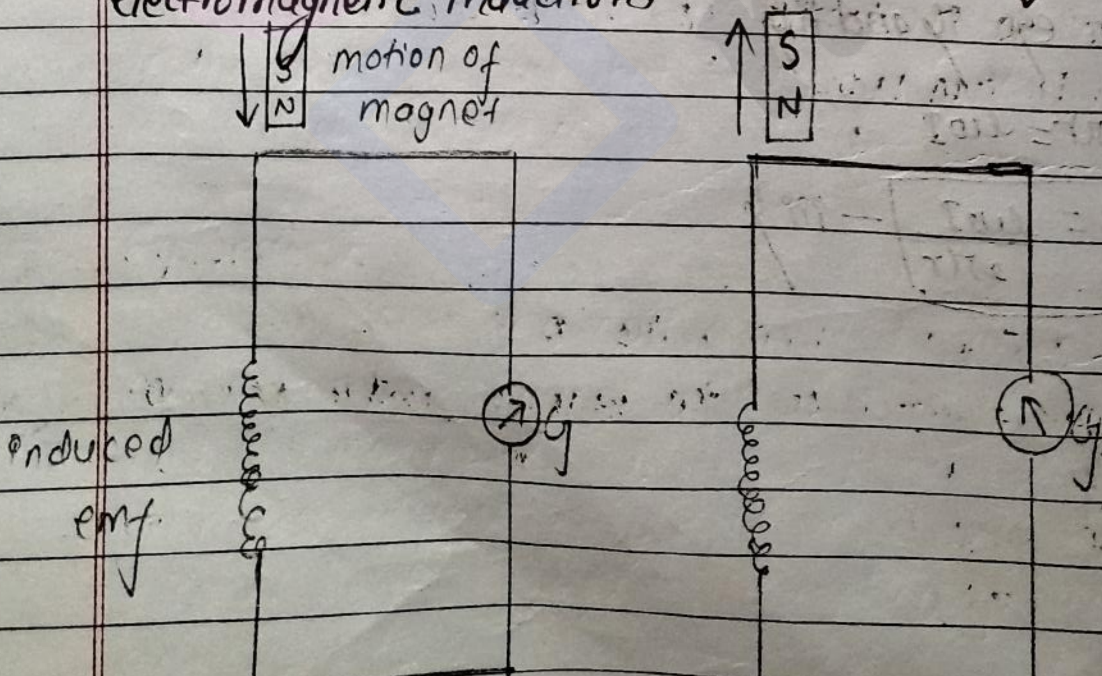
Electromagnetic Induction

faraday's discovery for electromagnetic :-

Faraday's did an experiment for the production of current in the coil or conductor due to relative motion betn the coil and magnet. A/C to him, when the magnet is moved toward the coil without touching, the galvonometer is connected to coil shows the deflection. , when the magnet is moved away from the coil the galvonometer again shows the deflection but in opposite direction to that of previous case.

The same phenomenon was observed when magnet is kept stationary but the coil is moving towards or away from the magnet. In doing so, the magnetic flux-linked with the coil changes as a result emf to developed in the coil which is called induced emf. Due to this induced emf, the current is generated in the coil called induced current

Hence, phenomenon of development of emf in the coil due to relative motion betn coil & magnet is called electromagnetic Induction.



* Magnetic flux (ϕ) = BA = BA cos θ
It's unit is Tm^2 and weber (wb)

The cgs unit of magnetic flux is maxwell (mx)

1 maxwell = 1 gauss × $1 cm^2$

$1 wb = 1 T \times 1 m^2$

$1 wb = 10^4 gauss \times 10^4 cm^2$

$1 wb = 10^8 gauss\ cm^2$

$1 wb = 10^8$ maxwell.

Imp Faraday's law of electromagnetic induction:-

Faraday's law of electromagnetic induction states that:-

1. whenever magnetic flux linked with the coil or conducter change and emf is induced in it which lasts as longer as the change in magnetic flux continuous.

2. Magnitude of emf is induced in a coil or conductor a directly proportional to the rate of magnetic flux linked with coil.

Let ϕ_1 be the magnetic flux linked with the coil at times t1 and ϕ_2 be the magnetic flux linked with the coil at time t2 such that $t_2 > t_1$ and $\phi_2 > \phi_1$. Then a/c to faraday's law of electro magnetic induction,

$$\varepsilon \propto \frac{\phi_2 - \phi_1}{t_2 - t_1}$$

$$\Rightarrow \varepsilon = K\left(\frac{\phi_2 - \phi_1}{t_2 - t_1}\right)$$ where K is porportionally constant and its value in system is found to be 1 and negative sign shows the opposing nature of induced emf.

In general

$$\boxed{\varepsilon = -\frac{d\phi}{dt}}$$

If coil contain N no. of turns

$\phi_r = N\phi$

$\Rightarrow \varepsilon_r = \frac{-d\phi_r}{dt}$

$\Rightarrow \varepsilon_r = -\frac{d(N\phi)}{dt}$

$\Rightarrow \varepsilon_r = \frac{-N\,d\phi}{dt}$

Important

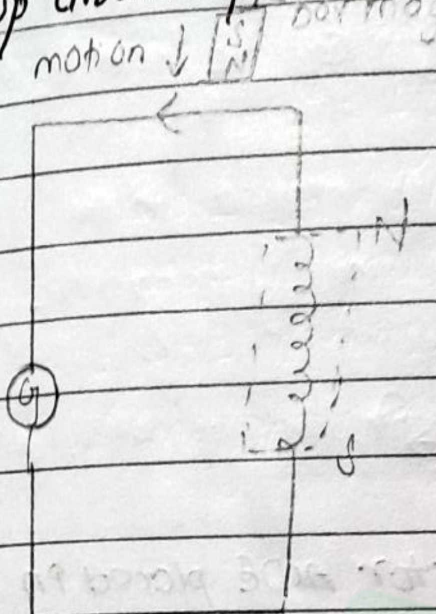
2. Lenz's law [What is Lenz's law ? How lenz's law lead to the conservation energy ? (Exam Q):

Statement:-

It states that the direction of induced current in the circuit is such that it always opposes the change of causes that produce it

Explanation

consider a coil connected with the galvanometer consider a bar magnet with its N-pole facing towards the coil and moving towards the coil. Due to the motion of bar magnet, the magnetic flux linked with the coil & moving towards the coil. Due to the motion of bar magnet, the magnetic flux linked with coil changes. As a result, an emf is induced in the coil. Due to the induced emf a magnetic field is setup around the coil which act as induced magnet.



