S.B. ARTS AND K.C.P SCIENCE COLLEGE VIJAYAPUR

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Class :- BSC II Sem ('B')

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Subject :- Physics

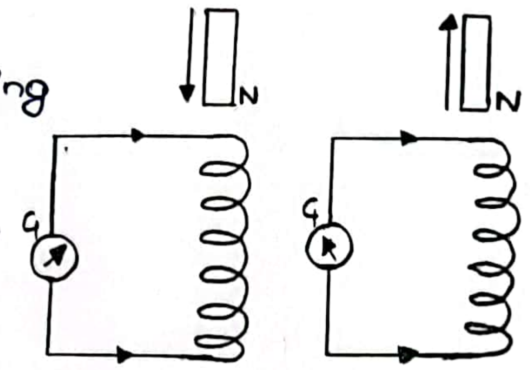
Topic :- Electromagnetic Induction

Seminar

ELECTROMAGNETIC INDUCTION

Faraday's Experiment on Electromagnetism

Faraday's First Experiment



* Figure shows a close containing galvanometer. As there is no source of emf so there is no deflection in galvanometer.

* We move a bar magnet towards the wire keeping the wire stationary, and say north pole facing the wire, the galvanometer needle is deflected indicating that a current has been set in the circuit.

* However, the deflection is observed only when the magnet is in motion.

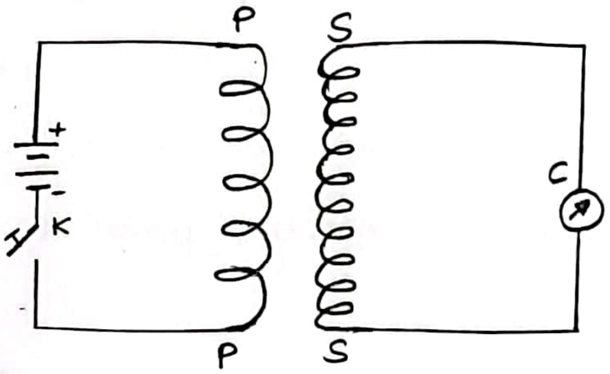
* If the magnet is moved away from the wire, the galvanometer needle is deflected in the opposite direction to that when the magnet moves towards the wire indicating that the current set up in the circuit is in opposite direction.

* There is no deflection in the galvanometer when the magnet is held stationary and wire is moved towards or away from magnet.

* Faraday discovered that moving the magnet towards the wire one way has the same effect as moving the wire towards the magnet the other way.
* It is immaterial which of them is moved.

Faraday's second Experiment

* The magnet is replaced by a coil carrying current, we expect to observe the same effect because the coil carrying current produces magnetic field.



* P is a primary coil carrying current, S is a secondary coil and a galvanometer is connected in series with secondary.
* The motion of either of the coils show a deflection in the galvanometer.
* He also observed that galvanometer shows a sudden deflection in one direction when current was started in primary and in the opposite direction when current was stopped.

Equations of continuity

Statement: If the net charge crossing a surface bounded by a volume is not zero then the charge density within the volume must change with time in a manner that the time rate of decrease of charge within the volume is equal to the net rate of flow of charge out of the volume.

Consider a closed surface S enclosing a volume V of electric charge distribution. Direction of charge flow in unit time is defined as the current density $\vec{J}$. The total electric current I flowing outward through a closed surface is given by

$$I = \oint_S \vec{J} \cdot \vec{ds} \rightarrow (1)$$

As the charge is conserved,

$$I = -\frac{dq}{dt} \rightarrow (2)$$

$$q = \int_V \rho \, dv$$

$$I = -\frac{d}{dt}\int_V \rho \, dv \rightarrow (3)$$

comparing eq (1) and (3)

$$\oint_S \vec{J} \cdot \vec{ds} = -\frac{d}{dt}\int_V \rho \, dv$$

(or)

$$\oint_S \vec{J} \cdot \vec{ds} = -\int_V \frac{d\rho}{dt} dV \rightarrow (4)$$

from gauss divergence theorem

$$\oint_S \vec{J} \cdot \vec{ds} = \int_V (\nabla \cdot \vec{J}) dv \rightarrow (5)$$

