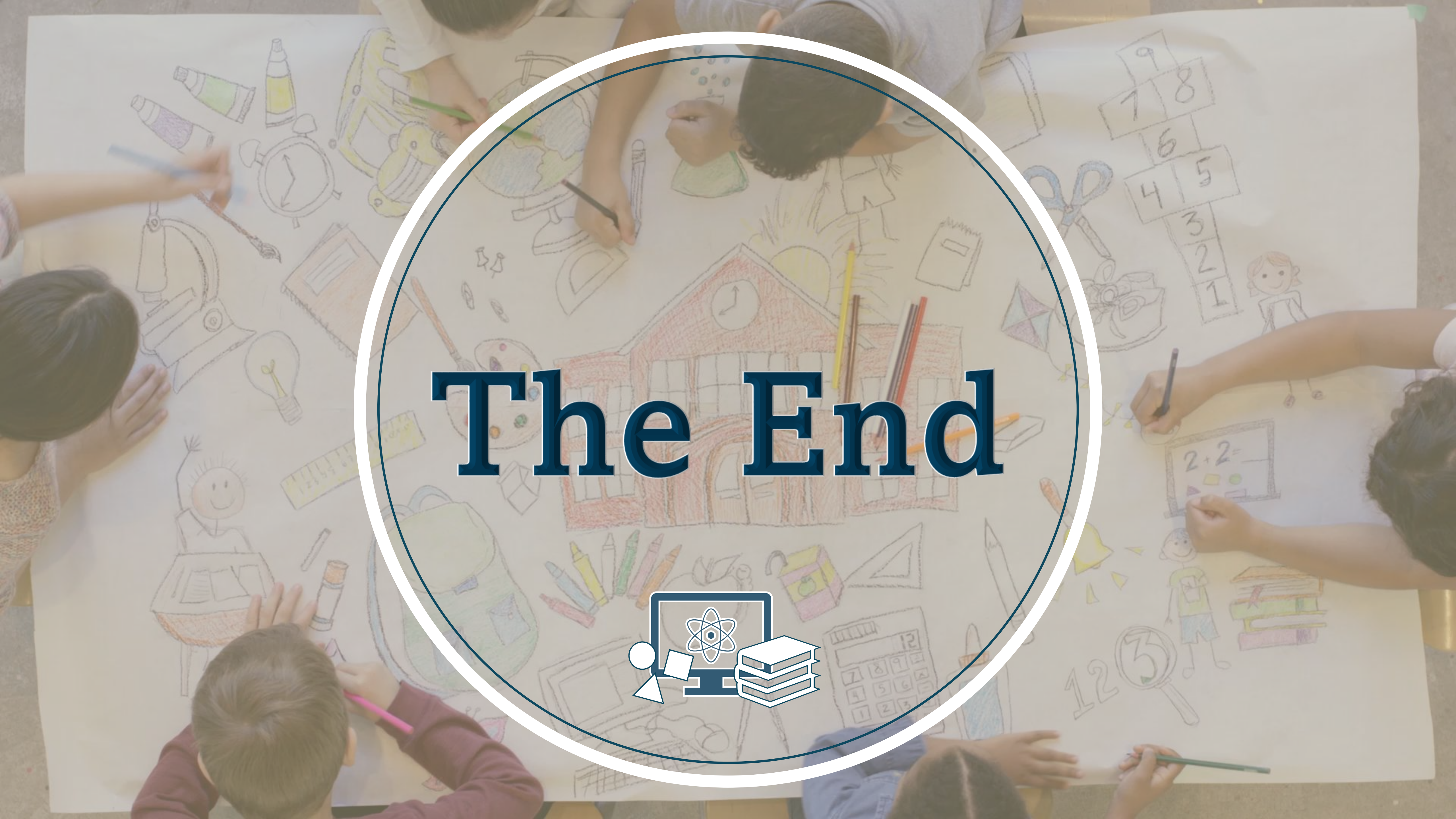
Dispersion of light:

Dispersion of light is the decomposition of light into its initial components.

We can distinguish between monochromatic and polychromatic light using prim experiment



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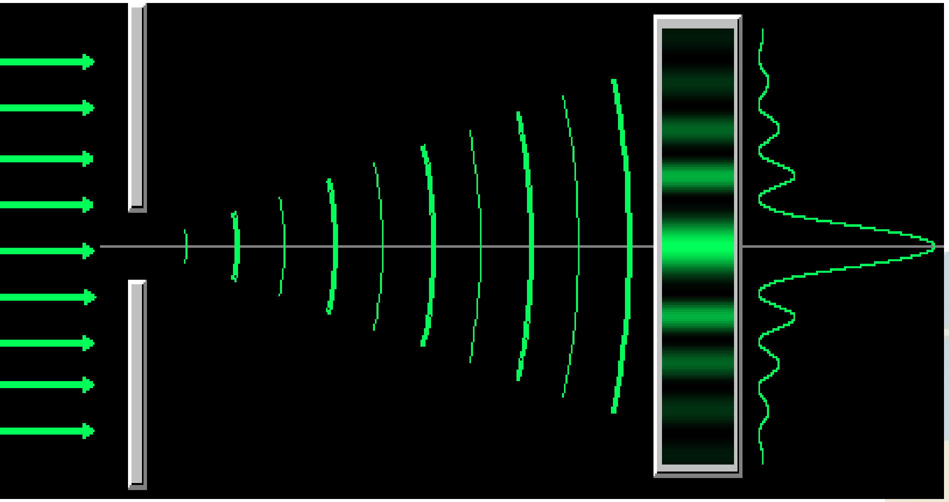
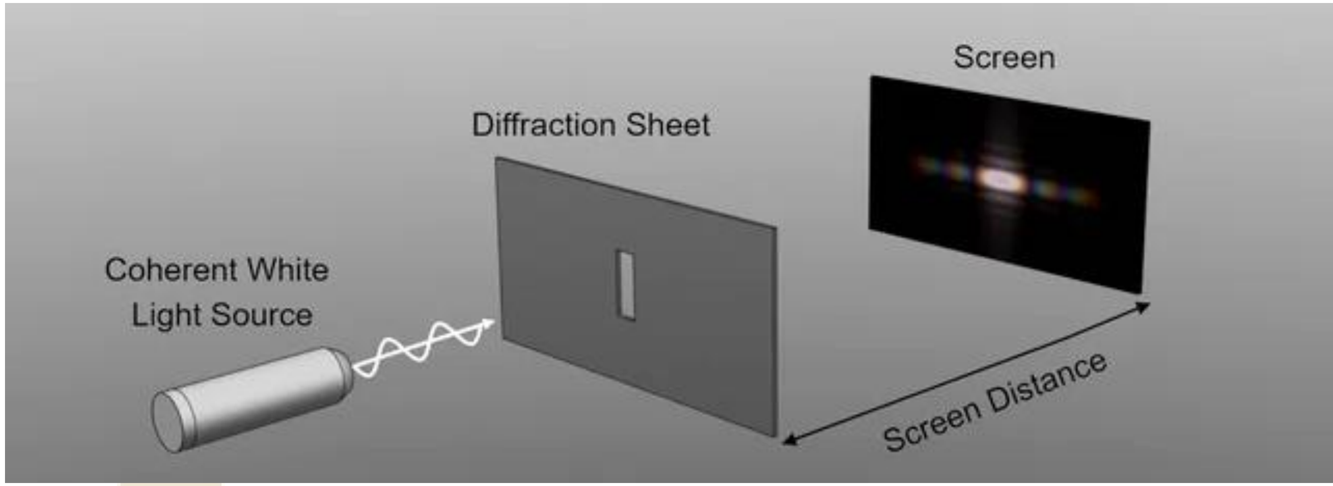