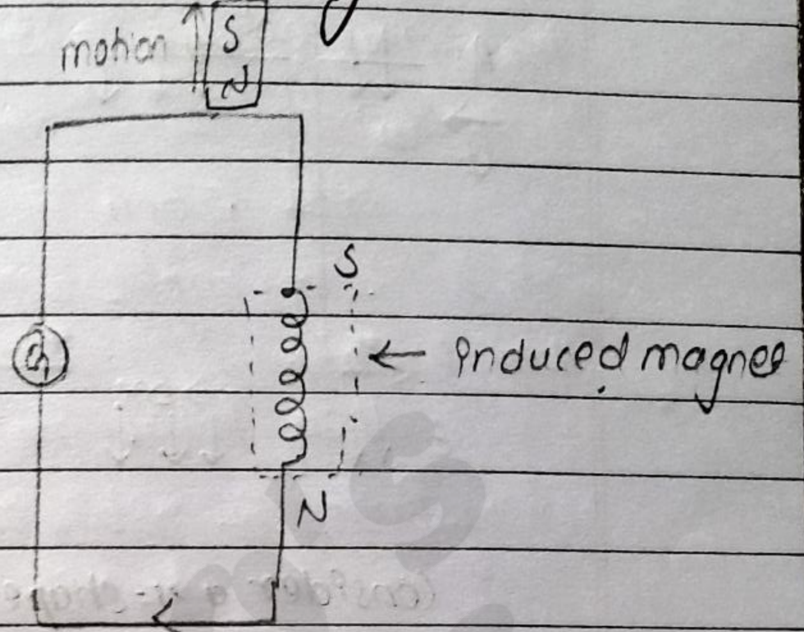


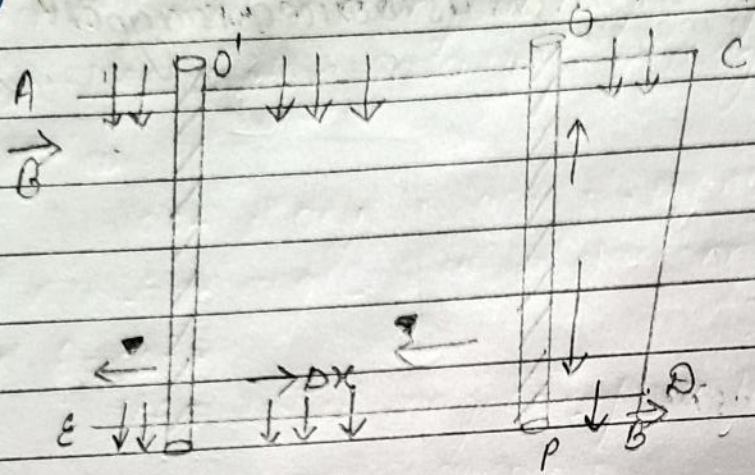
fig (a) fig (b)

The north pole of induced magnet is falling forward the north pole of moving bar magnet and there exist the repulsive force between two magnets which proves that the direction of induced emf is such that which oppose that cause that produce it.

Similarly, when the bar magnet is moving away from the coil, the south pole of induced magnet is facing towards the N-pole of moving bar magnet and there exists a attractive force between two magnets which proves that the direction of induced emf is such that it oppose the motion of bar magnet.

Here, external source has to do the work to give the continuity of to the motion of bar magnet. The work repulsive force betn bar magnet & induced magnet which appears as a electrical energy. Hence, len's law obey law of conservation of energy.

Emf induced in a rod moving in a magnetic field.



Consider a u-shaped conductor ACDE placed in uniform magnetic field of field strength B. Suppose a straight conductor of long (l) area cross section 'A' placed over the u-shaped conductor. The straight conductor is moving over the u-shaped conductor in the direction perpendicular to the direction of magnetic field. Let OP be the initial position of conductor & O'P' be the final position of the conductor after time 'dt' such that.

$$OO' = PP' = dx.$$

The area swept by the conductor in the time dt is

$$dA = OO' \times OP.$$
$$= dx \times l.$$

Then the rate of area swept is

$$\frac{dA}{dt} = l\frac{dx}{dt}$$

$$\frac{dA}{dt} = l.v \text{ ——— } i) \quad \text{where } v = \frac{dx}{dt} = \text{velocity.}$$

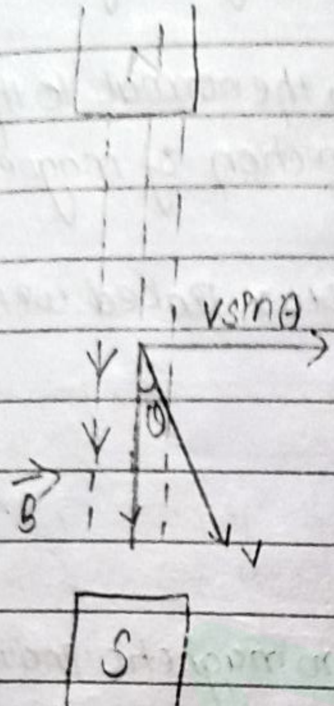
A/c to Faraday's law of electromagnetic induction induced emf $(E) = \frac{-d\phi}{dt}$.

But $\phi = BA$

$$E = \frac{-d(BA)}{dt}$$

$\boxed{\varepsilon = -BVL}$ — ii ½ [(–)ve sign is not used in numerical]

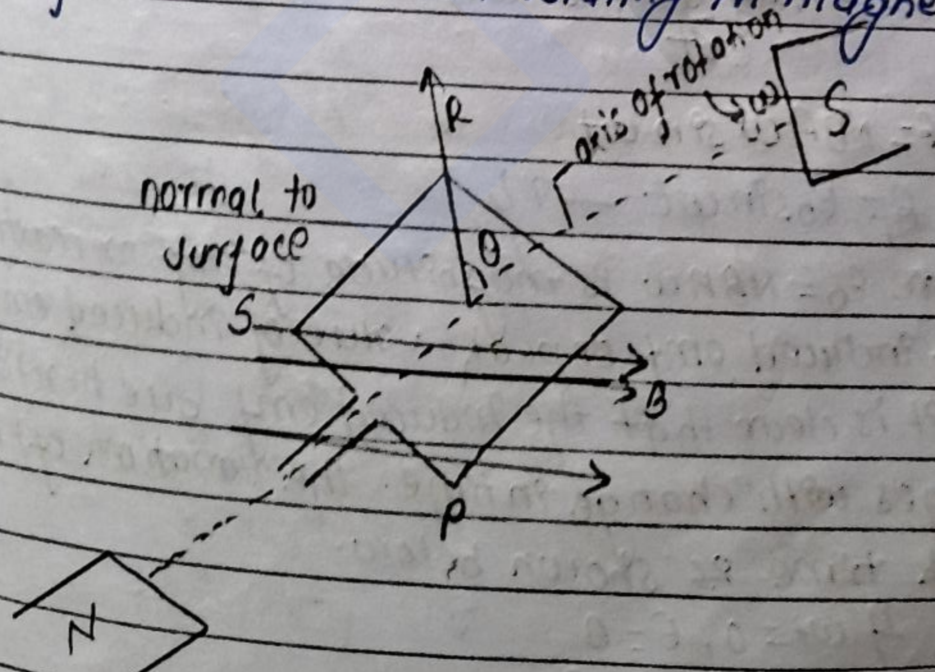
$\boxed{\text{field in magnitude } (\varepsilon) = BVl}$ — iii ½ (N)