Substituting ④ in ⑤,

$$\int_V (\nabla . \vec{J}) dv = - \int_V \frac{d\rho}{dt} dV$$

$$\boxed{\nabla . \vec{J} = - \frac{d\rho}{dt}} \quad \text{or} \quad \boxed{\nabla . \vec{J} + \frac{d\rho}{dt} = 0}$$

This is called the equation of continuity which is mathematical form of law of conservation of charge. For stationary current or steady current, $\frac{d\rho}{dt} = 0$. Thus, $\nabla . \vec{J} = 0$

Maxwell's equations

Maxwell using the four basic laws of ~~elet~~ electricity and magnetism, namely Gauss's law, Biot-Savart's law, Faraday's law and Ampere's circuital law, formulated four fundamental equations called Maxwell's equations.

There are four fundamental equations of electromagnetism known as Maxwell's equations.

1. $\vec{\nabla} . \vec{D} = \rho$

   It represents Gauss law in electrostatics. wher $\vec{D}$ is electric displacement & ρ is free charge density.

2. $\vec{\nabla} . \vec{B} = 0$

   It represents Gauss law in magnetostatics. where, $\vec{B}$ is magnetic induction.

3. $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{dt}$

It represents Faraday's law of electromagnetic induction, where $\vec{E}$ is electric field intensity and $\vec{B}$ is magnetic induction.

4. $\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{dt}$

It represents Maxwell's modification in Ampere's law. where $\vec{E}$ is electric field intensity and $\vec{B}$ is magnetic induction.

Integral form of Maxwell's equations and their physical significance

1. $\int_s \vec{D}\, ds = q$

This maxwell's equation signifies.

The total flux of the electric displacement linked with the closed surface is equal to the total charge enclosed by the close surface.

2. $\int_s \vec{B} \cdot ds = 0$

This maxwell's equation signifies

(i) The total outward flux of magnetic induction linked with a closed surface is zero. That is magnetic flux lines are continuous forming closed loops implying that there are no sink or sources in the case of magnetic flux.

(ii) It confirms the non existence of magnetic monopole and hence establishes that the magnetic poles always appear as dipoles.

3. $\int \vec{E}\, dl = -\int_s \frac{\partial \vec{B}}{\partial t}\, ds$

This Maxwell's equations signifies.

Line integral of electric intensity around closed path i.e, electromotive force is equal to the negative rate of change of magnetic flux linked with the path.

4. $\int_c \vec{H}\, dl = \int_s \left[\vec{J} + \frac{\partial \vec{D}}{\partial t}\right] ds$

This Maxwell's equation signifies

Line integral of magnetic field intensity around closed path i.e, magnetomotive force is equal sum of conduction current and the displacement current linked with that path.

