WELCOME

ELECTROMAGNETIC

WAVES

- An electromagnetic wave in a vacuum consists of mutually perpendicular and oscillating electric and magnetic fields.

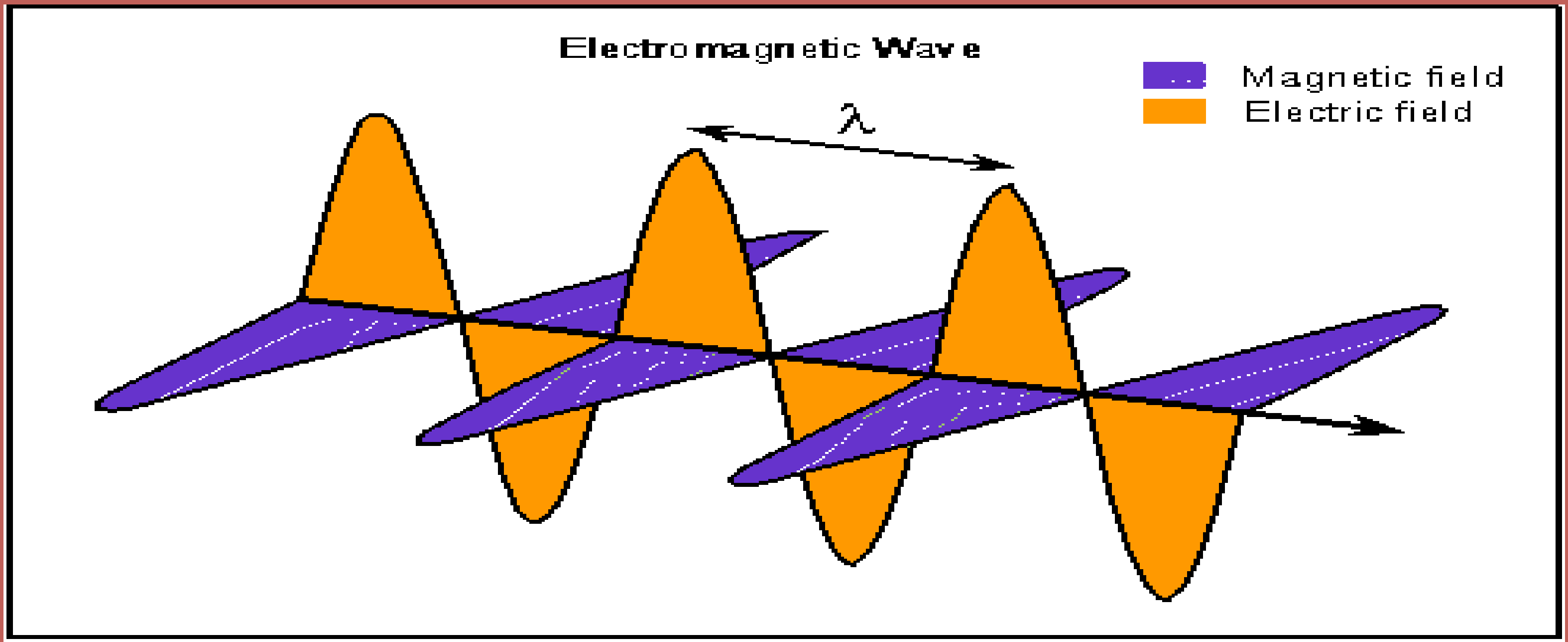
- The wave is a transverse in nature.

- The fields are perpendicular to the direction in Which the wave travels.

- All electromagnetic waves regardless of their frequency, travel through a vacuum at the same speed, the speed of light *c* .