Unit III

Chapter 13

Wave Aspect of Light - Diffraction

Prepared and Presented by: Mr. Mohamad Seif

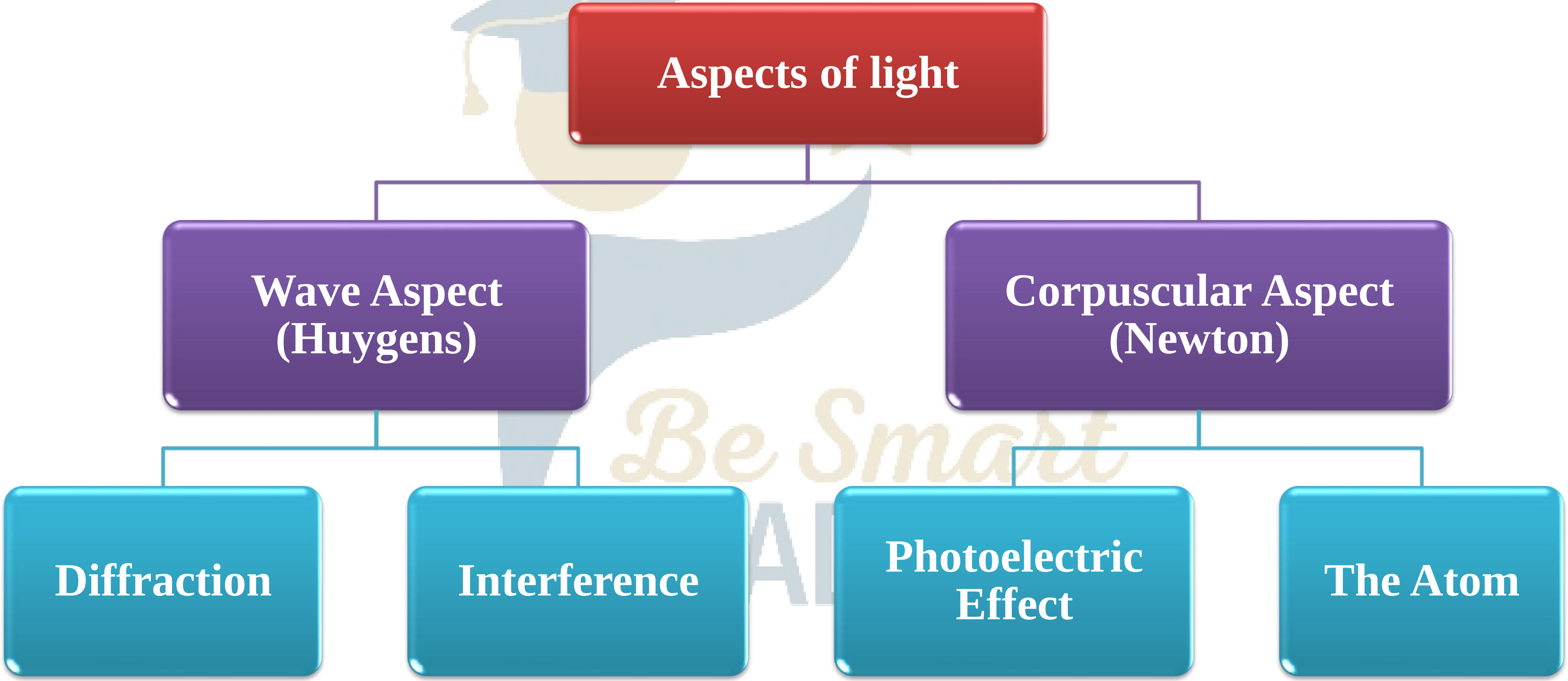
OBJECTIVES

1 **Definition of Diffraction of light**

2 **Description of Diffraction Pattern**

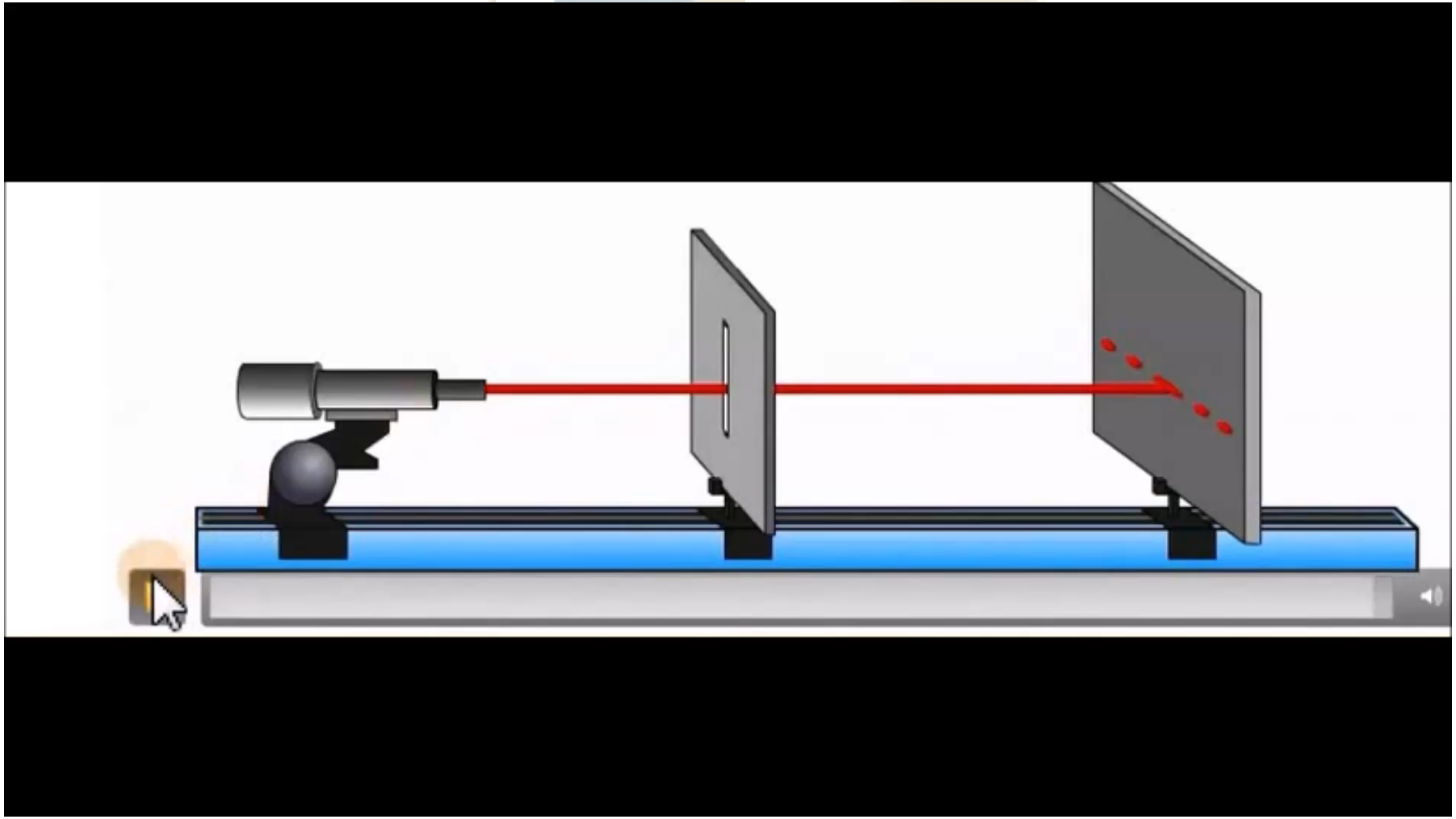
3 **Interpretation of Diffraction Pattern**

Diffraction of light

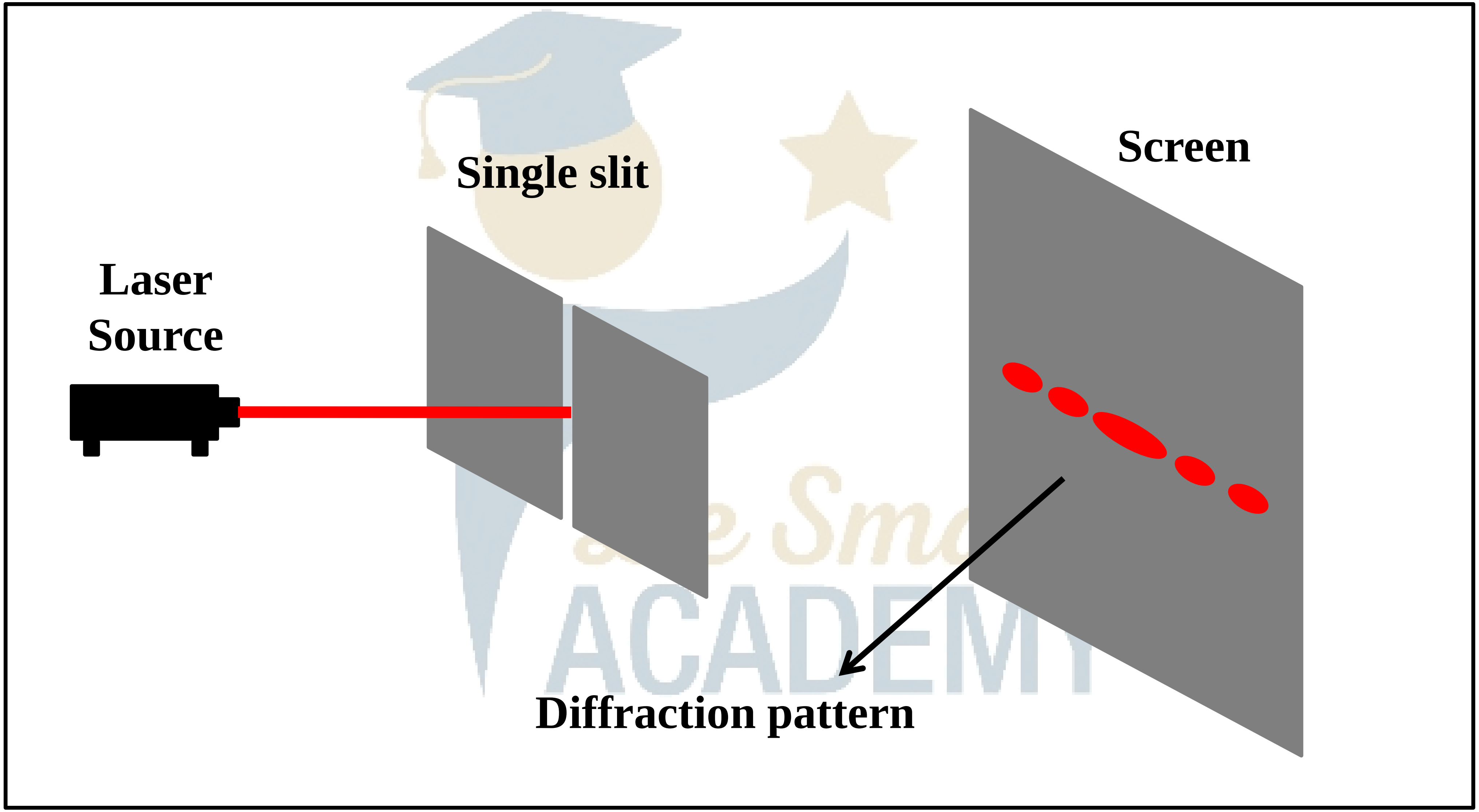


Diffraction of light

Diffraction: **is a phenomenon that takes place when the light passes through a very small opening(slit) ($a \leq 1mm$).**