If the conductor makes an angle θ with the direction of magnetic field that effective component of velocity in $v\sin\theta$

$\boxed{\therefore \text{Induced emf } (\varepsilon) = Bvl \sin\theta}$ (N)

The emf induced in a coil rotating in magnetic field.



Consider a rectangular coil having area 'A', no. of turns 'N' which is placed in a uniform magnetic field of field strength 'B'. The coil is rotating in a uniform magnetic field with angular velocity 'ω'.

Let at any instant 't', the normal to the of the coil makes an angle 'θ' with direction of magnetic field such that $\theta = \omega t$.

Then, total magnetic flux linked with 'N' an number of turns of coil is given by,

$$\phi = NBA\cos\theta$$

$$\text{But } \theta = \omega t$$

$$\phi = NBA\cos\omega t$$

A/c to faraday's law of electromagnetic induction, the induced emf is given by

$$\mathcal{E} = -\frac{d\phi}{dt}$$

$$\Rightarrow \mathcal{E} = -\frac{d}{dt}(NBA\cos\omega t)$$

$$\Rightarrow \mathcal{E} = -NBA\frac{d}{dt}(\cos\omega t)$$

$$\Rightarrow \mathcal{E} = NBA\omega\sin\omega t$$

$$\Rightarrow \mathcal{E} = \mathcal{E}_0\sin\omega t \quad \text{— i}$$

where $\mathcal{E}_0 = NBA\omega$ is magnitude of emf or maximum value of induced emf or peak value of induced emf. From eqn i it is clear that the induced emf due to rotating coil changes with change in time. The variation of induced emf with time is shown below.

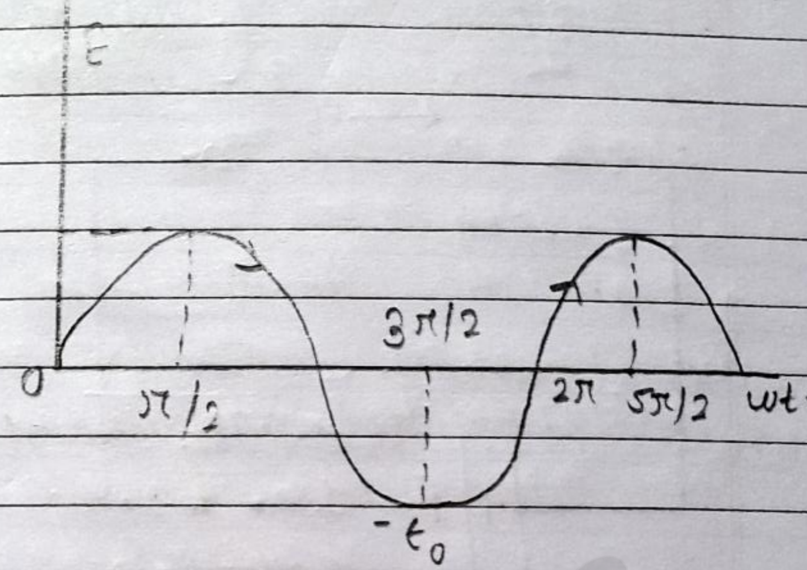
If $\omega t = 0$, $\mathcal{E} = 0$

$\omega t = \frac{\pi}{2}$, $\mathcal{E} = \mathcal{E}_0$

$\omega t = \pi$, $\mathcal{E} = $

$\omega t = \frac{3\pi}{2}, \ \mathcal{E} = -\mathcal{E}_0$

$\omega t = 2\pi, \ \mathcal{E} = 0$

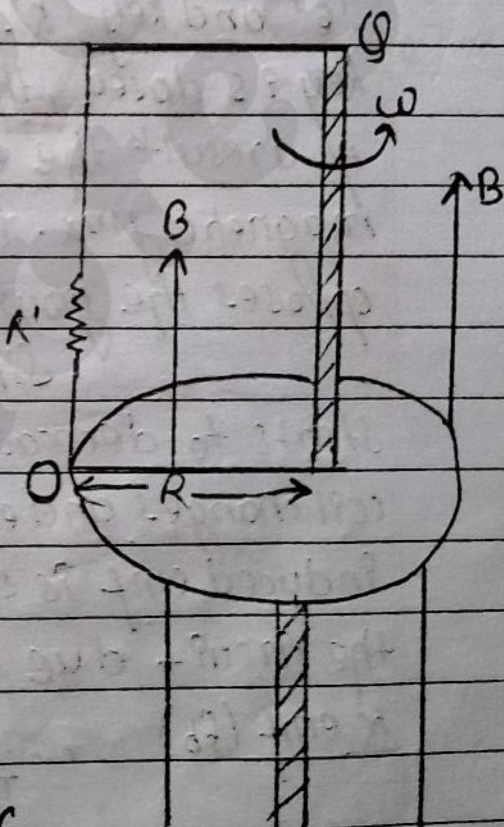


* Disc generator (For numerical and objective)

Length of conductor, l = radius(R)

Average velocity of straight conductor PQ is

$$V = \frac{R\omega + 0}{2} = \frac{R\omega}{2}$$



We know, emf induced in the conductor RQ,

$$\mathcal{E} = BVl$$

$$\Rightarrow \mathcal{E} = B\frac{R\omega}{2} \cdot R$$

$$\Rightarrow \mathcal{E} = \frac{B(2\pi f)R^2}{2}$$

$$\Rightarrow \boxed{\mathcal{E} = BAf} \quad [\because A = \pi R^2]$$

Objective :- If R_1 = internal radius of disc

R_2 = external radius of disc

$$A = A_{ex} - A_{in}$$

$$= \pi R_2^2 - \pi R_1^2$$

$$= \pi (R_2^2 - R_1^2)$$

$$\therefore \boxed{\mathcal{E} = B\pi (R_2^2 - R_1^2) f} \quad \text{(For hallow disk)}$$

