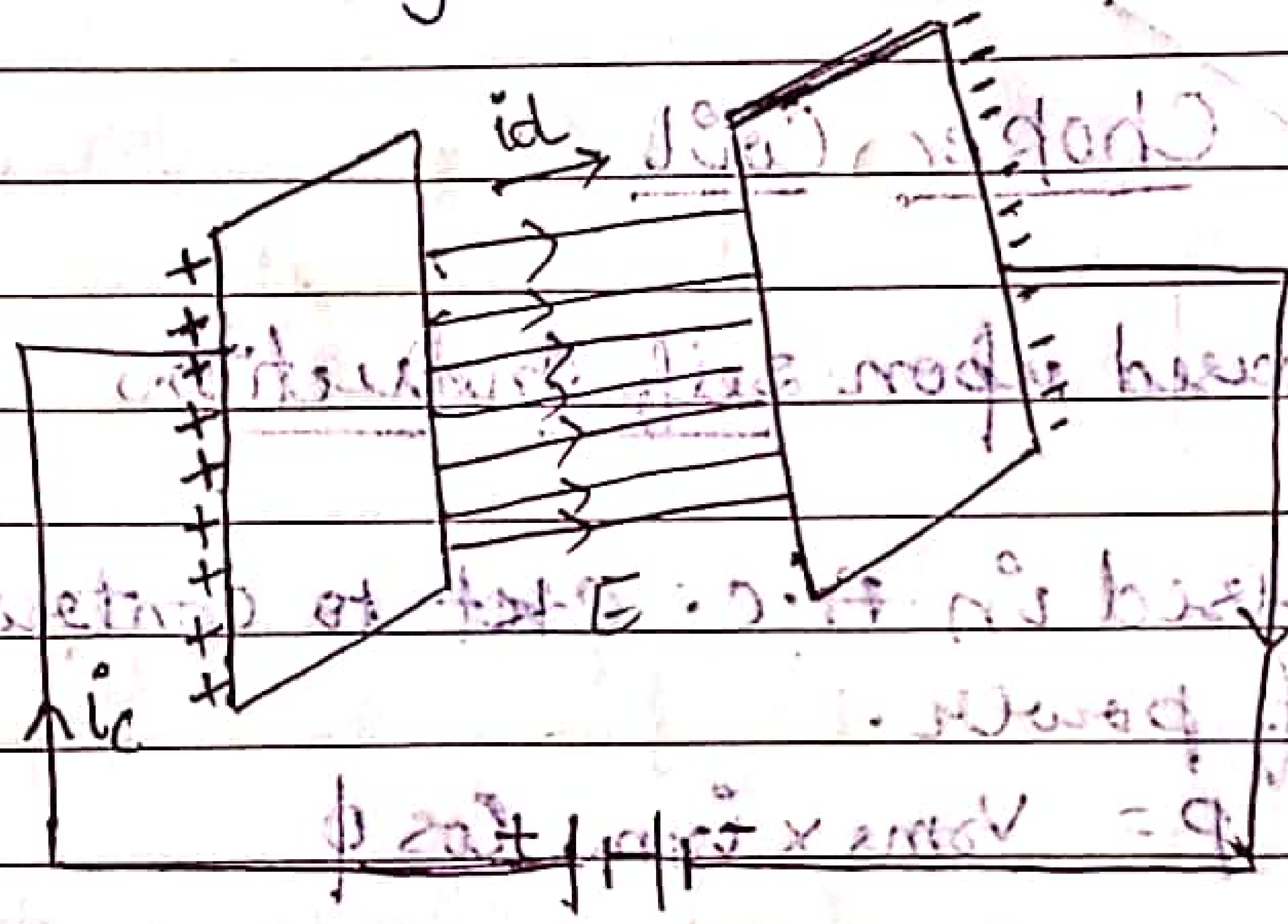
Ch-8 Electromagnetic Waves

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

$$E = \frac{\sigma}{\epsilon_0} \quad ; \quad \sigma = \frac{q}{A}$$

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

$$\Rightarrow q = E A \epsilon_0 \quad \because EA = \phi_E$$

$$\Rightarrow q = \phi_E \epsilon_0$$

diff. w.r.to t

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

$$\left[i_d = \epsilon_0 \frac{d\phi_E}{dt} \right]$$

Where id is displacement current.

Ampere's Circutal law

$\oint \vec{B}.\vec{dl} = \mu_0 i$ is modified that

$\oint \vec{B}.\vec{dl} = \mu_0 i_c + \mu_0 i_d$

$$\left[\oint \vec{B}.\vec{dl} = \mu_0 (i_c + i_d) \right]$$

This is called Maxwell Ampere circutal law.

$$\left[\oint \vec{B}.\vec{dl} = \mu_0 \left(i_c + \epsilon_0 \frac{d\phi_E}{dt} \right) \right]$$

Maxwell's equations

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

① Gauss's theorem in electrostatic

$$\left[\oint \vec{E}.\vec{dA} = \frac{q}{\epsilon_0} \right]$$

This is 1st maxwell's equation.