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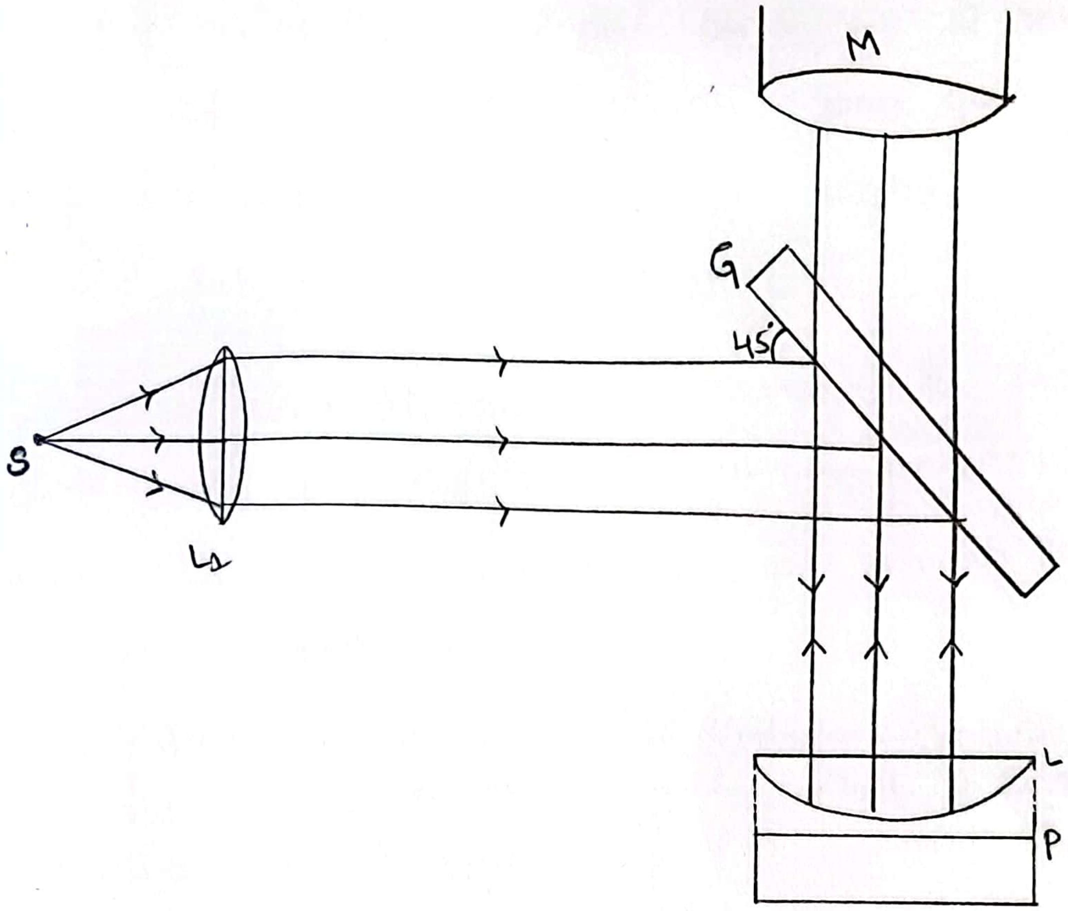
Newton's Rings due to reflected light and transmitted light



S - Source of monochromatic light.

L_1 - Convex lens.

G - plane glass plate inclined at an angle of 45°

L - plano convex lens.

P - plane glass plate of same material as of G.

M - Travelling microscope.

* When convex surface of plano convex lens of large radius of curvature is placed on a plane glass plate.

* A thin layer film of increase in thickness is formed between the lens and the plate.

* The thickness of this film is zero of the point of contact and gradually increases as one proceds outwards.

* When a beam monochromatic light is made to fall on such a film.

* A pattern of alternate bright and dark concentric rings are observed formed the point of contact. this rings are called Newton's rings.

* Newton's rings are formed due to the interference of light waves reflected from the upper and lower surfaces of the air enclosed between lens and plate.

* A parallel beam of light rays fall on glass plate G of angle of 45°.

* When the microscope is focuses at the point of contact of the lens and plate a pattern of alternate dark and bright rings.

* The rings are also seen in transmitted light that is the light passing towards through plate P.

Newton's Rings due to reflected light

Let R be the radius of curvature of plano convex lens L. the Condition for bright fringe is path difference

$$\Delta = n\lambda$$

$$2\mu t \cos r - \frac{\lambda}{2} = n\lambda$$

$$2\mu t \cos r = n\lambda + \frac{\lambda}{2}$$

$$2\mu t \cos r = (2n+1)\frac{\lambda}{2}$$

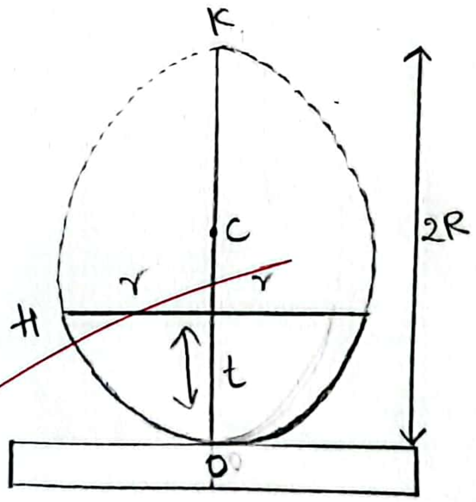
For normal incidence $\angle i = \angle r = 0$

