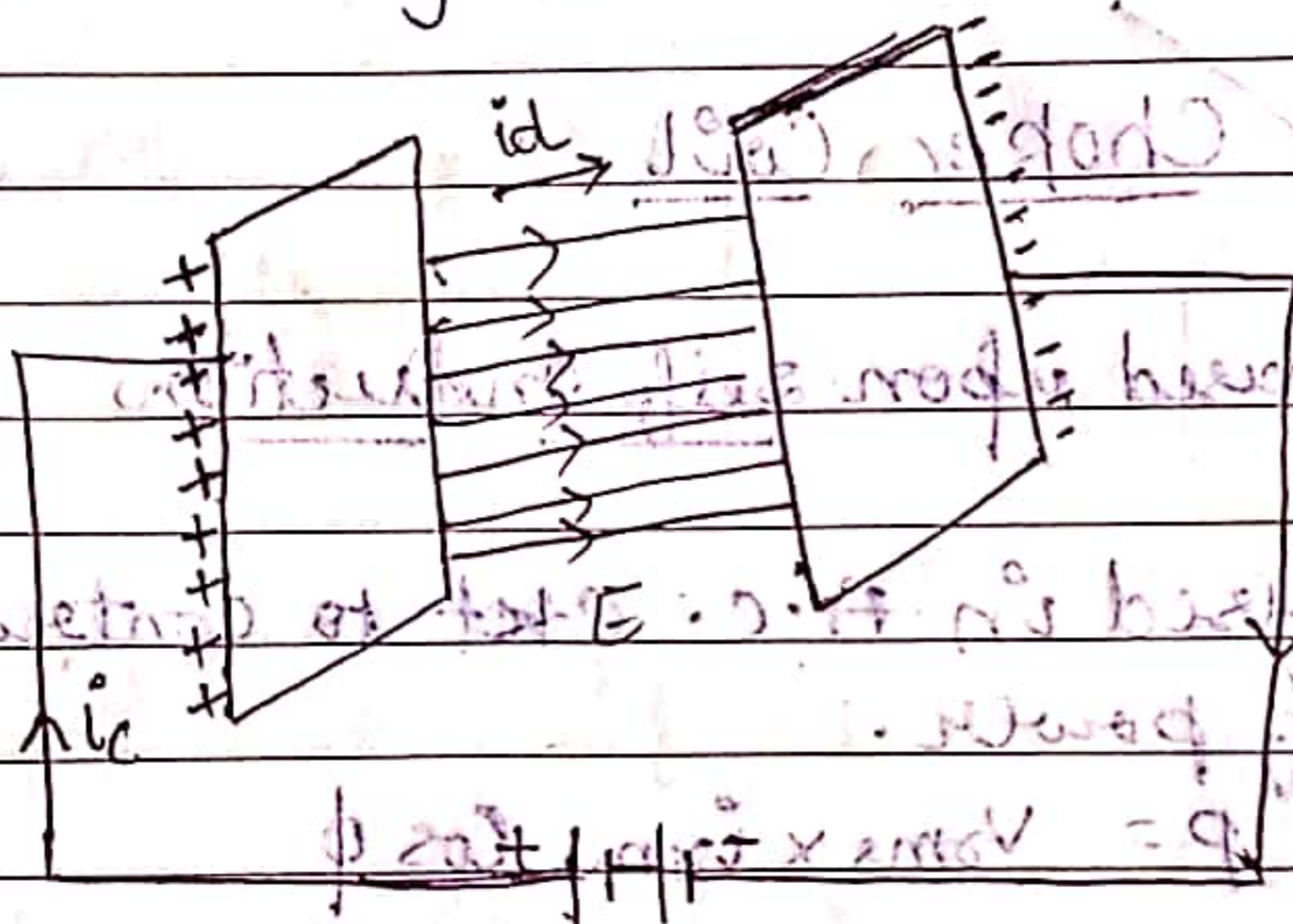


Displacement Current

Displacement current is that current which comes into play in the region in which the electric field and electric flux is changing with time.

- It is denoted by  $i_d$



The electric field b/w charged plates

$$E = \frac{\sigma}{\epsilon_0}$$

$\sigma = \frac{q}{A}$

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$$E = \frac{q}{\epsilon_0 A}$$

$$q = EA \epsilon_0 \implies EA = \frac{q}{\epsilon_0}$$

$$\implies q = \epsilon_0 EA$$

[D.C. - capacitor]  
[A.C. - coil]

diff. w.r. to t

$$\frac{dq}{dt} = \epsilon_0 \frac{d\phi_E}{dt}$$

$$[i_d = \epsilon_0 \frac{d\phi_e}{dt}] \quad (11)$$

Where  $i_d$  is displacement current.