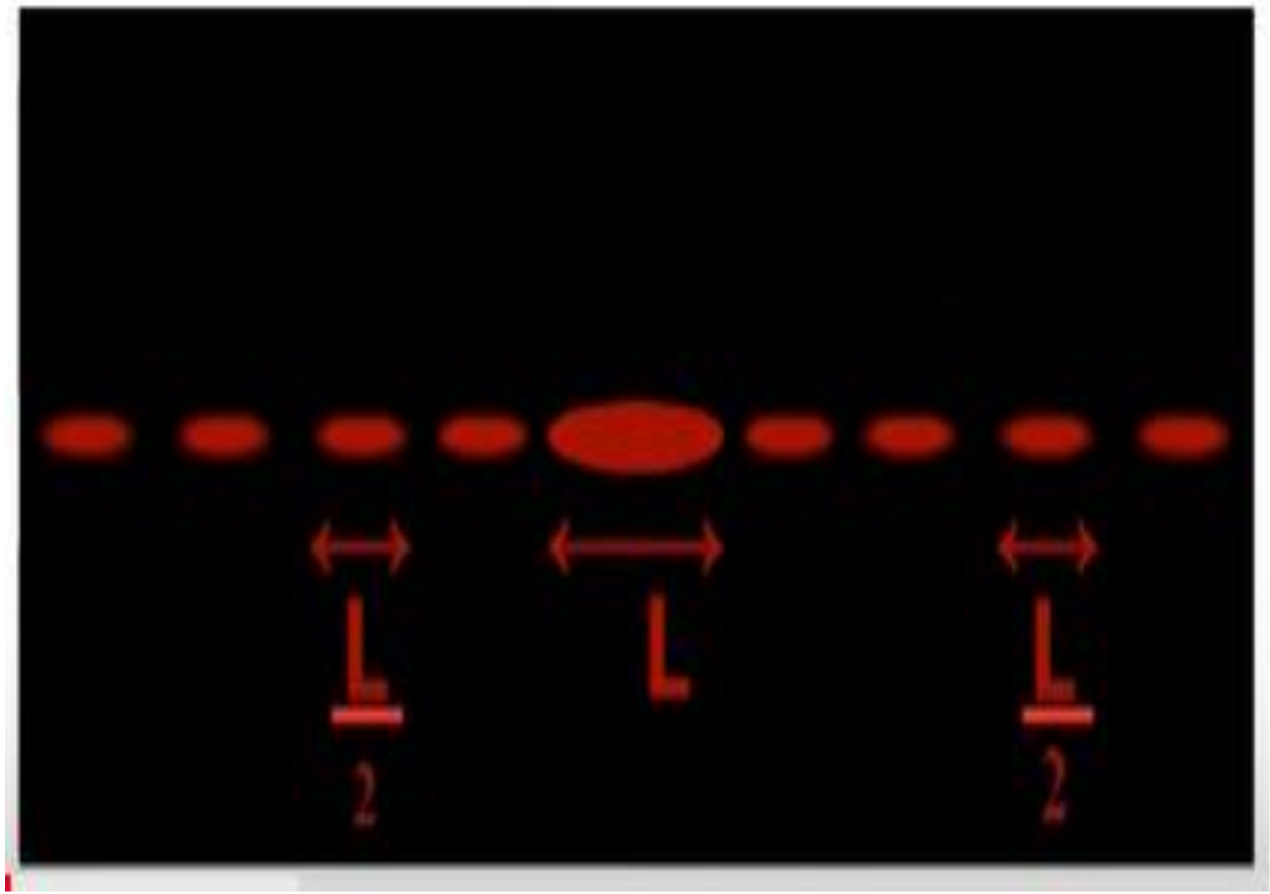


Diffraction of light



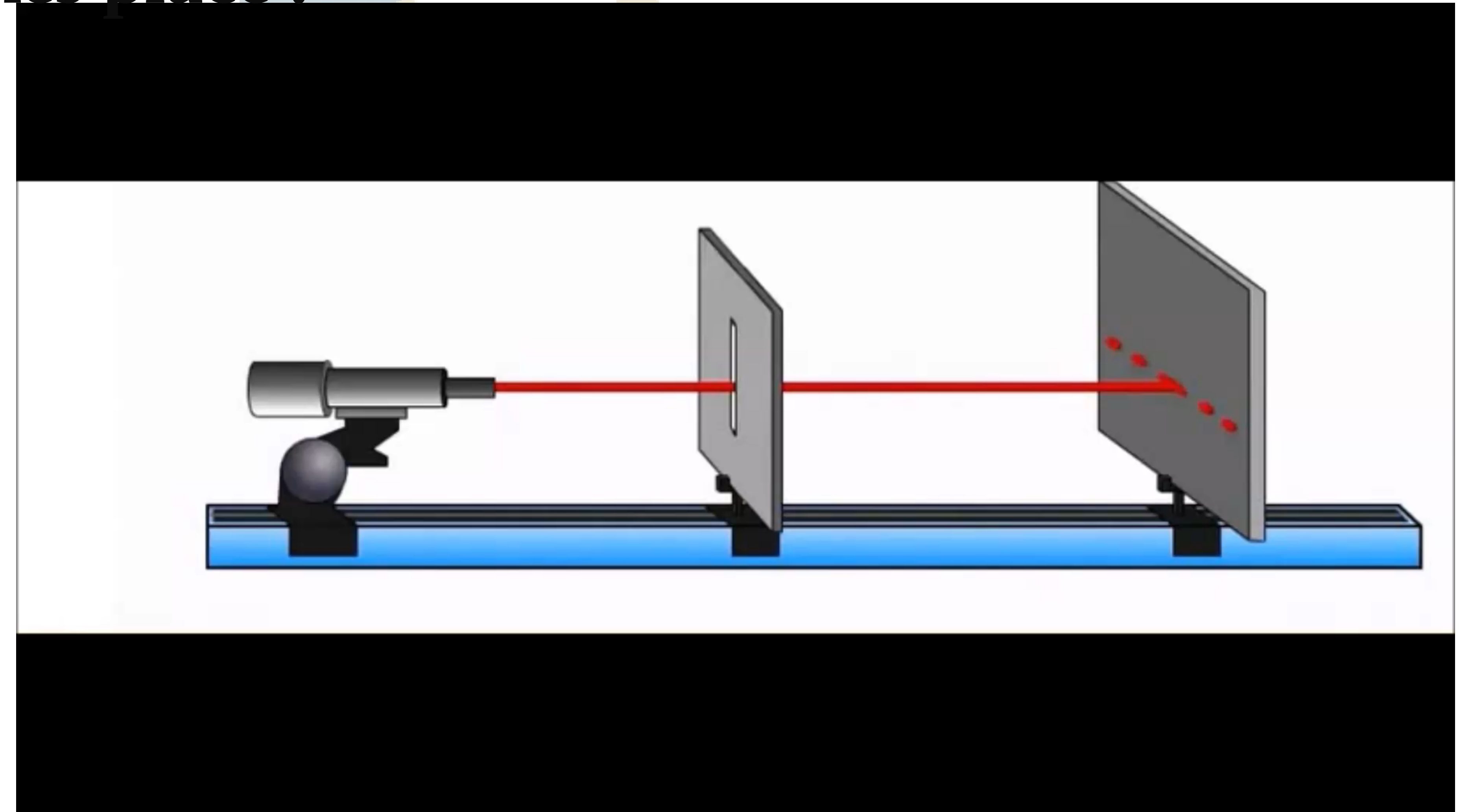
Diffraction of light

In the illuminated region some points are more illuminated called bright fringes (B.F), and some others less illuminated and called dark fringes (D.F).



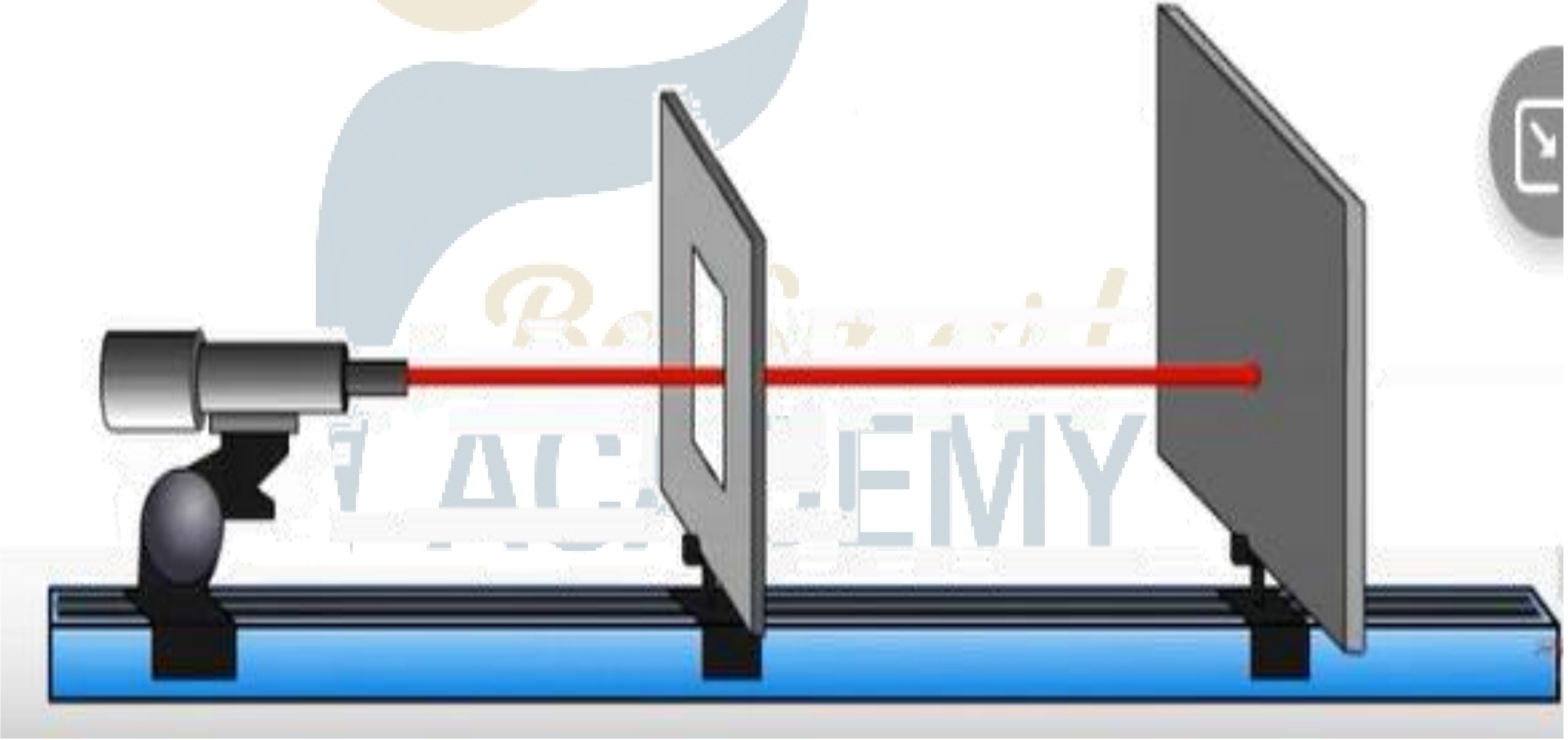
Diffraction of light

When the light passes through a small circular hole, diffraction takes place .



Diffraction of light

When the width (a) of the used slit is large (a=1cm) compared to the wavelength (λ), a rectilinear propagation of light occur, and no diffraction takes place.



Description of Diffraction Pattern

The characteristics of the diffraction pattern obtained:

1
- **Alternating bright and dark fringes**

2
- **The size of the central bright fringe is double that of any other bright fringe**

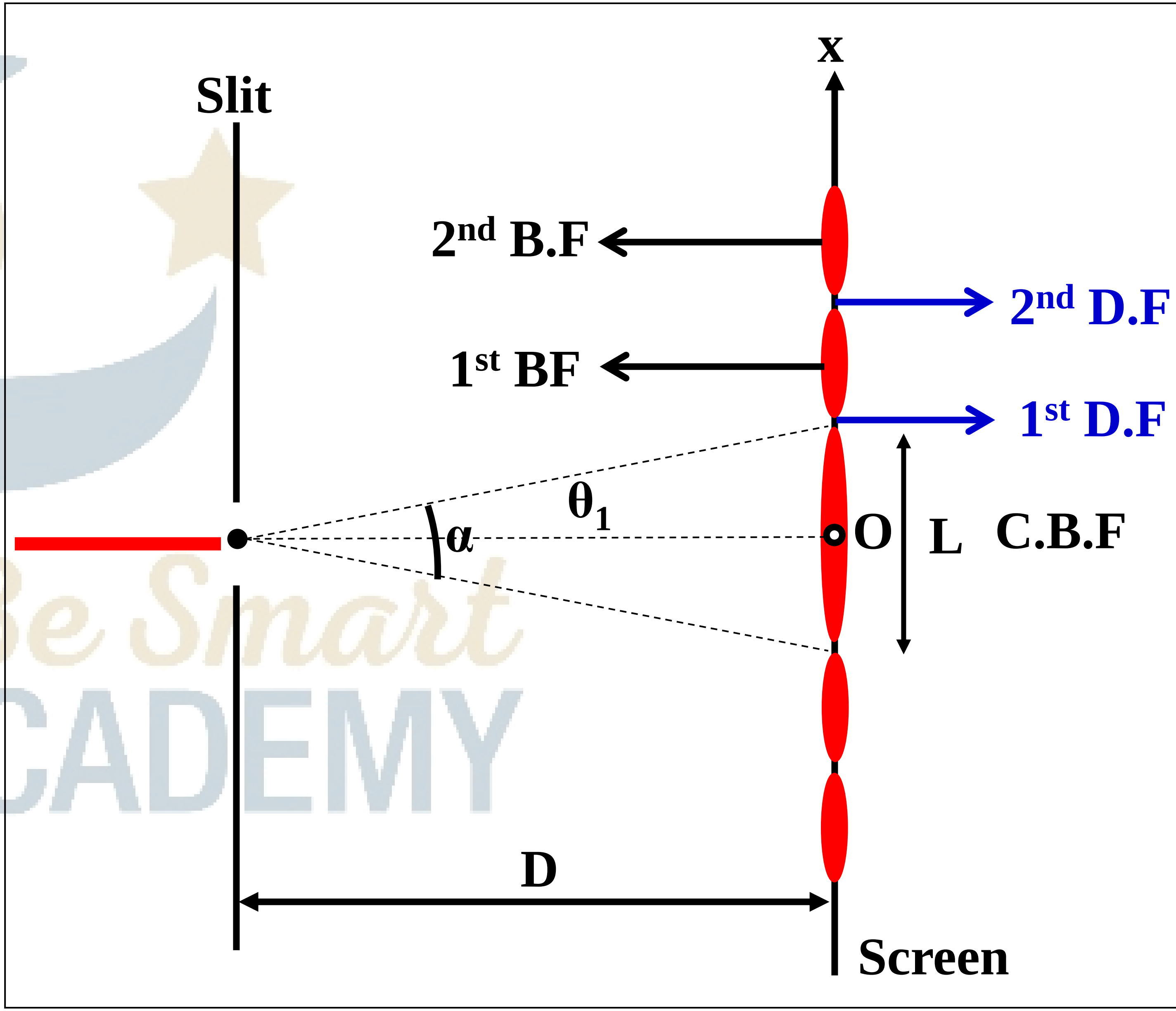
3
- **The direction of the pattern of fringes is perpendicular to that of the slit**