Self Induction

{ log is closed → current growth / increase → magnetic flux change → emf Induced → oppose the growth current

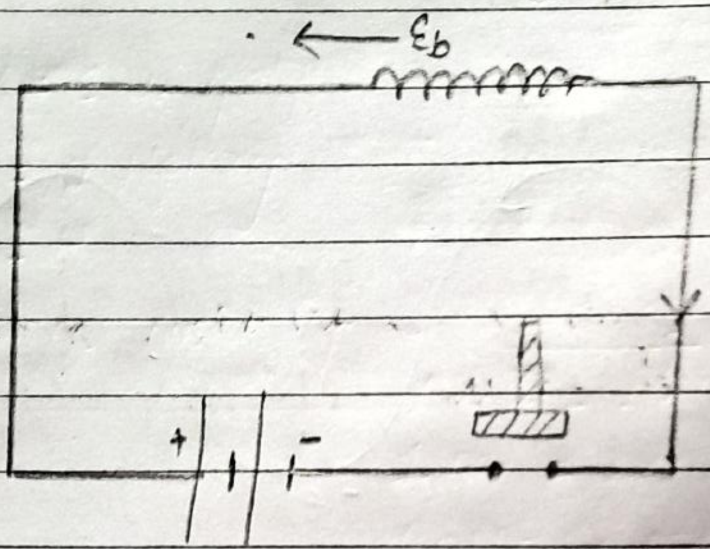


fig (a)

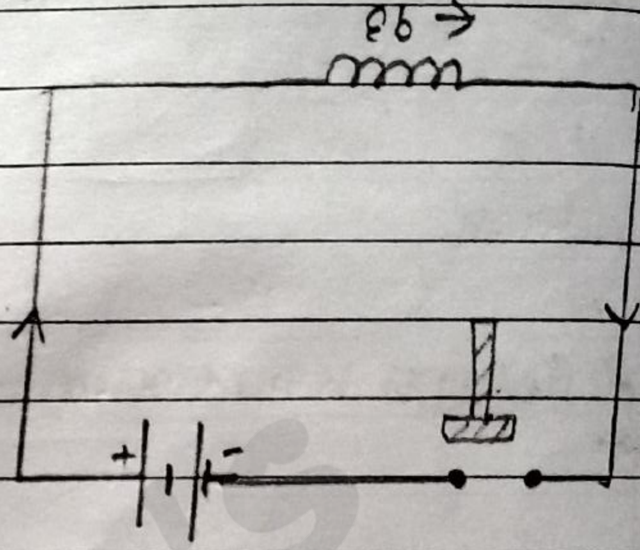


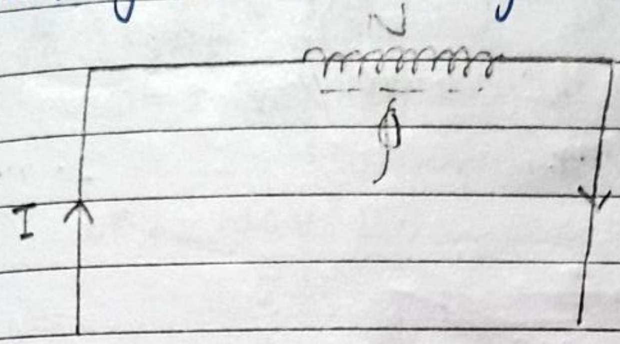
fig (b)

Consider a coil connected to the battery of emf 'ε' and key 'K'. Initially let the key is opened. when the key is closed, the current through the coil starts to increase As a result the emf is induced in the coil due to change in magnetic flux. the direction of induced emf is such that it opposes the growth of the current.

Similarly when key is opened the current starts to decrease. As a result, magnetic flux linked with the coil changes and emf is induced in the coil. the direction of induced emf is such that it opposes the decay of current in the circuit due to change in magnetic flux is called black emf (ε_b)

The phenomenon of production of opposing emf in the coil due to change in current passing through it is called self-induction.

Coefficent of Induction (self Inductance)



Let I be the current flowing through the coil and ϕ be the magnetic flux linked with the coil. Then it is found that

$$\phi \propto I$$

$\Rightarrow \phi = LI$ where L is proportionally constant called coeffcient self induction or simply self-inductance.

If $I = 1A$, $\phi = L$.

Hence, self inductance is numerically equal to magnetic flux if current passing through it is 1A.

Also, $E = \frac{d\phi}{dt}$

$$\Rightarrow E = \frac{d(LI)}{dt}$$

$$\Rightarrow E = L\frac{dI}{dt} \quad \text{if } \frac{dI}{dt} = 1As^{-1}$$

$$\Rightarrow \boxed{E = L}$$

Hence, self-inductance is also defined as the emf induced in the coil if the rate of change of current in the coil is $1As^{-1}$

Unit of L

$$E = L\frac{dI}{dt}$$

$$\Rightarrow L = \frac{E}{\frac{dI}{dt}}$$

$\Rightarrow L = \frac{1 \text{ volt}}{\frac{1A}{1s}}$

$\Rightarrow L = 1 \, VsA^{-1}$

$\Rightarrow L = 1$ Henry

$\Rightarrow 1H$

Hence unit of L is Henry (H)

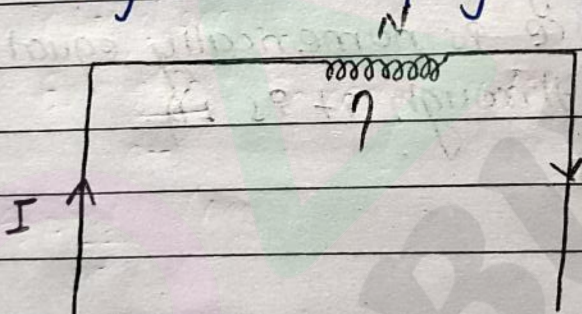
$1 \mu H = 1 \times 10^{-6} H$.

$1 mH = 1 \times 10^{-3} H$.

$1 nH = 1 \times 10^{-9} H$.

$1 pH$ or $1 \mu\mu H = 1 \times 10^{-12} H$.

Self induction of long-solenoids.