Ampere's Circuital law

$\oint \vec{B} \cdot d\vec{l} = \mu_0 i$  is modified that

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 i_c + \mu_0 i_d$$

$$[\oint \vec{B} \cdot d\vec{l} = \mu_0 (i_c + i_d)]$$

This is called Maxwell Ampere circuital law.

$$[\oint \vec{B} \cdot d\vec{l} = \mu_0 (i_c + \epsilon_0 \frac{d\phi_e}{dt})]$$

Maxwell's equations

Maxwell's equations are the basic laws of electricity and magnetism these equations give complete description of all electromagnetic interaction. There are 4 Maxwell's equations.

① Gauss's theorem in electrostatics

$$[\oint \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}]$$

This is 1st Maxwell's equation.

(II) Gauss's theorem in magnetostatic

$$\left[ \oint \vec{B} \cdot d\vec{s} = 0 \right]$$

This is called second Maxwell's equation.

(III) Faraday law of induction

$$e = - \frac{d\phi_B}{dt}$$

$$\therefore e = \oint \vec{E} \cdot d\vec{l}$$

$$\left[ \therefore \oint \vec{E} \cdot d\vec{l} = - \frac{d\phi_B}{dt} \right]$$

This is called third Maxwell's equation.

(IV) Maxwell-Ampere law

$$\left[ \oint \vec{B} \cdot d\vec{l} = \mu_0 i_c + \mu_0 \epsilon_0 \frac{d\phi_E}{dt} \right]$$

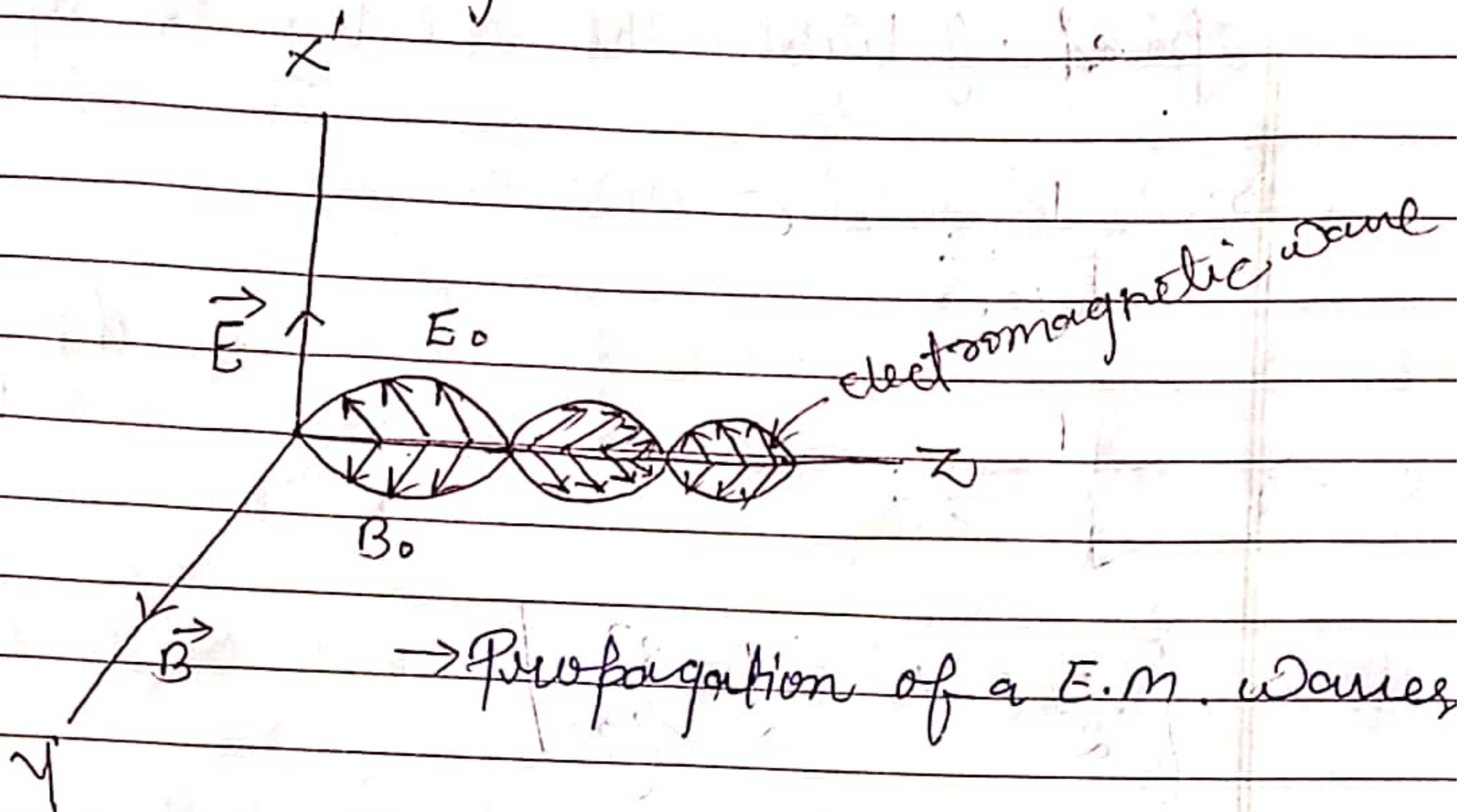
This is fourth Maxwell's equation.