(II) Gauss's theorem in magnetostatic

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

This is called second maxwell's equation.

(III) Faraday law of induction

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

$$\because e = \oint \vec{E}\cdot\vec{dl}$$

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

This is called third maxwell's equation.

(IV) Maxwell-Ampere law

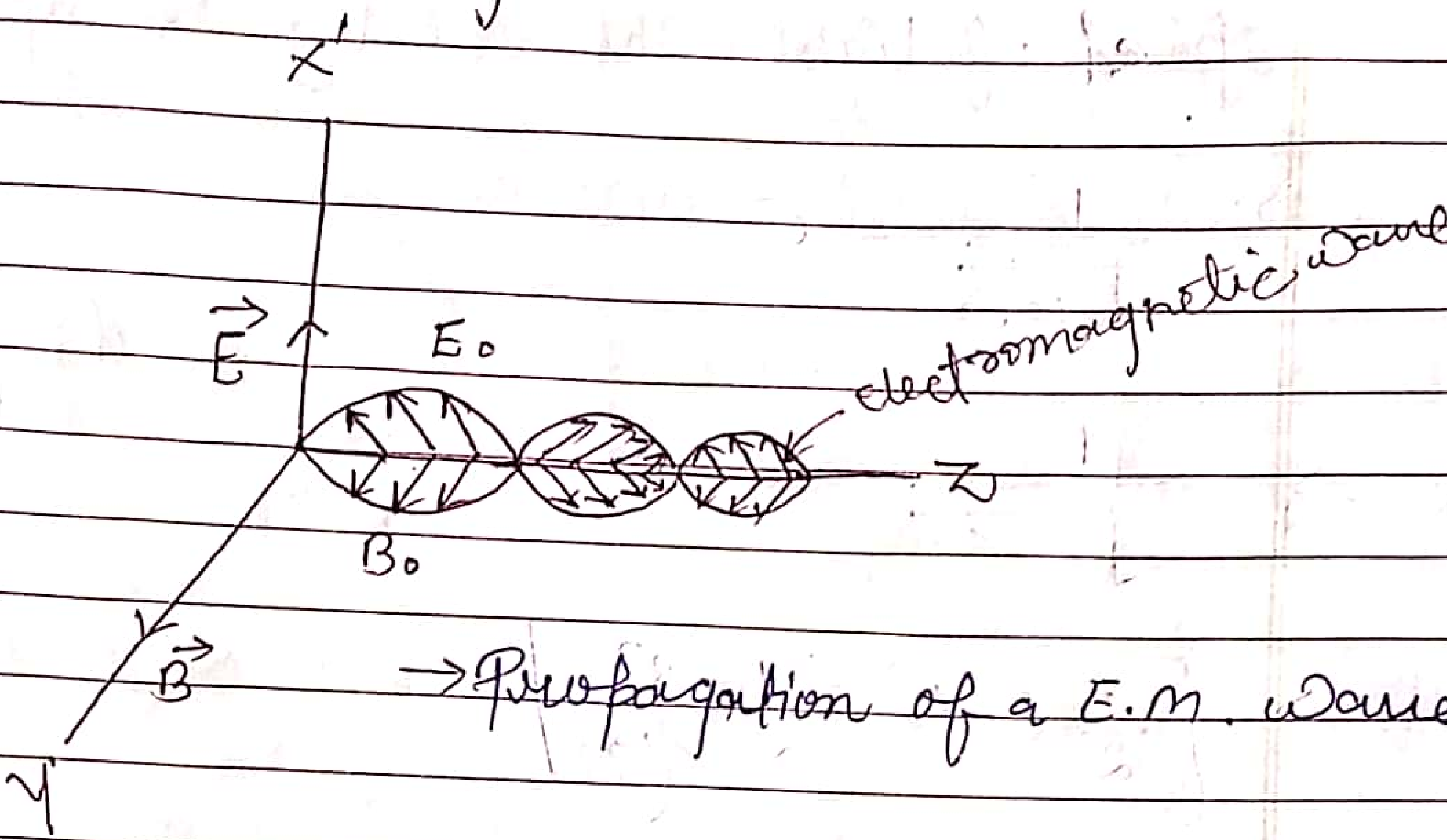
$$\left[\oint \vec{B}\cdot\vec{dl} = \mu_0 i_c + \mu_0\epsilon_0\frac{d\phi_E}{dt}\right]$$

This is fourth maxwell's equation

Electromagnetic waves

The waves produce due to the change in electric field & magnetic field sinosiudally and propogating through space such that the two fields are perpendicular to each other & ⊥ to the direction of wave propagation is

Called electromagnetic wave.