Let us consider a long solenoid containing 'N' no of turns having cross sectional area 'A' carrying current 'I'. Let 'n' be the no. of turns per unit length of solenoid. Then, total magnetic field strength inside the long solenoids:-

$$B = \mu_0 n I \quad \text{---(i)}.$$

But $n = \frac{N}{l}$

$$\therefore B = \frac{\mu_0 N I}{l} \quad \text{---(ii)}.$$

Also, total magnetic flux linked with 'N' no. of turns of solenoid is;

$$\phi = NBA$$

$$\Rightarrow \phi = \frac{\mu_0 N^2 I A}{l} \quad \text{---(iii)}$$

Also, magnet flux, $\phi = LI$ — (iv).
from eqn (iii) & (iv)

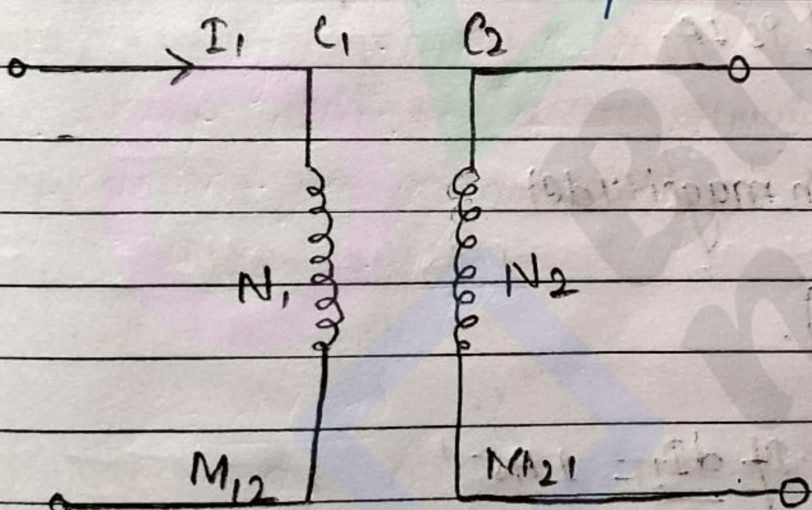
$$LI = \frac{\mu_0 N^2 I A}{l}$$

$$\text{or } L = \frac{\mu_0 N^2 I A}{I l}$$

$$\therefore \boxed{L = \frac{\mu_0 N^2 A}{l}} \quad \text{— (v)}$$

This gives the required expression for self inductance of long solenoid.

Mutual Induction



Let us consider two coils are placed very close to each other without any electrical contanct & current passing through one of them is varied then emf is induced in the another coil due to change in magnetic flux. This phenomenon is called mutual Induction.

Similarly, let I_2 be the current flowing in the coil C_2. Then the magnetic field inside solenoid C_2 is:-

$$B_2 = \mu_0 n_2 I_2$$

But $n_1 = \frac{N_2}{l}$

$$\therefore \cancel{B_2 = \mu_0 N_2 I_2} \quad \therefore B_2 = \frac{\mu_0 N_2 I_2}{l} \text{ — (v)}$$

In this magnetic field the coil C_1 is placed. so, magnetic flux linked with the coil C is

$$\phi_1 = N_1 B_2 A$$

$$\boxed{\phi_2 = \frac{\mu_0 N_1 N_2 A I_2}{l}} \text{ — vi}$$

Also,

$$\phi_1 \propto I_2$$

$$\phi_2 = M_{12} I_2 \text{ --- (vii)}$$

when M_{12} is mutual inductance of coil C_1 w.r.t to coil C_2

from (vi) & (vii)

$$M_{12} I_2 = \frac{\mu_0 N_1 N_2 I_2 A}{l}$$

$$\therefore \boxed{M_{12} = M_{21}}$$

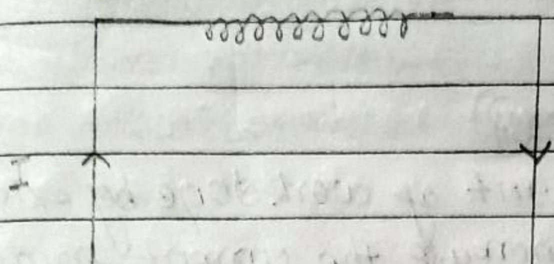
In general, $\boxed{M = \frac{\mu_0 N_1 N_2 A}{l}}$ (mutal inductance of long solenoid formula).

If coil contains same no of turns i.e $N_1 = N_2 = N$ (say)

$$\boxed{M = \frac{\mu_0 N^2 A}{l}}$$

Important

Energy stored in an Inductor or coil.



consider a inductor of self inductance 'α'. Let the resistance of the inductor is zero so that no energy is dissipated within the inductor. suppose the inductor is connected to the source of emf 'ε'. Initially, let the current through the coil is zero. when current in the coil increase from 0 to its maximum value (I_0) emf is induced in it due to change in magnetic flux. A/c to lenz law, the induced emf opposes the growth of current in the coil. The external source has to do the work against the back emf to allow (growth) current in the coil. This workdone by external ~~current~~ source to increase current in the coil is stored in the form of energy in an inductor.

Let 'I' be the current flowing in an inductor & dI be the rate of flow of current in an inductor dt the magnitude of back emf is given by,

$$\varepsilon_b = \alpha \cdot \frac{dI}{dt} \quad \text{----- (9)}$$

The rate at which the external source does the work is equal to the power supplied by source & which is given by.

$$P = \varepsilon_b I \quad (V = \varepsilon_b)$$

$$P = \alpha I \frac{dI}{dt} \quad \text{--- (11)}$$

Then small amount of workdone by the external source against the back emf is given by.

$$P = \frac{dw}{dt}$$

$\Rightarrow dw = P dt$

$\Rightarrow dw = LI \frac{dI}{dt} \cdot dt$

$\Rightarrow dw = LI dI$ — (iii)

Then, total amount of work done by external source against the back emf to increase the current from 0 to maximum value (I_0) can be ~~determ~~ obtained by integrating eqn (iii) from limit 0 to I_0 as,

$$W = \int_0^{I_0} dw = L \int_0^{I_0} I dI$$

$$\Rightarrow W = L \left[\frac{I^2}{2}\right]^{I_0}$$

$$\Rightarrow \boxed{W = \frac{1}{2} L I_0^2} \quad \text{— (iv)}$$

This gives the required expression for energy stored in an inductor or coil.

Transformer

It is a device to transform energy from one coil to another coil. It works on the principal of mutual induction. It converts low alternating voltage at high current into high alternating voltage at low current & vice versa.