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Electromagnetic waves

The waves produce due to the change in electric field & magnetic field sinusoidally and propagating through space such that the two fields are perpendicular to each other &  $\perp$  to the direction of wave propagation is

called electromagnetic wave.



$$E = E_x = E_0 \sin(kx - \omega t)$$

$$B = B_y = B_0 \sin(kx - \omega t)$$

Where  $E_0$  &  $B_0$  is the amplitude of electric vector & magnetic vector

$$\omega = 2\pi\nu$$

$$k = \frac{2\pi}{\lambda}$$

## Characteristics of Electromagnetic waves

1. The accelerated charge produce electromagnetic waves which are transverse in nature.
2. These waves do not required any material medium for propagation.

3. These waves travel in free space with the speed of light which is given by the relation -

$$\Rightarrow \frac{1}{\sqrt{\mu_0 \epsilon_0}} = c$$

$$\Rightarrow \frac{1}{\sqrt{\mu_0 \epsilon_0}} = c$$

$$\Rightarrow \left[ \frac{1}{2} \epsilon_0 E_0^2 = \frac{1}{2} \frac{B^2}{\mu_0} \right]$$

4. The direction of variation of electric and magnetic field are perpendicular to each other also perpendicular to the direction of propagation of light.

5. In free space the magnitude of electric and magnetic field are related by -

$$\left[ \frac{E_0}{B_0} = c \right]$$

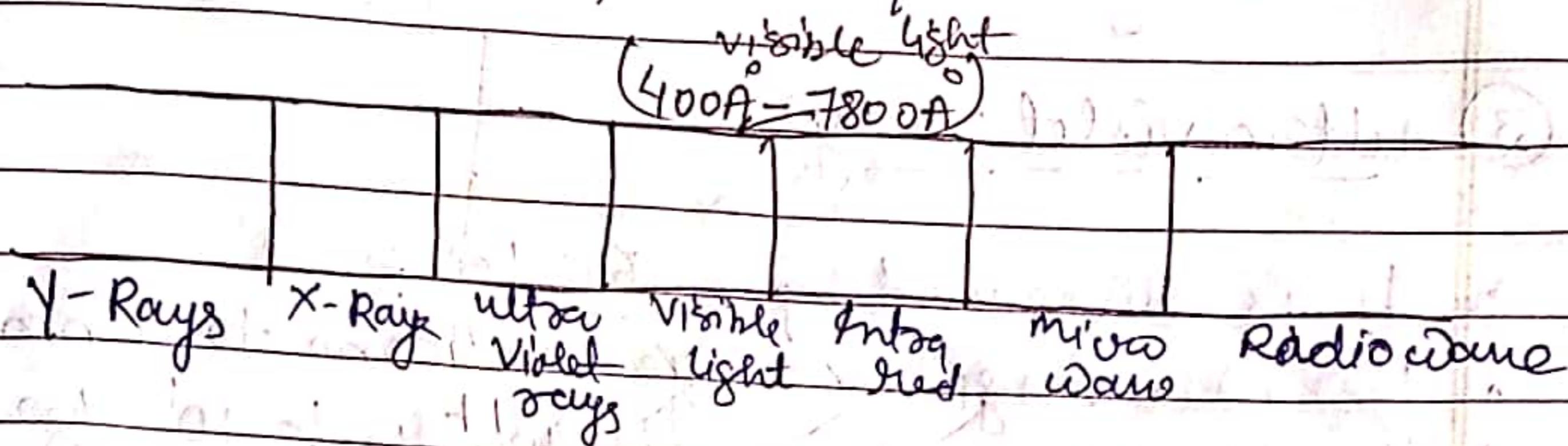
6. The energy density in an electric field and a magnetic field will be equal.