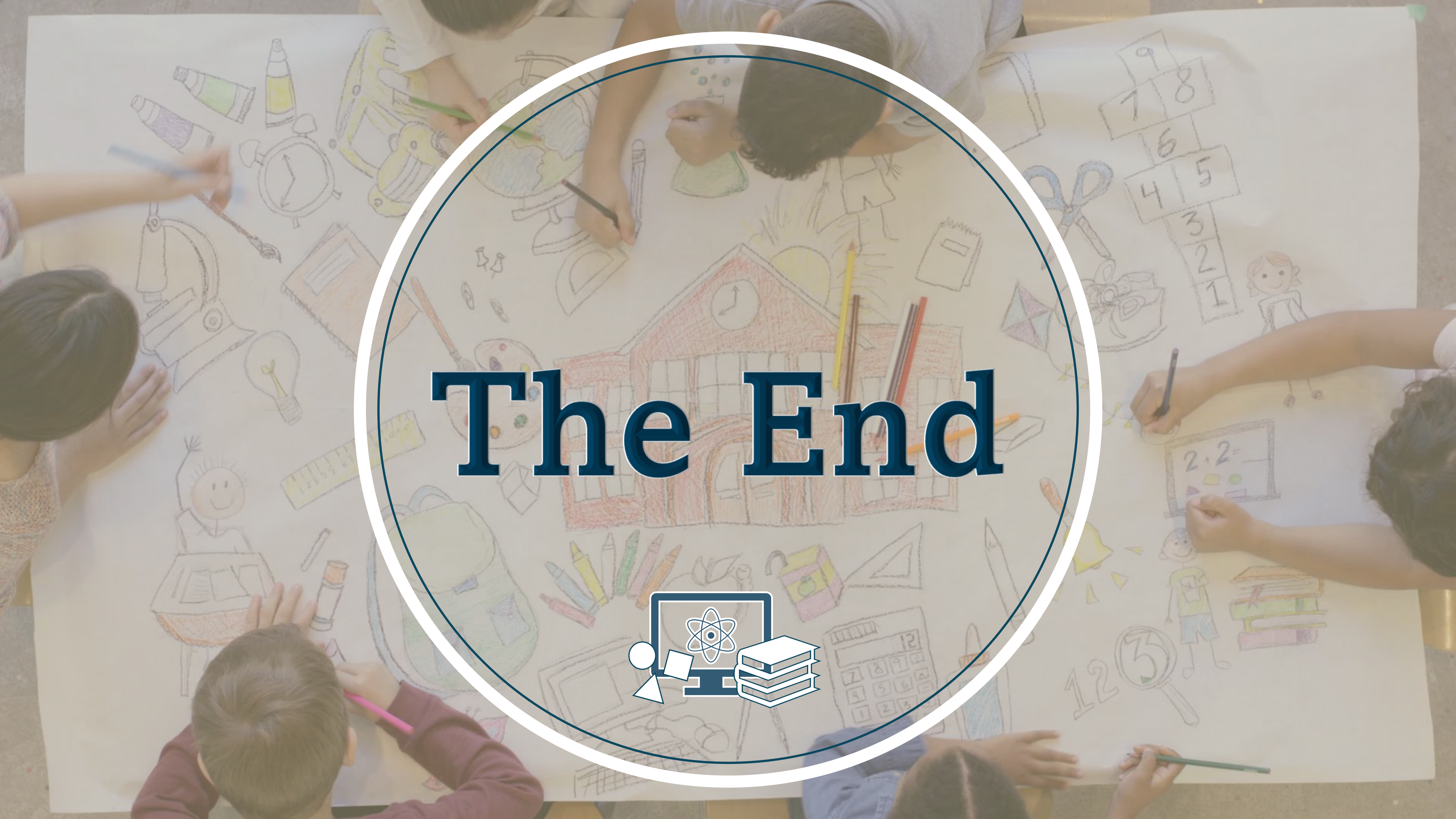
4
- **Central bright fringe of maximum intensity**

Interpretation of Diffraction Pattern

From the phenomenon of diffraction, we can deduce:

1. Diffraction gives an evidence of the wave aspect of light .
2. Diffraction needs a monochromatic light to takes place.
3. Light is an electromagnetic wave.





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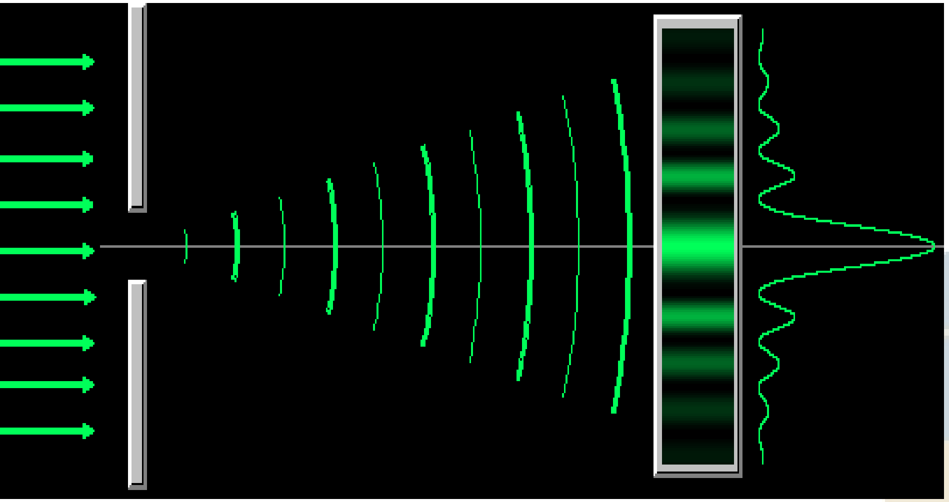
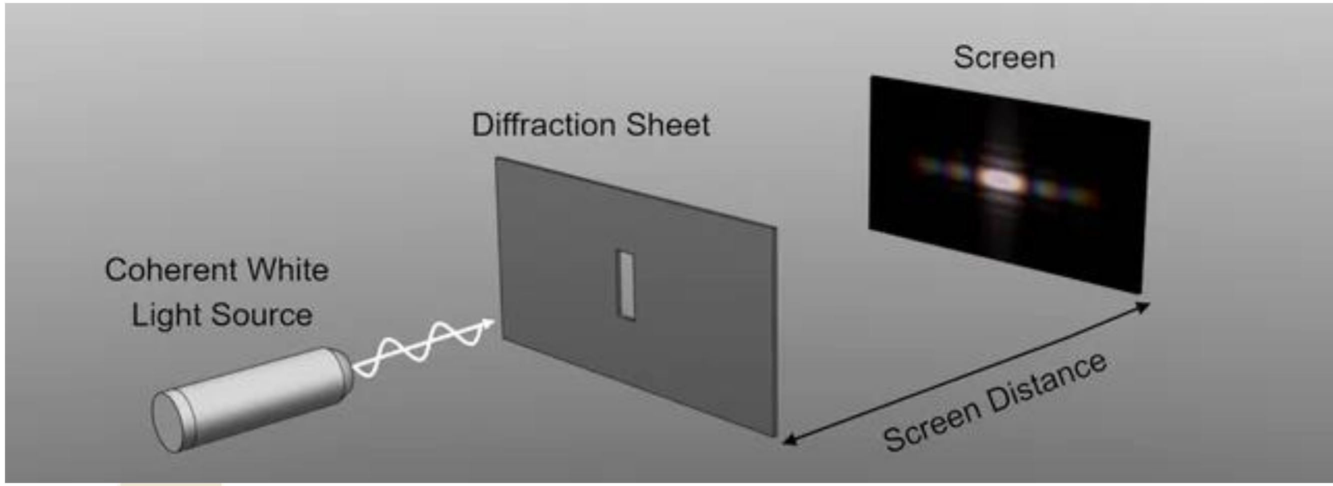




Unit III

Chapter 13

Wave Aspect of Light - Diffraction

Prepared and Presented by: Mr. Mohamad Seif

OBJECTIVES

4. Angular width of the dark fringes
5. Angular width of the central bright fringe
6. Linear width of the central fringe

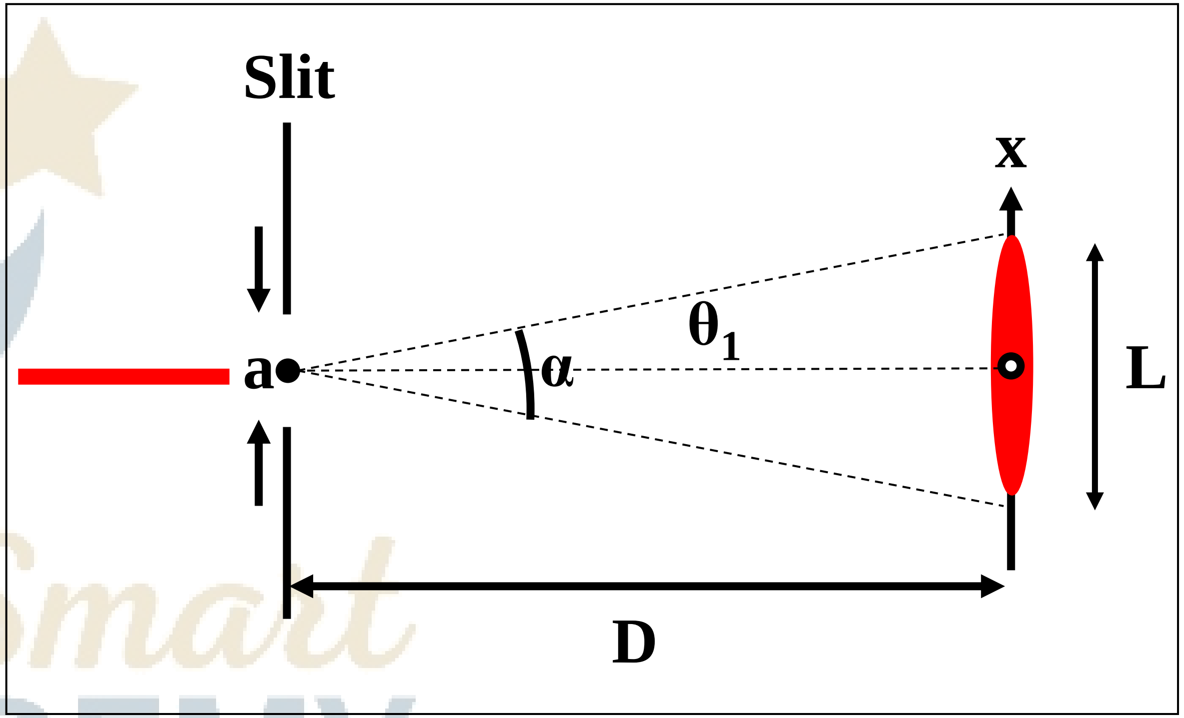
Angular width of the dark fringes

The dark fringe of nth order makes an angle θ_n:

$$\sin\theta_n = \frac{n\lambda}{a}$$

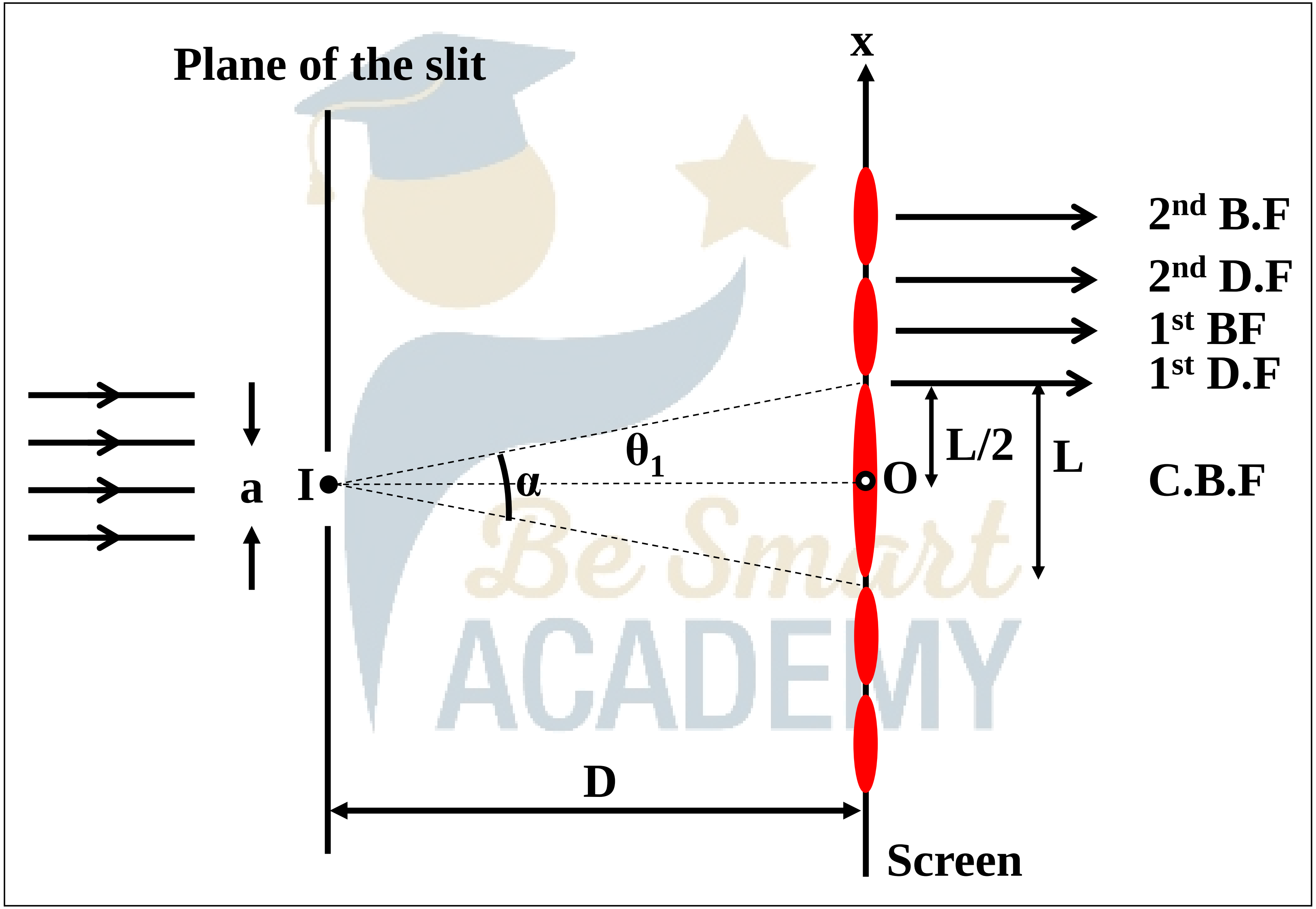
The angles supposed to be very small: $\sin\theta_n \approx tan\theta \approx \theta$

$$\theta_n = \frac{n\lambda}{a}$$



- θ_n**:Angle of diffraction of the center of the n**th **D.F.**
- n**:Oder of the D.F.** $n = \mp1;\ \mp2;\ \mp3;\ \dots$
- a**:Width of the slit**