Construction:-

It consists of two insulated coils wound over a soft iron core. The coil to which AC input is give called primary coil. & the coil from which transformed output is taken is called secondary coil. [The use of soft iron core increase the magnetic flux linkage between primary & secondary coil. The core is laminated to reduce heating by adding eddy current. Lamination increases the resistance of core & reduces the eddy current] S.Q

Theory:-

Let N_p & N_s be the no. of turns in primary coil & secondary coil respectively. Both coils are wound over a same core. So, the cross sectional area of both coils is same. Let A be the area of ~~current~~ crosssectional of each coil & B be the magnetic field intensity in the core at any time. Then magnetic flux linked with primary & secondary coil are

$$\cancel{\phi_p = N_pBA} \quad \phi_p = N_pBA \quad \text{--- (i)}$$

$$\phi_s = N_sBA \quad \text{--- (ii)}$$

According to Faraday's law of electromagnetic induction, the induced emf in primary & secondary coils are,

$$E_p = -\frac{d\phi_p}{dt} = -\frac{d}{dt}(N_pBA)$$

$$E_p = -N_pA\frac{dB}{dt} \quad \text{--- (iii)}$$

Similarly, $E_s = -N_sA\frac{dB}{dt}$ --- (iv)

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Dividing eqn (iv) by (iii)

$$\frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p} \quad \text{--- (v)}$$

For ideal transformer resistance, resistance is zero. so, induced emf in primary coil, ε_p = Terminal pd across primary coil V_p $[\varepsilon_p = V_p]$

Similarly, $\varepsilon_s = V_s$

from eqn (v)

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = k\,(\text{say}) \quad \text{--- (vi)}$$ where $k = \frac{N_s}{N_p}$ is called transformation ratio.

i) If $k > 1$ i.e $\frac{N_s}{N_p} > 1 \Rightarrow N_s > N_p$. Such type of transformer is ~~set~~ step-up transformer

ii) If $k < 1$ i.e ~~$N_s < 1$~~ $\frac{N_s}{N_p} < 1 \Rightarrow N_s < N_p$.

Then, such type of transformer is step-down transformer

Efficency of transformer (η)

It is defined as the ratio of output power to the input power i.e

$$\text{Efficency}(\eta) = \frac{\text{output power}(P_0)}{\text{Input power}(P_I)} \times 100\% \quad \text{....(vii)}$$

Then, output power $(P_0) = \varepsilon_s I_s$.

Input power $(P_{In}) = \varepsilon_p I_p$.

$$\therefore \eta = \frac{\varepsilon_s I_s}{\varepsilon_p I_p} \times 100\%.$$

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For ideal transformer, $P_0 = P_i$

i.e $E_s I_s = E_p I_p$

$$\frac{E_s}{E_p} = \frac{I_p}{I_s} \text{ --- (VIPP)}$$

Finally, $\boxed{\frac{E_s}{E_p} = \frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}}$ — ix

S.Q Energy losses in transformer.

1. Copper losses:-

The coil of transformer are made of copper. Due to resistance of copper, certain amt of input electrical energy is converted into heat energy. If heat developed is so high than it can break the insulation of coil.

2. Flux losses:- Total magnetic flux produced in primary coil never get linked with secondary coil. The ~~jut~~ flux loss can be minimized by ~~dree~~ decreasing the distance betn primary & secondary coil.

3. Hysteresis loss:-

The iron core of transformer is situated in a variable magnetic field of AC in the primary coil. This fluctuating magnetic field magnetizes & demagnetises the core again and again over a complete cycle of AC. During magnetization & demagnetization of the core of the transformer, some energy is lost which is called Hysteresis loss.

4. Loss due to eddy current (variable magnetic → magnetic flux → faraday's law $\varepsilon = \frac{d\phi}{dt}$ → induced current → closed loop

As iron core of transformer is situated in a variable mag

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PAGE

netic field of AC in the coils of transformer. Due to this va
riable magnetic flux. magnetic flux linked with the coil changes
and a/c to Faraday's law of electromagnetic induction, emf is induced
in the ~~cor~~ core of transformer which produce induced current
in the formed of closed loop which is called eddy current.
Hence, due to eddy current some energy is lost in the form of
heat (of heat produced is so high which may damage the insu
lation of copper winding. The losses due to eddy current can be
minimized by taking lamination iron core. In laminated iron core
the iron strip is quite thin and posses large resistance and it
reduces eddy current produced.

Numerical *

1. The magnetic flux passing perpendicular to the plane of a coil is given by $\phi = 4t^2 + 5t + 2$ where ϕ is in weber and t is in second. Calculate the magnitude induced emf in the coil when $t = 3$ sec.

⇒ Given →

$\phi = 4t^2 + 5t + 2$

Time $(t) = 2$ sec.

Induce emf $(\epsilon) = ?$

we know,

$$\epsilon = \frac{d\phi}{dt}$$

$$= \frac{d}{dt} 4t^2 + 5t + 2$$

$$= 8t + 5 + 0.$$

where, $t = 3$

$$\epsilon = 8 \times 3 + 5$$

$$= 29\ V.$$

The induced emf in the coil is 29V.

(2) A conducting circular loop is placed in a uniform transverse magnetic field of 0.02 T. Somehow radius of loop begin to decrease at a constant rate of 1 mm/s. Find the emf induced in the loop at the instant when radius is 2 cm.

⇒ Given→

Magnetic field $(B) = 0.02 T$.

$\frac{dr}{dt} = \frac{1 mm}{s} = 1 \times 10^{-3} m/s$

radius$(r) = 2 cm$.

Now,

$\phi = NBA \cos\theta$

where, $N = 1$, $\theta = 0$.

$\phi = BA$.

$\phi = B\pi r^2$ [where Area$(A) = \pi r^2$]

we know,

$e = \frac{d\phi}{dt}$

$= \frac{d B\pi r^2}{dt}$

$= B\pi \frac{dr^2}{dt}$

$= B\pi \frac{dr^2}{dr} \times \frac{dr}{dt}$

$= B\pi \times 2r \times \frac{dr}{dt}$

$= 0.02 \times \pi \times 2 \times 2 \times 10^{-2} \times 10^{-3}$

$= 2.51 \times 10^{-6}$ #

(8) A straight wire (conductor) of length 15 cm is moving with a uniform speed of 10m/s at an angle of 30°. uniform magnetic field 10^{-4} T. calculate the emf induced across the length.

⇒ Soln

length(l) = 15 cm = 15×10^{-2} m.

velocity(v) = 10 m/s.

$\theta = 30°$

Magnetic field = 10^{-4} T.