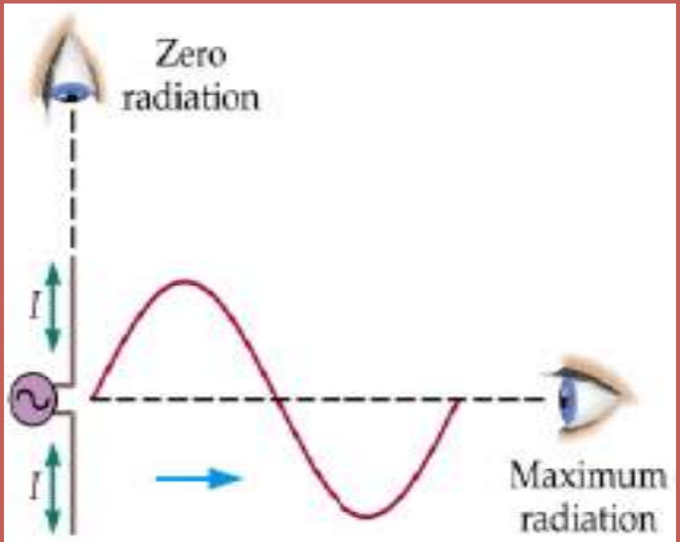
- The frequency *f* and wavelength λ (*lambda)* of an electromagnetic wave in a vacuum are related to its speed through the relation

$$c = f\lambda$$



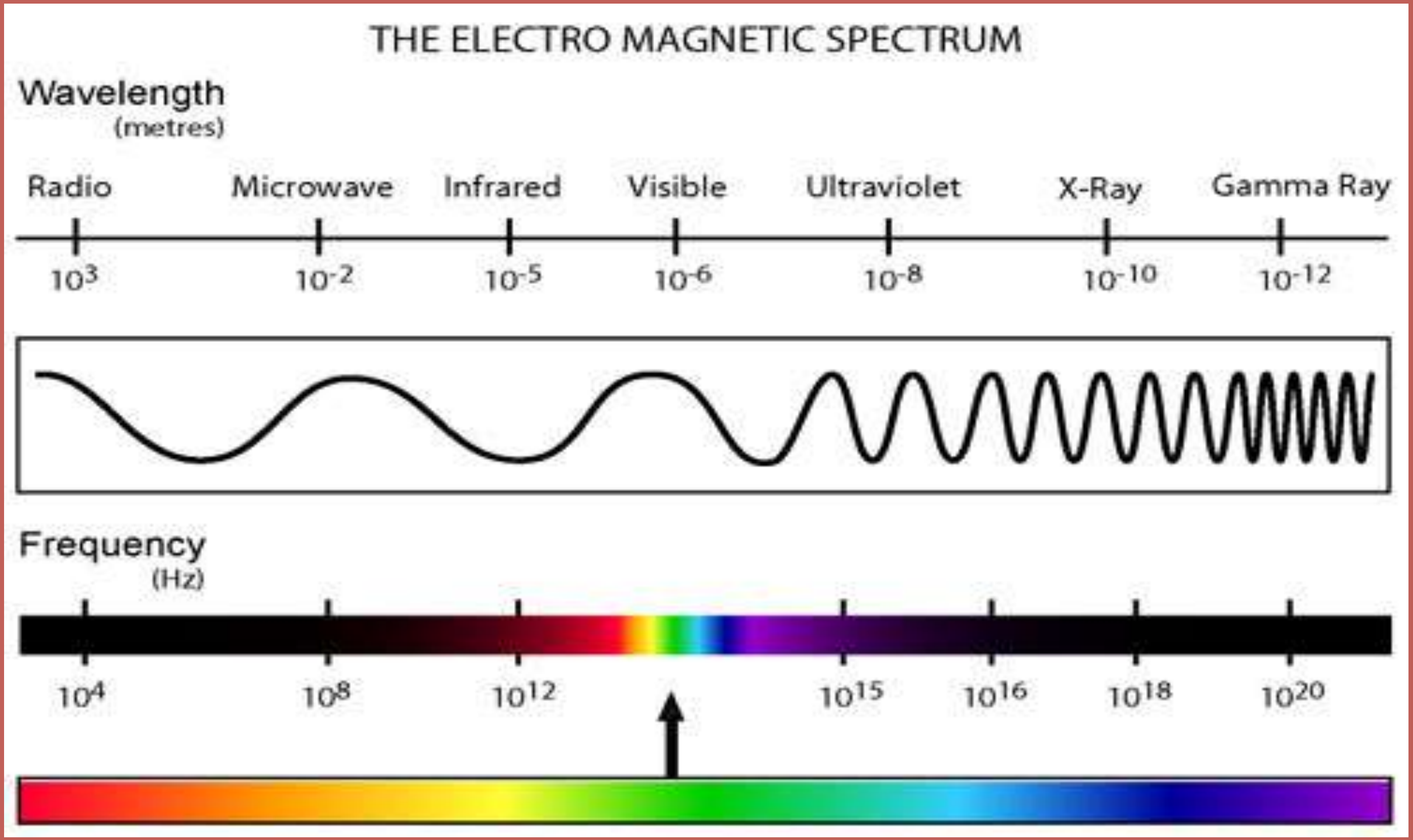
An electromagnetic wave propagating in the positive x direction.