Angular width of the dark fringes



Angular width of the central bright fringe

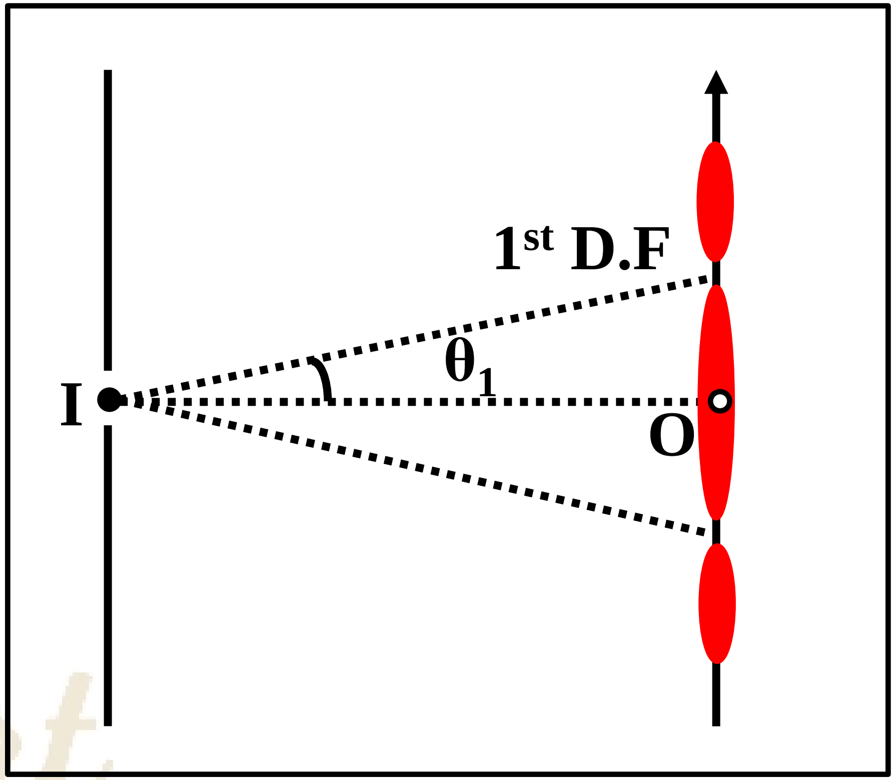
$$\theta_n = \frac{n\lambda}{a}$$

For $n = \mp 1$: 1st dark fringe $\theta_1 = \mp \frac{\lambda}{a}$

For $n = \mp 2$: 2nd dark fringe $\theta_2 = \mp 2 \frac{\lambda}{a}$

The angular width of C.B.F

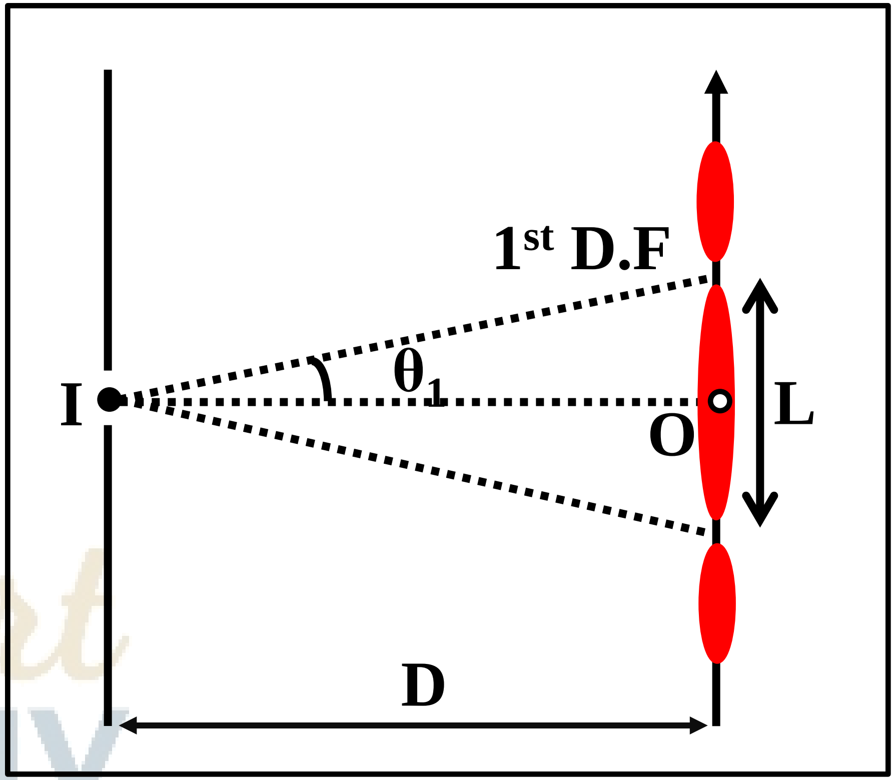
$$\alpha = 2\theta_1 = \frac{2\lambda}{a}$$



Linear width of the central bright fringe (L):

The angle between the center of C.B.F and 1st D.F is θ_1:

$$\theta_1 = \frac{\lambda}{a}$$



$$\tan\theta_1 = \frac{opp}{adj} = \frac{L/2}{D} = \frac{L}{2D}$$

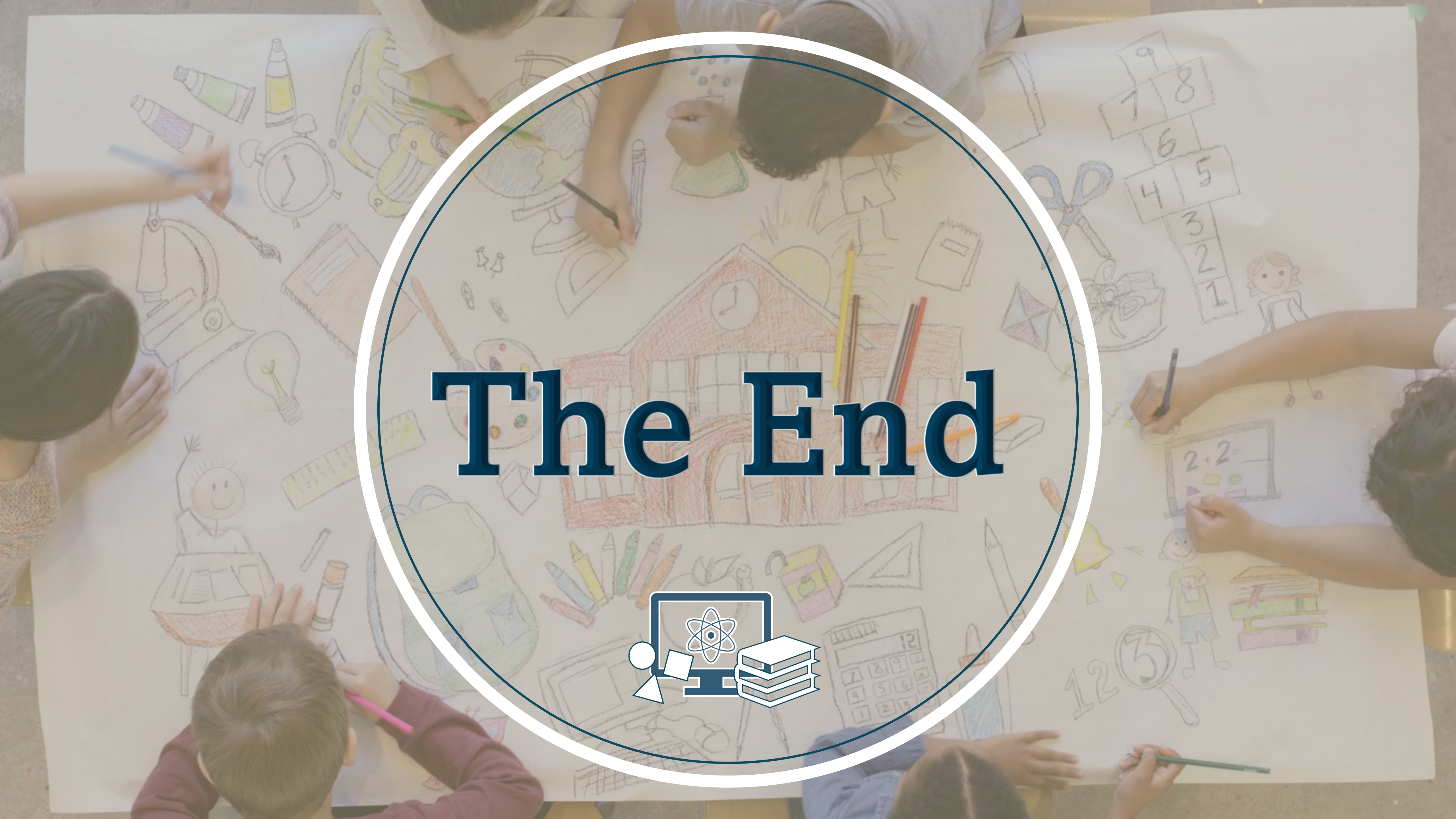
The angles supposed to be very small:

$$\sin\theta_1 \approx tan\theta_1 \approx \theta_1$$

$$\theta_1 = \theta_1$$

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

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



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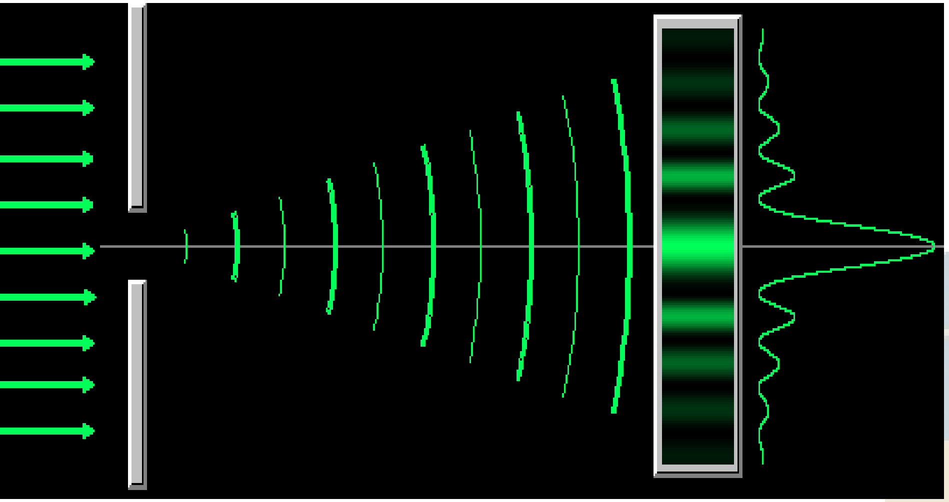
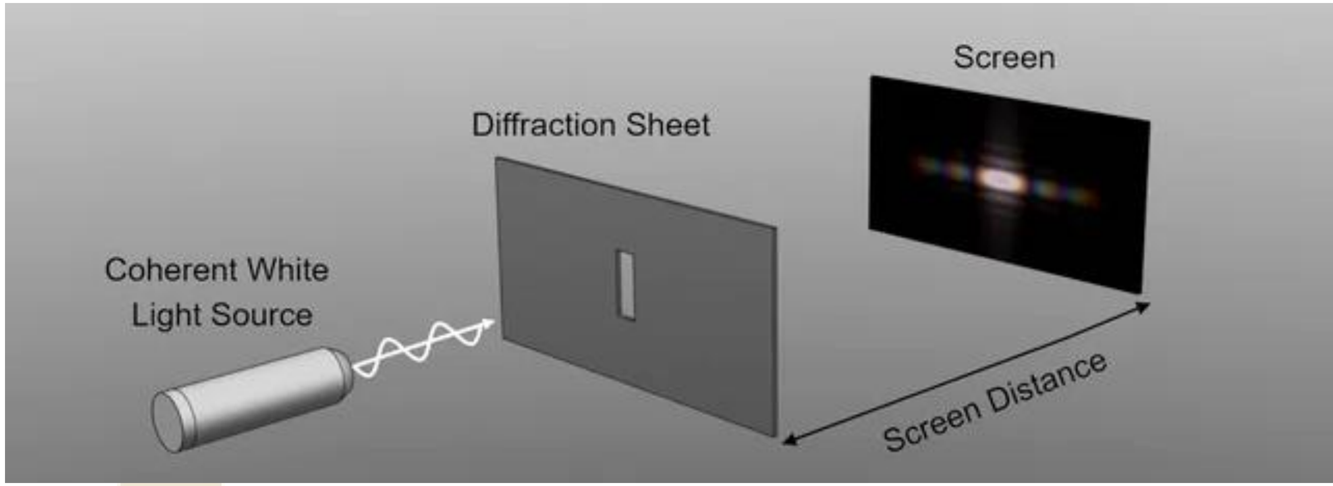