Induced emf (ε) = ?

we know

$$\varepsilon = Bvl \sin\theta$$

$$= 10^{-4} \times 10 \times 15 \times 10^{-2} \times \sin 30°$$

$$= 150 \times 10^{-6} \times \frac{1}{2}$$

$$= 7.5 \times 10^{5} \text{ V.}$$

(9) A coil of 100 turn each of area 2×10^{-3} has a resistance of 12Ω. It lies in a horizontal plane in a vertical magnetic field of 3×10^{-3} wb/m². what charge circulate through the coil of its end are short circulated and coil is rotated through 180° about a diameter?

⇒ Given

No of turns (n) = 100 turn.

Area (A) = 2×10^{-3} m².

Magnetic field (B) = 3×10^{-3} T.

q = ? (C)

Resistance (R) = 12 Ω.

Since, coil is rotated through 180°.

i.e. $d\phi = \phi_1 - \phi_2$

or, $d\phi = NBA \cos\theta_1 - NBA \cos\theta_2$

or, $d\phi = NBA \cos 0 - NBA \cos 180°$

or, $d\phi = NBA + NBA$

or, $d\phi = 2NBA$

we know,

$$\varepsilon = \frac{d\phi}{dt}$$

or, $IR = \frac{d\phi}{dt}$

or, $\frac{dq}{\cancel{dt}} R = \frac{d\phi}{\cancel{dt}}$

or, $dq = \frac{d\phi}{R}$

or, $dq = \frac{2NBA}{R}$

or, $dq = \frac{2 \times 100 \times 3 \times 10^{-3} \times 2 \times 10^{-3}}{12}$

$= 100 \times 10^{-6}$

$= 10^{-4}$ C Ans.

(5) A rectangular coil of 100 turns has dimension 15cm×10cm It is rotated at the rate of 300 revoluter per minute in a uniform magnetic field of flux density 0.6T. calculate the maximum emf induced.

→ Given→

Number of turns $(n) = 100$.

Dimension $(A) = 15 \times 10\,cm^2 = 150\,cm^2 = 150 \times 10^{-4}$ cm.

frequency = 300 rev/min

$= \frac{300}{60} \frac{rev}{sec} = 5Hz$

Magnetic field $(B) = 0.6T$.

Induced emf $(\varepsilon) = ?$

we know →

$E = NBA\,\omega \sin \omega t$.

For E_{max} $\sin \omega t = 1$

$e_x = NBA\omega$

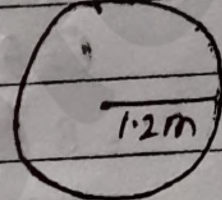
$= NBA\, 2\pi f$.

$= 100 \times 0.6 \times 150 \times 10^{-4} \times 2 \times \pi \times 5$

$= 28.27$ V.

The maximum emf induced is 28.27 V.

(8) When a wheel with metal spokes 1.2 m long is rotated in a uniform magnetic field of 5×10^{-5} tesla normal to the plane of wheel, An emf of 10^{-2} V induced between rim and axley. find the rate of rotation of wheel.



⇒ Given,

Radius $(r) = 1.2$ m

Magnetic field $(B) = 5\times10^{-5}$ T

EMF $(e) = 10^{-2}$ V

rate of rotation of wheel $(f) = ?$

Now,

$E = BAf$

$e = \cancel{B}\ \frac{e}{BA} = \frac{e}{B\pi r^2}$

$f = \frac{10^{-2}}{5\times10^{-5}\times\pi\times(1.2)^2}$

$= 4.4\times10^{-2}$ rev/sec.

7. A wheel with 10 metallic spokes each 0.5 m long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of earth's magnetic field BH at a place. If $B_H = 0.44$ at the place. What is the induced emf between the axle and rim of the wheel.

⇒ Soln →

Radius of the wheel (r) = length of the spokes (l) = 0.5m
frequency of rotation (f) = 120 rev/min = 2 rev/sec.
Horizontal component of earth's magnetic field (B_H) = 0.44
$= 0.4 \times 10^{-4}$ Tesla

we have →

Induced emf between rim and axle of the wheel,

$E = BAf$
$= B(\pi r^2) f$
$= 4 \times 10^{-5} \times \pi \times (0.5)^2 \times 2$
$= 6.28 \times 10^{-5}$ V.

All 10 spokes are connected with their one end. For 10 spokes induced emf is same.

8. A long solenoid with 15 turns per cm has a small loop of area 2 cm² placed inside, normal to the axis of the solenoid. If the current carried by the solenoid changes steadily from 2A and 4A in the ~~or~~ 0.1 second, what is the induced voltage in the loop, while the current changing?

⇒ Soln →

no of turns per unit length = 15 turns/cm

$= \frac{15 \text{ turns}}{\frac{1}{100} m} = 1500$ turns/m.

Area (A) = $2 cm^2 = 2 \times 10^{-4} m^2$

current $(I_1) = 2A$.

current $(I_2) = 4A$.

$\Delta I = I_2 - I_1 = 4 - 2 = 2A$

Magnetic flux linkage $(\phi) = BA$ -- (i)

But $B = \mu_0 n I$ -- (ii)

from (i) and (ii)

$\phi = \mu_0 n I A$.

Induced emf $(e) = \frac{d\phi}{dt}$

$$E = \frac{d\mu_0 n I A}{dt}$$

$$= \mu_0 n A \frac{dI}{dt}$$

$$= \mu_0 n A \frac{\Delta I}{dt}$$

$$= \frac{4\pi \times 10^{-7} \times 1500 \times 2 \times 10^{-4} \times 2}{0.1}$$

$$= 7.54 \times 10^{-6}\ V.$$

9) An air-cored solenoid with length 30 cm, area of cross-section $25\ cm^2$ and number of turns 500, carries a current of 2.5 A. The current is suddenly switch off in a brief time 10^{-3} sec. How much is the average back emf induced across the ends of the open switch in the current.

Soln →

length of core $(l) = 30\ cm = 30 \times 10^{-2}\ m$.

Area of cross-section $(A) = 25\ cm^2$

$= 25 \times 10^{-4}\ m^2$.

No of turns $(N) = 500$

current $(I_1) = 2.5\ A$

$dt = 10^{-3}$ sec

Current $(I_2) = 0$ (The current is switched off)

$$dI = I_2 - I_1$$
$$= 0 - 2.5 = -2.5 A$$

Self inductance $(L) = \frac{\mu_0 N^2 A}{l}$

$$= \frac{4\pi \times 10^{-7} \times (500)^2 \times 25 \times 10^{-4}}{30 \times 10^{-2}}$$
$$= 2.61 \times 10^{-03}$$

We know,

Induced emf $(\varepsilon) = -L\frac{dI}{dt}$

$$= \frac{-2.61 \times 10^{-3} \times -0.25}{10^{-3}}$$
$$= \frac{6.55 \times 10^{-03}}{10^{-03}}$$
$$= 6.55\ V$$ #.