→ Propagation of a E.M. Waves

$$E = E_x = E_0 \sin(Kx - \omega t)$$
$$B = B_y = B_0 \sin(Kx - \omega t)$$

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 travell in free space with the speed of light which is given by the relation—

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

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

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—

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

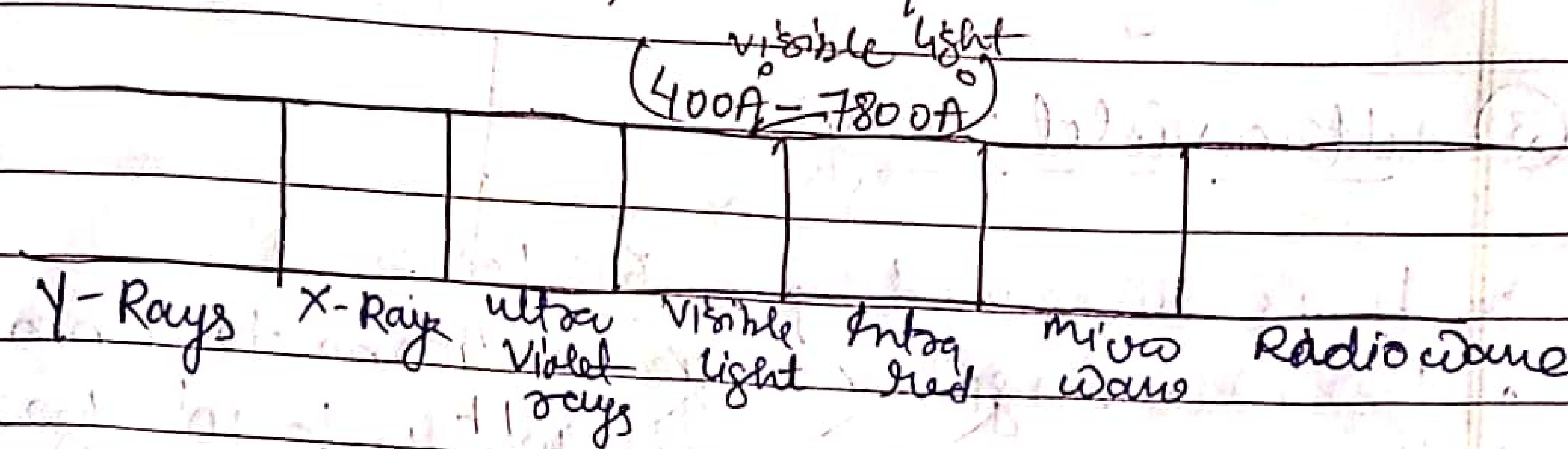
6. The energy density in an electric field and a magnetic field will be equal.

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

[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.
- It's wavelength is less than 10^{-3} nm.
- It's frequency range is 3×10^{18} Hz to 5×10^{22} Hz
- It is produced by radio active decay
- It uses to produce nuclear reaction, it uses as radiotherapy for the treatment of cancer & tumour

② X - rays

- This ray was discoverd by proffesor. Roentgen
- Its wavelength range is 1nm to 10^{-3}nm.
- Its frequency range is 3×10^{16} Hz to 3×10^{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 ~~is~~ Ritter.
- Its wavelength range is 400nm to 1nm.
- Its frequency range is 10^{14} Hz to 10^{16} Hz.
- It is uses in checking mineral sample, study molecular structure etc.

④ Visible light

- It is discovered by Rutherford
- Its wavelength range in 700nm to 400nm.
- Its frequency range is 4×10^{14} Hz to 7×10^{14} Hz
- It uses to see things.

⑤ Ifrared ~~rays~~ wave

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

⑥ Microwave

- This waves is produced by vacuum tubes
- it is also called short wavelength Radio wave
- Its wavelength range in 0.1 m to 1 mm.
- Its forequency 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 0.1m.
- Its frequency range is 500 KHz to 1000 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	3×10^{11} to 4×10^{14}	Vibration of atoms and molecules.	Thermopile, Bolometer, infrared photographic film
Light	700 nm to 400 nm	4×10^{14} to 8×10^{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	8×10^{14} to 8×10^{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	1×10^{16} to 3×10^{21}	X-ray tubes or inner shell electrons.	Photographic film Geiger tubes, ionisation chamber
γ-rays	$<10^{-3}$ nm	5×10^{18} to 5×10^{22}	Radioactive decay of the nucleus.	Photographic film, ionisation chamber