Unit III

Chapter 13

Wave Aspect of Light - Diffraction

Prepared and Presented by: Mr. Mohamad Seif

OBJECTIVES

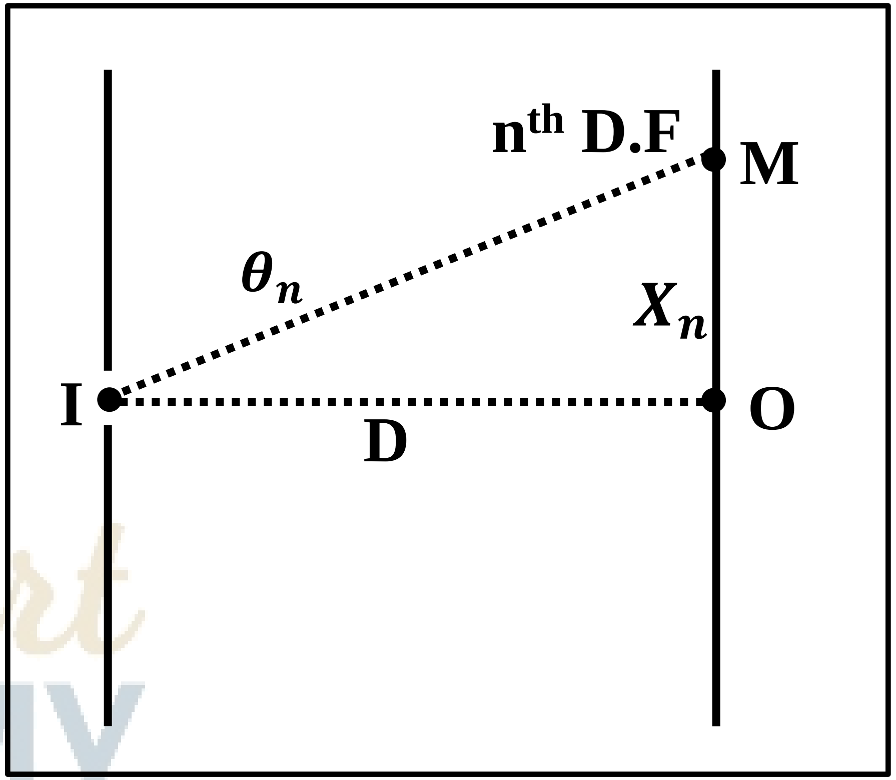
7 **Position of any dark fringe**

8 **Intensity distribution of a Diffraction Pattern**

Position of nth dark fringe (x_n)

$$\theta_n = \frac{n\lambda}{a}$$

From the geometry of the figure:



$$\tan\theta_n = \frac{x_n}{D} \quad \Rightarrow \quad \theta_n = \frac{x_n}{D}$$

$$\theta_n = \theta_n$$

$$\frac{n\lambda}{a} = \frac{x_n}{D}$$

$$x_n = \frac{n\lambda D}{a}$$

Position of any dark fringe

Application 1:

A laser emits light of wavelength λ that falls normally on horizontal wire of diameter a.

The diffracted pattern is observed on a screen parallel to the wire and situated at $D = 2m$. Figure 1.

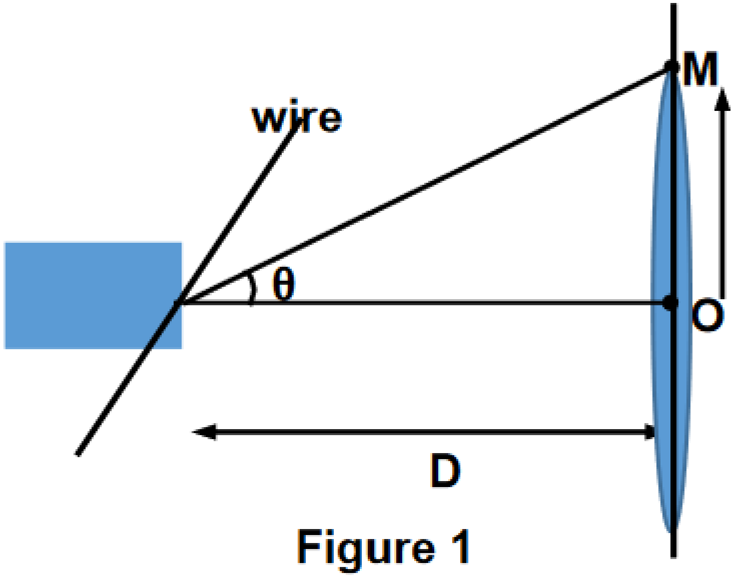


Figure 1

1)When the thin wire is illuminated by a laser, the light diffracts. Give the definition of diffraction phenomenon.

2)Determine the expression of the angular position of the first dark point obtained on the screen in terms λ & a.

Position of any dark fringe

1) When the thin wire is illuminated by a laser, the light diffracts. Give the definition of diffraction phenomenon.

Diffraction is a phenomenon that takes place when the light passes through a very small opening, called slit ($a \leq 1mm$).

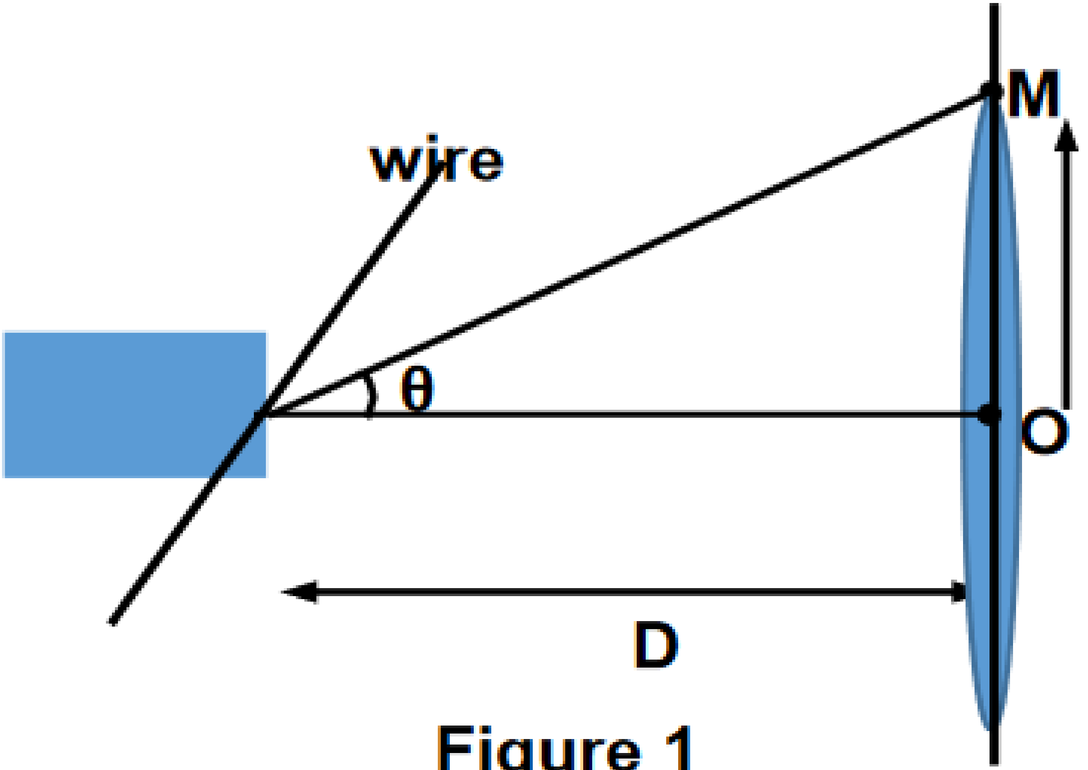


Figure 1

Position of any dark fringe

2) **Determine the expression of the angular position of the first dark point obtained on the screen in terms λ & a.**

The position of any dark fringe is given by:

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

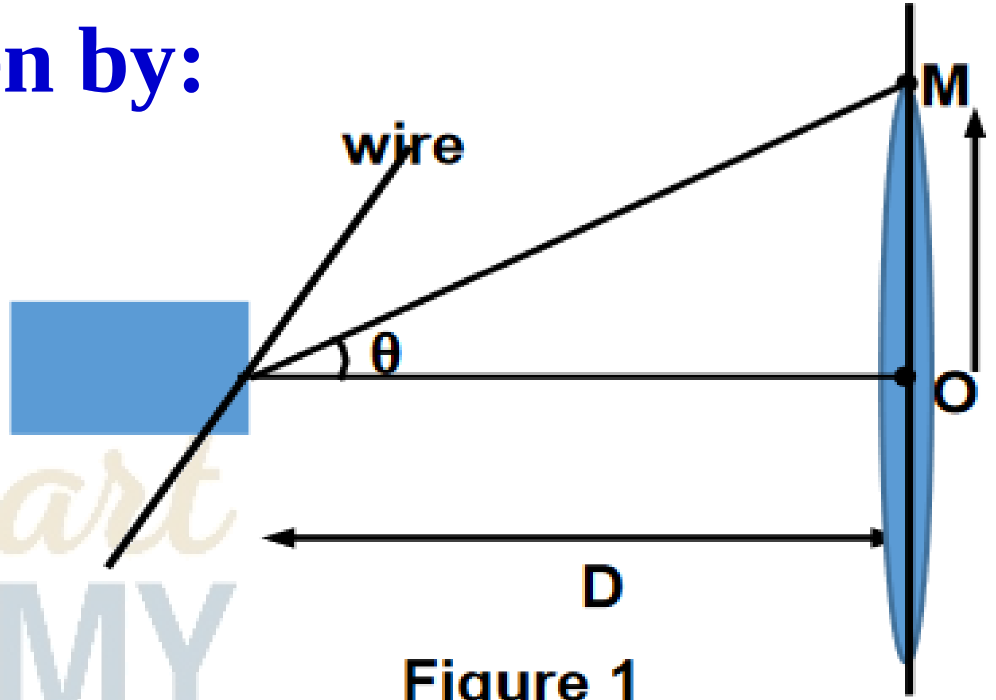


Figure 1

For the 1st dark fringe n=1:

$$\theta_1 = \frac{\lambda}{a}$$

Position of any dark fringe

3)If the first dark point is at 1.2cm from the point O while using a blue radiation whose wavelength this $\lambda = 500nm$. Determine a.