Note that E and B are perpendicular to each other and in phase. The direction of propagation is given by the thumb of the right hand, after pointing the fingers in the direction of E and curling them toward B.



Electromagnetic radiation is greatest when charges accelerate at right angle to the line of sight. Zero radiation is observed when the charges accelerate along the line of sight. These observations apply to electromagnetic waves all frequencies.

ELECROMAGNETIC SPECTRUM



MECHANICAL WAVES VERSUS ELECTROMAGNETIC WAVES

1. Electromagnetic waves travel in a vacuum whereas mechanical waves do not.

2. The ripples made in a pool of water after a stone is thrown in the middle are an example of mechanical wave. whereas examples of electromagnetic waves include light and radio signals.

3.Mechanical waves are caused by wave amplitude and not by frequency.

Electromagnetic Waves are produced

by vibration of the charged particles.

4. While an electromagnetic wave is called just a disturbance, a mechanical wave is considered a periodic disturbance.

Some Electromagnetic Quantities

Physical Quantity	Units
1. Electric field strength	1. Volt per meter
2. Magnetic field strength	2. Ampere per meter
3. Electric Displacement vector	3. Coulomb per meter

4. Magnetic Induction — 4. Tesla

5. Permittivity — 5. F per meter

6. Permittivity of free space — 6. F per meter

7.Relative Permittivity — 7. Dimensionless

8.Permeability — 8. H per meter

9.Permeability of free space — 9. H per Meter

10. Relative Permeability — 10. Dimensionless Constant

11. Current Density	11. A per Meter square
12. Displacement Current	12. A per Meter
13. Charge Density	13. C per Meter
14. Conductivity	14. S per Meter

Maxwell’s Equations

Four Maxwell’s Equations

- Differential form
- Integral Form

Differential form

1. Gauss' law for electricity

$$\nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0} = 4\pi k \rho$$

Significance

1. It relates the spatial variation of electric field with charge density.
2. It is time independent equation.
3. Electric flux depends upon charge density.
4. It summarises the Gauss's law of electrostatics.

2.

Gauss' law for magnetism

$$\nabla \cdot B = 0$$

Significance

1. It deals with spatial variation of magnetic induction.
2. It is time independent equation.
3. It shows that there is no sources or sink of magnetic flux.
4. It summarises the gauss's law of magnetism.

3. Faraday's law of induction

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

Significance

1. It relates the spatial variation of electric field with time variation of magnetic field.
2. It is time dependent equation.
3. It shows time variation of magnetic field generates electric field.
4. It summarises the faraday’s law of electromagnetism , including the Lenz’s law.

4.

Ampere's law

$$\nabla \times B = \frac{4\pi k}{c^2} J + \frac{1}{c^2}\frac{\partial E}{\partial t}$$

$$= \frac{J}{\varepsilon_0 c^2} + \frac{1}{c^2}\frac{\partial E}{\partial t}$$

Significance

1. It relates the spatial variation of magnetic intensity with current density and Displacement current.

2. It is time dependent equation.

3. It summarises the Ampere's law.

Integral form

1. Gauss' law for electricity

$$\oint \vec{E} \cdot d\vec{A} = \frac{q}{\varepsilon_0}$$

2. Gauss' law for magnetism

$$\oint \vec{B} \cdot d\vec{A} = 0$$

3. Faraday's law of induction

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

4. Ampere's law

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i + \frac{1}{c^2} \frac{\partial}{\partial t} \int \vec{E} \cdot d\vec{A}$$

Poynting vector

- The cross product of electric vector **E** and magnetic vector **H** is called poynting vector.