$$\left[ \frac{1}{2} \epsilon_0 E_0^2 = \frac{B^2}{2\mu_0} \right]$$

Electromagnetic Spectrum

The order arrangement of electromagnetic

waves in increasing or decreasing order of wavelength is called electromagnetic spectrum



Increasing order of wavelength →

← Decreasing order of frequency

### ① γ-rays

- It is discovered by Rutherford.
- Its wavelength is less than  $10^{-3}$  nm.
- Its frequency range is  $3 \times 10^{18}$  Hz to  $5 \times 10^{22}$  Hz.
- It is produced by radioactive decay.
- It uses to produce nuclear reaction, it uses as radiotherapy for the treatment of cancer & tumour.

### ② X-rays

- This ray was discovered by professor Roentgen.
- Its wavelength range is 1 nm to  $10^{-3}$  nm.
- Its frequency range is  $3 \times 10^{16}$  Hz to  $3 \times 10^{21}$  Hz.

- It is used in surgery to detect the fracture disease organs, stones in the body etc.

### ③ ultraviolet ray

- It is discovered by Ritter.
- Its wavelength range is 400 nm to 1 nm.
- Its frequency range is  $10^{14}$  Hz to  $10^{16}$  Hz.
- It is used in checking mineral sample, study molecular structure etc.

### ④ Visible light

- It is discovered by Rutherford
- Its wavelength range is 700 nm to 400 nm.
- Its frequency range is  $4 \times 10^{14}$  Hz to  $7 \times 10^{14}$  Hz.
- It is used to see things.

### ⑤ Infrared rays wave

- It is discovered Herschell
- Its wavelength range is 1 mm to 700 nm.
- Its frequency range is  $3 \times 10^{11}$  Hz to  $4 \times 10^{14}$  Hz.
- It is used in physical therapy, ~~Rutherford~~ solar cell etc.

### ⑥ Microwave

- This wave is produced by vacuum tubes.
- It is also called short wavelength Radio wave
- Its wavelength range is 0.1 m to 1 mm.
- Its frequency range is 1 GHz to 300 GHz.

- It uses in radar system.

## ⑦ Radio waves

- These are produced by oscillating charge particle.
- Its wavelength is greater than  $0.1\text{m}$ .
- Its frequency range is  $500\text{kHz}$  to  $1000\text{MHz}$ .
- It is used in amplitude modulation (a.m.) and also for frequency modulation (Fm)



## Different types of electromagnetic waves

Type	Wavelength range	Frequency range (Hz)	Production	Detection
Radio wave	> 0.1 m	$10^4$ to $10^9$	Rapid acceleration and deceleration of electrons in aerials.	Receiver's aerials
Microwave	0.1 m to 1 mm	$10^9$ to $10^{11}$	Klystron valve or magnetron valve.	Point contact diodes
Infrared wave	1 mm to 700 nm	$3 \times 10^{11}$ to $4 \times 10^{14}$	Vibration of atoms and molecules.	Thermopile, Bolometer, infrared photographic film
Light	700 nm to 400 nm	$4 \times 10^{14}$ to $8 \times 10^{14}$	Electrons in atoms emit light when they move from one energy level to a lower energy level.	The eye, photocells, photographic film
Ultraviolet rays	400 nm to 1 nm	$8 \times 10^{14}$ to $8 \times 10^{16}$	Inner shell electrons in atoms moving from one energy level to a lower level.	Photocells, photographic film
X-rays	1 nm to $10^{-3}$ nm	$1 \times 10^{16}$ to $3 \times 10^{21}$	X-ray tubes or inner shell electrons.	Photographic film Geiger tubes, ionisation chamber
$\gamma$ -rays	$< 10^{-3}$ nm	$5 \times 10^{18}$ to $5 \times 10^{22}$	Radioactive decay of the nucleus.	Photographic film, ionisation chamber