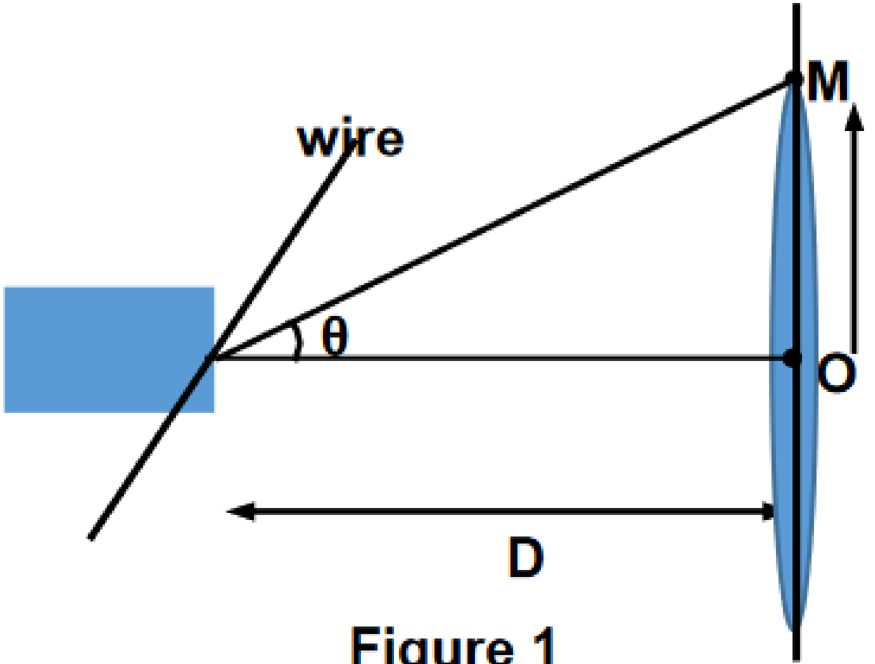


Figure 1

From the geometry of the figure:

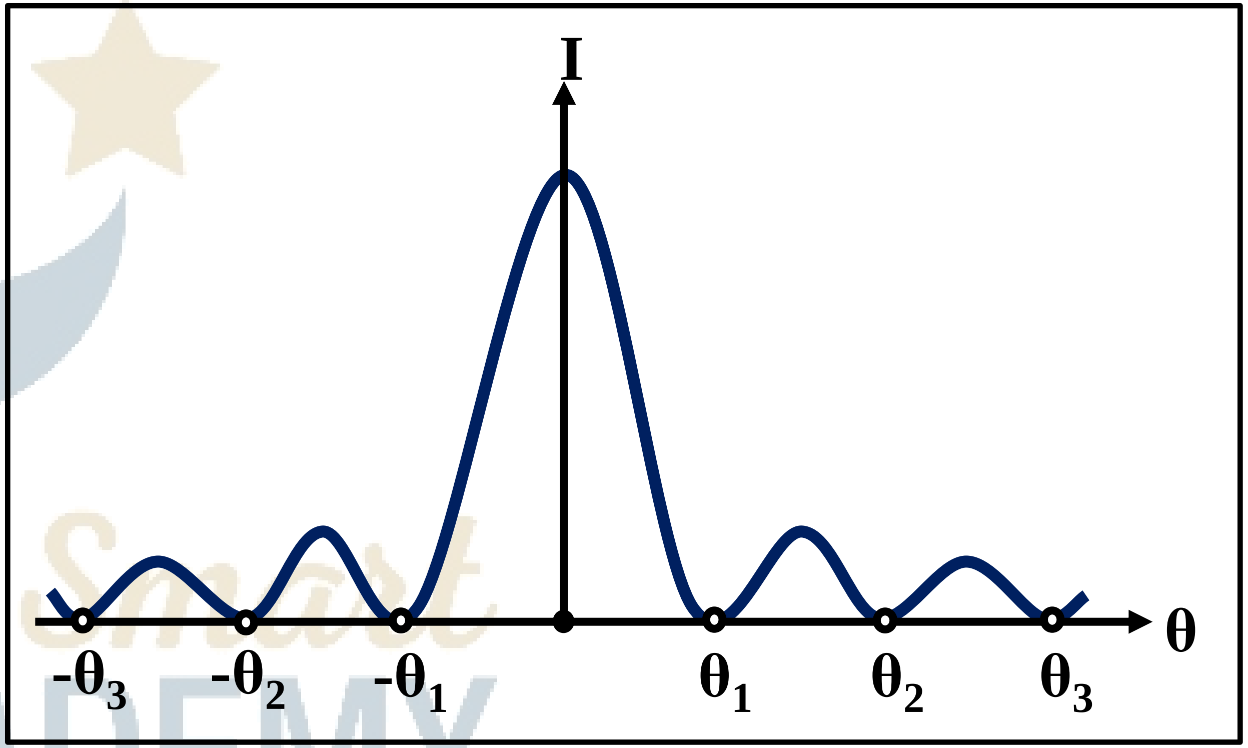
$$\tan\theta_1 = \frac{x_1}{D} \Rightarrow \theta_1 = \frac{x_1}{D}$$

$$\theta_1 = \theta_1 \Rightarrow \frac{\lambda}{a} = \frac{x_1}{D}$$

$$a = \frac{\lambda D}{x_1} \Rightarrow a = \frac{500\times10^{-9}\times 2}{1.2\times10^{-2}} = 8.3\times10^{-5}m$$

Intensity distribution of a Diffraction Pattern

The variation of intensity of light (I) as a function of the angle θ or X.



The Intensity is maximum at the center of the C.B.F.

The Intensity decreases as going from the center to reach zero at first D.F.

The intensity then increase again to another value at the middle of first B.F, then decrease again to zero at second D.F…

Intensity distribution of a Diffraction Pattern

Application2:

A laser beam of light, of wavelength in vacuum $\lambda = 0.5\mu m$,falls normally on a horizontal slit of width $a = 0.1mm$.

The diffraction pattern is observed on a screen placed perpendicularly to the laser beam at a distance D from the slit (figure 1).

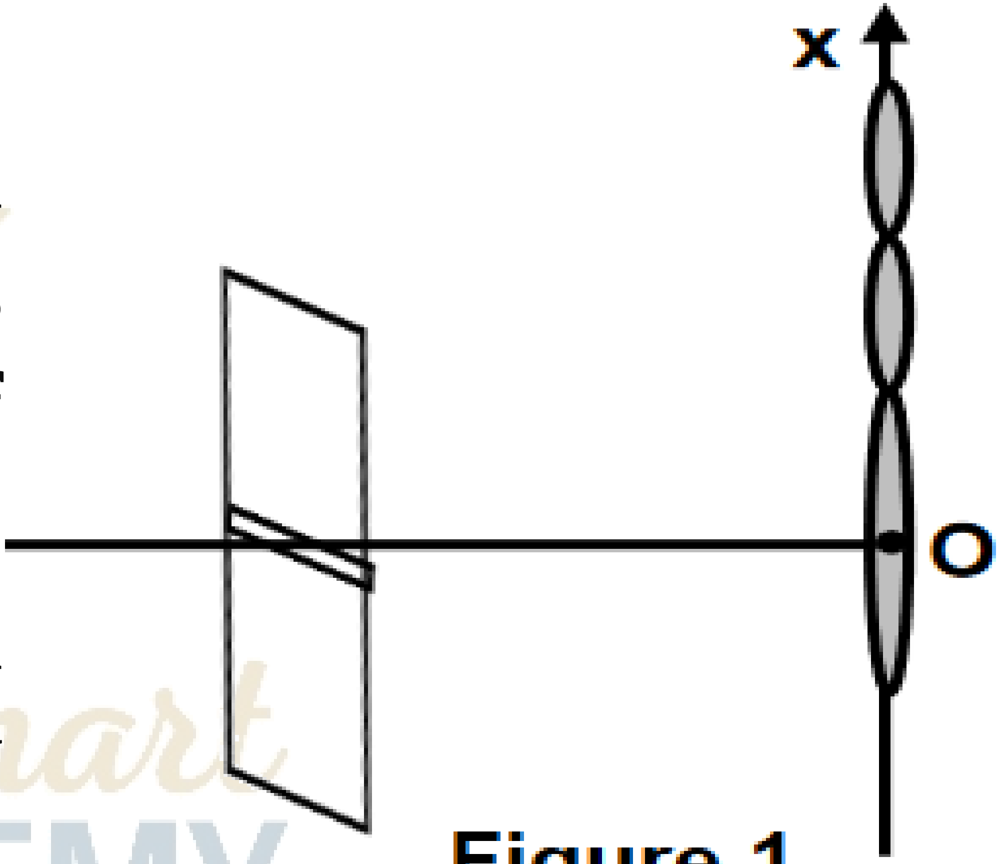


Figure 1

Intensity distribution of a Diffraction Pattern

An appropriate device records the intensity of the light received from S on the screen (E) as a function of x.

The curve in figure 2 shows the intensity as a function of x.

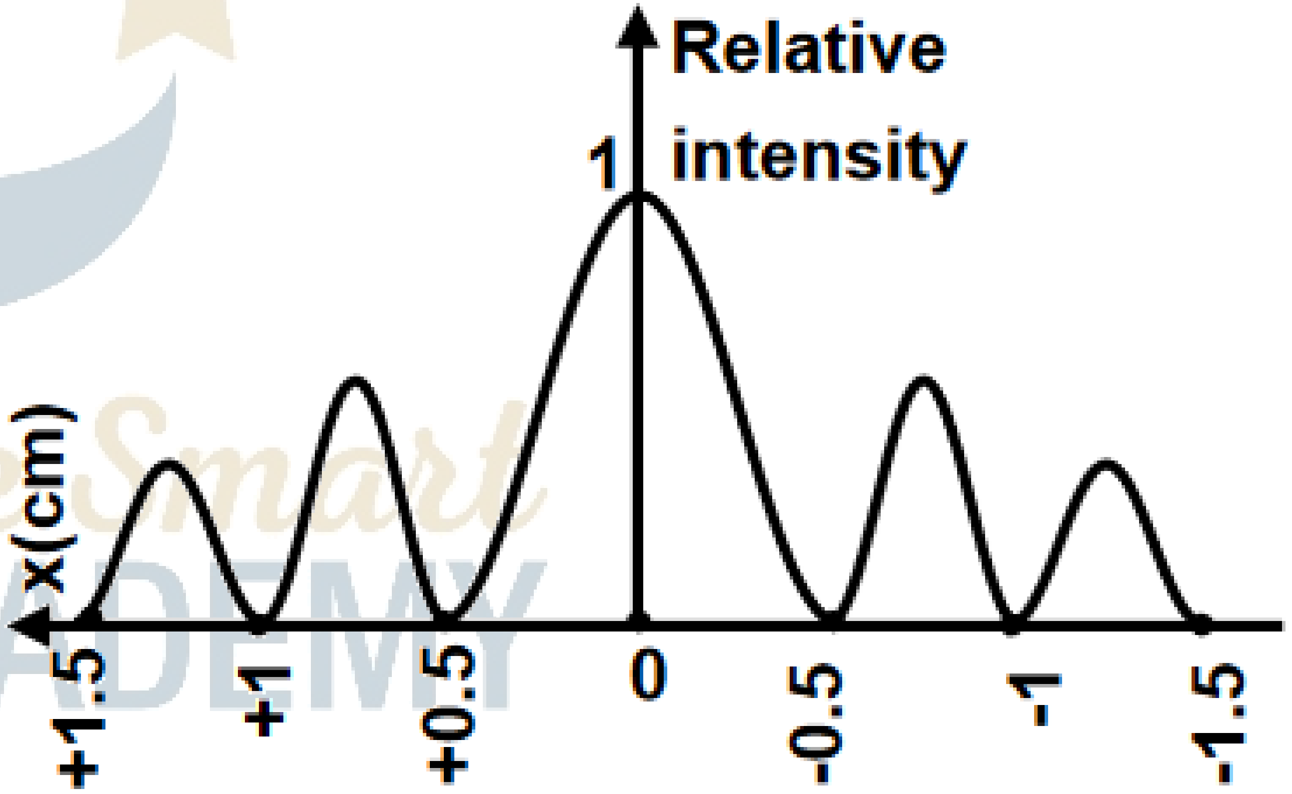


Figure 2

Intensity distribution of a Diffraction Pattern

1) Specify the nature of the point of abscissas $-0.5cm$, 0 & $0.75cm$.
2) Indicate the position of the first and second dark point from the positive side.
3) Refer to figure 2, give the linear width of the central bright fringe L.
4) Give the expression of L as a function of the given.
5) Deduce the value of D.