For air film $\mu = 1$

$$2(1)\, t \cos 0 = (2n+1)\frac{\lambda}{2}$$

$$2t = (2n+1)\frac{\lambda}{2} \rightarrow (1)$$

For Geometry



$HE \times EP = KE \times EO$

$r \times r = (2R - t) \times t$

$r^2 = 2R \times t$

$$t = \frac{r^2}{2R} \rightarrow (2)$$

Put (2) in (1)

$$\frac{2r^2}{2R} = (2n+1)\frac{\lambda}{2}$$

$$r_n^2 = (2n+1)\frac{\lambda R}{2}$$

$$r_n = \sqrt{\frac{(2n+1)\lambda R}{2}}$$

Diameter of n^{th} bright ring

$$D_n = 2\sqrt{\frac{(2n+1)\lambda R}{2}}$$

Condition for dark ring

path difference $\Delta = (2n+1)\frac{\lambda}{2}$

$$2\mu t\cos r + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$$

$$2\mu t\cos r = -\frac{\lambda}{2} + (2n+1)\frac{\lambda}{2}$$

$$2\mu t\cos r = n\lambda$$

For normal incidence $r=0$

For air film $\mu=1$

$$2(1)t\cos 0 = n\lambda$$

$$2t = n\lambda \rightarrow (3)$$

put (2) in (3)

$$2\left(\frac{r^2}{2R}\right) = n\lambda$$

$$r_n^2 = n\lambda R$$

$$\sqrt{n\lambda R}$$

$$D_n = 2r_n$$

$$D_n = 2\sqrt{n\lambda R}$$

Newton's rings in transmitted light:-

The condition for bright ring in transmitted light is given by

path difference $\Delta = n\lambda$ $n = 0, 1, 2, 3 \dots$

$2\mu t \cos r = n\lambda$

For normal incidence $\angle i = \angle r = 0$

For air film $\mu = 1$

$2(1)t\cos(0) = n\lambda$

$2t = n\lambda \rightarrow (1)$

And we know that $t = \frac{r^2}{2R} \rightarrow (2)$

put (2) in (1)

$\cancel{2}\left(\frac{r^2}{\cancel{2}R}\right) = n\lambda$

$r_n^2 = n\lambda R$

$r_n = \sqrt{n\lambda R}$

Diameter of n^{th} bright ring is given by

$D_n = 2r_n$

$D_n = 2\sqrt{n\lambda R}$

Condition for dark ring in trasmitted light

path difference $\Delta = (2n+1)\frac{\lambda}{2}$

$n = 0, 1, 2, 3 \ldots$

$2\mu t \cos r = (2n+1)\frac{\lambda}{2}$

For a normal incidence $\angle i = \angle r = 0$

For air film $\mu = 1$

$2(1)t \cos(0) = (2n+1)\frac{\lambda}{2}$

$2t = (2n+1)\frac{\lambda}{2} \rightarrow (3)$

put (2) in (3) we get

$$\frac{2r^2}{2R} = (2n+1)\frac{\lambda}{2}$$

$$r_n^2 = (2n+1)\frac{\lambda}{2}R$$

$$r_n = \sqrt{(2n+1)\frac{R\lambda}{2}}$$

Diameter of nth dark ring is given by

$$D_n = 2r_n$$

$$D_n = 2\sqrt{(2n+1)\frac{R\lambda}{2}}$$ //