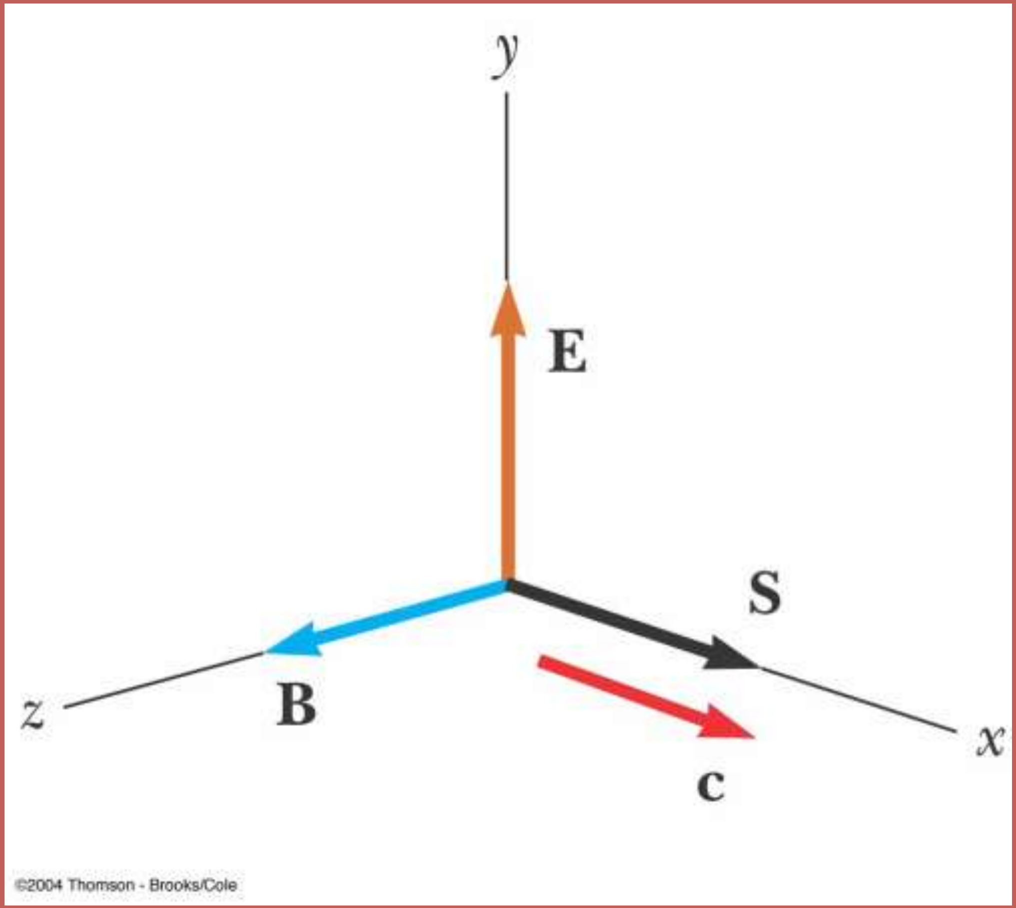
- It is denoted by vector **S**

- it is named after J.H Poynting.
- The units of **S** are joule per second per meter sq.
- Where **H=B/**u.

Mathematic formula

$$\mathbf{S} \equiv \frac{1}{\mu_o} \mathbf{E} \times \mathbf{B}$$

Representation



Main points

- Its magnitude varies in time

- Its magnitude reaches a maximum at the same instant as **E** and **B**

Refractive index of medium

- The ratio of velocity vector of em wave in free space to that in medium is called refractive index of medium.
- It is denoted by n.
- n=c/v
- where c is the velocity of em wave in free space & v in medium

Characteristic impedance of medium to the em waves

- The ratio of electric vector to magnetic vector of em wave at that instant is defined as impedance of medium to em wave.
- It is denoted vector **z**
- **where Z=E/H**

Skin Depth

- It is defined as distance beyond the surface of conductor inside it at which the amplitude of field vector is reduced to 1/e value at the surface.
- it is represented by δ
- $\delta = 1/k = (2/(\omega\mu\sigma))^{1/2}$

Relation between impedance & refractive index

$$n = z_0 / z$$

Where z_0 is impedance of free space &

Z is impedance of medium.

THANKS