Intensity distribution of a Diffraction Pattern

1) Specify the nature of the point of abscissas $-0.5cm$, 0 & $0.75cm$.

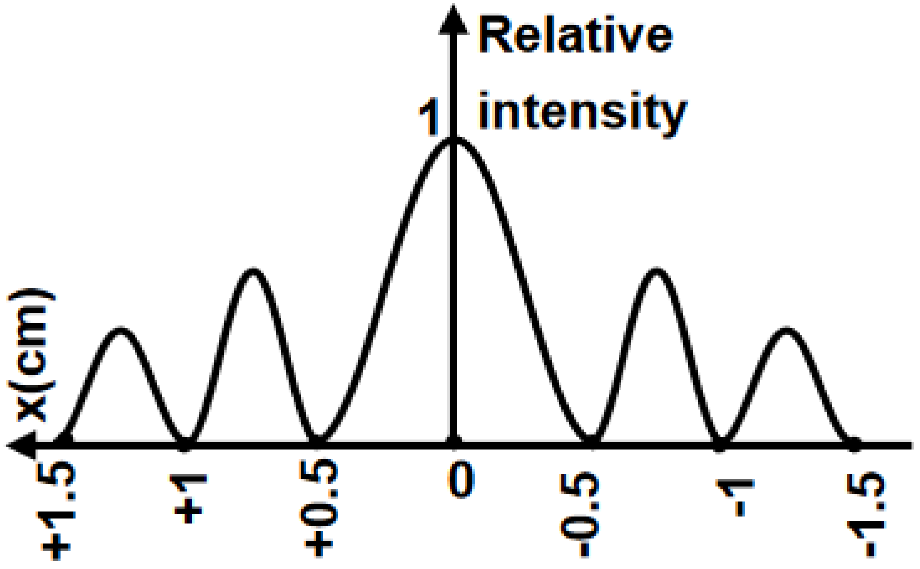


Figure 2

position	-0.5cm	0	0.75cm
nature	1st D.F in negative side	C.B.F	Center 1st B.F in positive side

Intensity distribution of a Diffraction Pattern

2) Indicate the position of the first and second dark point from the positive side.

- The first dark point at $0.5cm$.
- The second dark at $1cm$

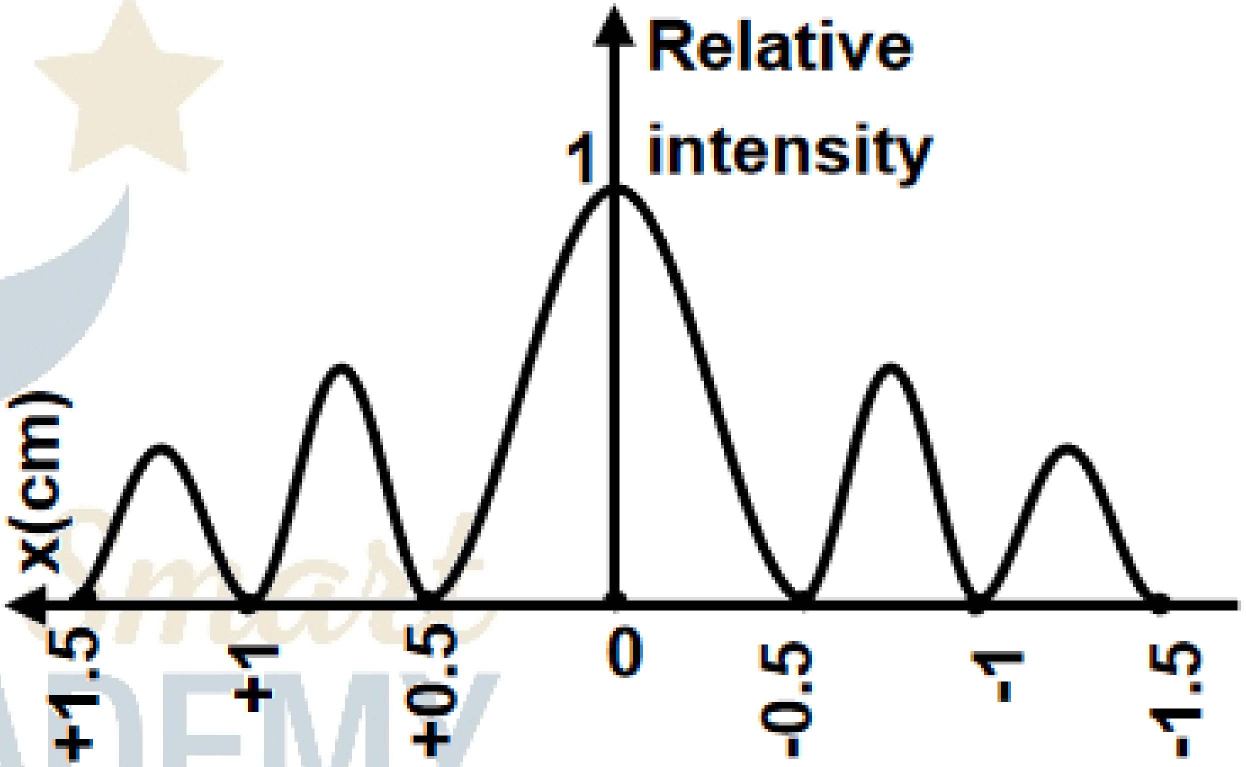


Figure 2

Intensity distribution of a Diffraction Pattern

3) Refer to figure 2, give the linear width of the central bright fringe L

The C.B.F is between the 1st D.F from the positive side to the 1st D.F from the negative side:

$$L = 0.5cm - (-0.5cm)$$

$$L = 1cm$$

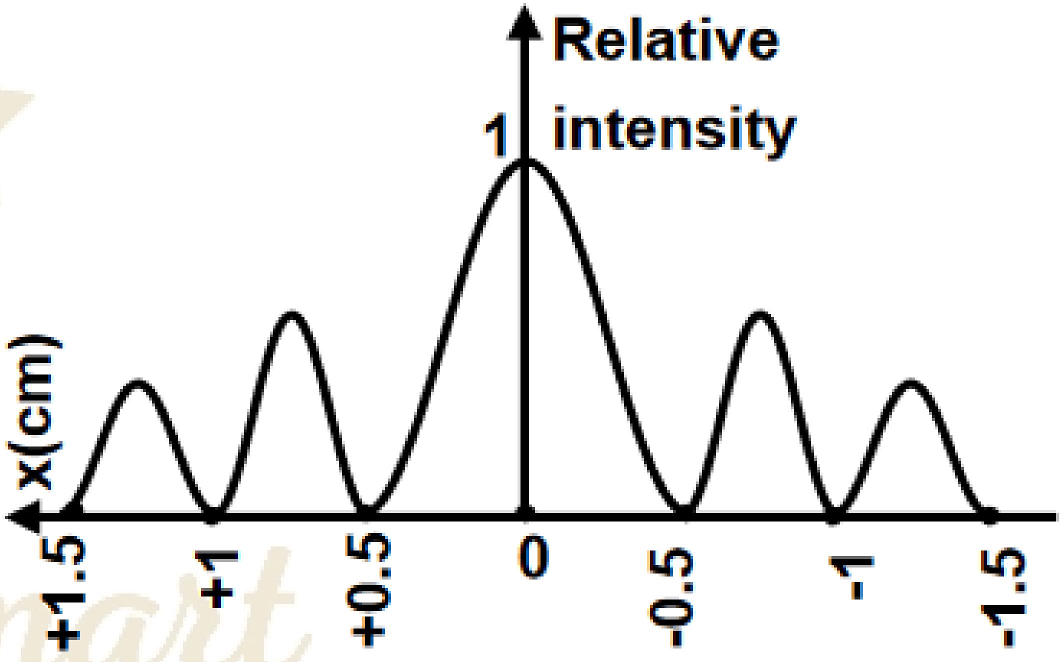


Figure 2

4) Give the expression of L as a function of the given.

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

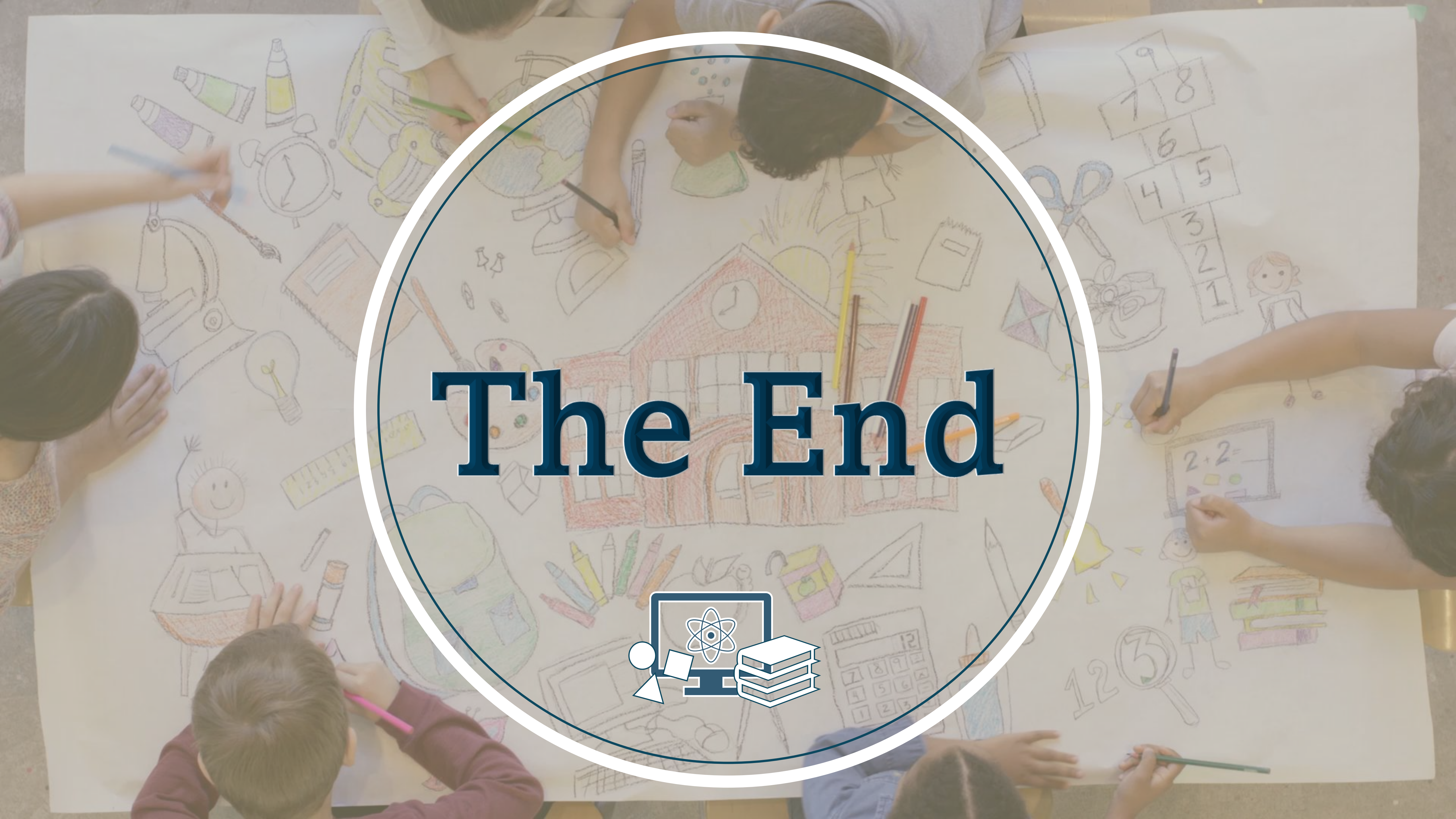
Intensity distribution of a Diffraction Pattern

5) Deduce the value of *D*

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

$$D = \frac{1 \times 10^{-2} \times 0.1 \times 10^{-3}}{2 \times 0.5 \times 10^{-6}}$$

$$D = 1m$$


The End