10) A long solenoid of 1000 turns and cross sectional area 2×10^{-3} m^2 carries a current of 2 A and produces a flux density 52×10^{-3} T inside it. Calculate the self inductance of the coil.

→ Given,

No of turns $(N) = 1000$

Area of cross section $(A) = 2\times10^{-3} m^2$

current $(I) = 2A$

magnetic flux density $(B) = 52\times10^{-3}$ T

self inductance $(L) = ?$

we know

$$\phi = L \cdot I$$

or, $NBA = LI$

or $L = \frac{NBA}{I}$

$= \frac{1000 \times 5.2\times10^{-3} \times 2\times10^{-3}}{2}$

$= 0.052\ H$ #

11. Over a solenoid of 50 cm length and 2cm radius and having 500 turns is wound another wire of 50 turns near the centre. calculate the (i) mutual induction of the coil (ii) induced emf is the second coil when the current in the primary changes from 0 to 5 A in 0.02 s.

Soln →

length of the solenoid $(l) = 50\ cm = 0.5\ m$

Radius $(r) = 2cm = 2\times10^{-2}\ m$.

Number of turns in first coil $(N_1) = 500$ turns

Number of turns in second coils $(N_2) = 50$ turns

Mutual inductance $(M) = ?$

current changes $(dI) = 0 - 5$

$= -5A$.

$dt = 0.02$ sec.

Now,

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

$$= \frac{4\times\pi\times10^{-7}\times500\times50\times\pi r^2}{0.5}$$

$$= \frac{4\times\pi\times10^{-7}\times500\times50\times\pi(2\times10^{-2})^2}{0.5}$$

$$= \cancel{4\times\pi\times10^{-7}}\ 7.89\times10^{-05}.$$

Again →

$$E = \frac{M\,dI}{dt}$$

$$= \frac{-7.89\times10^{-5}\times-5}{0.02}$$

$$= 1.974\times10^{-2}\ V$$

$$= 19.74\ mV.$$

12. An air filled toroide solenoid has mean radius of 15 cm and cross sectional area of 5 cm^2. When the current of 12 A, the energy is 0.39 J. How many turns does the windings have?

⇒ Given,

Radius of toroide solenoid $(r) = 15\,cm = 15 \times 10^{-2}\,m$

Cross sectional Area $(A) = 5\,cm^2 = 5 \times 10^{-4}\,m^2$

Current $(I) = 12\,A$

Energy $(E) = 0.39\,J$

No of turns $(N) = ?$

We know,

$$E = \frac{1}{2} L I^2 \quad \text{------} \ (1)$$

where, $L = \dfrac{\mu_0 N^2 A}{2\pi r}$ [because it is toroid solenoid $l = 2\pi r$]

Then in eqn (1)

$$E = \frac{1}{2} \frac{\mu_0 N^2 A I^2}{2\pi r}$$

$$N = \sqrt{\frac{4\pi r E}{\mu_0 A I^2}}$$

$$= \sqrt{\frac{\cancel{4} \times \cancel{\pi} \times 15 \times 10^{-2} \times 0.39}{\cancel{4} \times \cancel{\pi} \times 10^{-7} \times 5 \times 10^{-4} \times 12^2}}$$

$$= \sqrt{8125000}$$

$= 2850$ turns.

13. An inductor used in dc power supply has an inductance of 12 H and resistance of 180 Ω. It carries a current of 0.3 A.

(i) what is the energy stored in a magnetic field.

(ii) At what rate is thermal energy developed in induction?

⇒ Given →

Inductance (L) = 12 H

Resistance (R) = 180 Ω.

current (I) = 0.3 A

Energy (E) = ?

power (p) = ?

Now

i. $E = \frac{1}{2} LI^2$

$= \frac{1}{2} \times 12 \times 0.3^2$

$= 0.54$ J.

ii) Power (P) = I^2R

$= 0.3^2 \times 180$

$= 16.2$ W.

(1) The primary of an ideal step up transformer has 100 turns and the transformation ratio is 100. The input voltage and power are 220 V and 1100 watt. calculate (a) no of turns in secondary coil.

(b) current in primary.

(c) voltage across the secondary.

(d) por in the secondary

⇒ Given.

no of turns in primary (N_p) = 100 turns

Transformation ratio (K) = 100.

Input voltage (E_p) = 220 V.
Input power (P_i) = 1100 watt.

No. of turns in secondary coil (N_s) = ?
Current in primary (I_p) = ?

(a) we know,

$$K = \frac{N_s}{N_p}$$

$$\text{or, } N_s = K \times N_p$$
$$= 100 \times 100$$
$$= 10{,}000$$

(b)
$$P_i = V_1 I_p$$
$$P_i = E_p I_p$$
$$I_p = \frac{1100}{220} = 5A.$$

(c)
$$\frac{N_s}{N_p} = \frac{E_s}{E_p}$$

$$\text{or, } E_s = \frac{N_s \times E_p}{N_p}$$

$$= \frac{10{,}000 \times 220}{100}$$

$$= 22000.$$

(d)
$$P_0 = E_s I_s$$

for ideal transformer $P_i = P_0$.

$$P_i = E_s I_s$$
$$I_s = \frac{P_i}{E_s} = \frac{1100}{22000} = 0.05A$$

2. A transformer has 500 turn in the primary coil and 100 turn in the secondary coil. What is the output voltage if the input voltage is 4000 volts. If the transformer is assumed to have an efficiency of 100%. What primary current is required to draw 2000 watt from the secondary.

⇒ Given,

No of turns in primary (N_p) = 500 turns.
No of turns in secondary (N_s) = 100 turn.
Input voltage (E_p) = 4000 volts.
Efficiency (η) = 100%.
power output (P_o) = 2000 watt.
current in primary coil (I_p) = ?

Now,

$$\frac{N_p}{N_s} = \frac{E_p}{E_s}$$

or, $$\frac{500}{100} = \frac{400}{E_s}$$

$$\therefore E_s = 800\ V.$$

Again we have,

$$\eta = \frac{\text{output power}}{\text{Input power}} \times 100\%$$

or, $$100\% = \frac{2000}{\text{Input power}} \times 100\%$$

or, Input power = 20 W $\quad$ (Input power = $V_p \times I_p$)

$E_p \times I_p = 20$ W

or, $20,000 \times I_p = 20$

$\therefore I_p = 0.005$ A.

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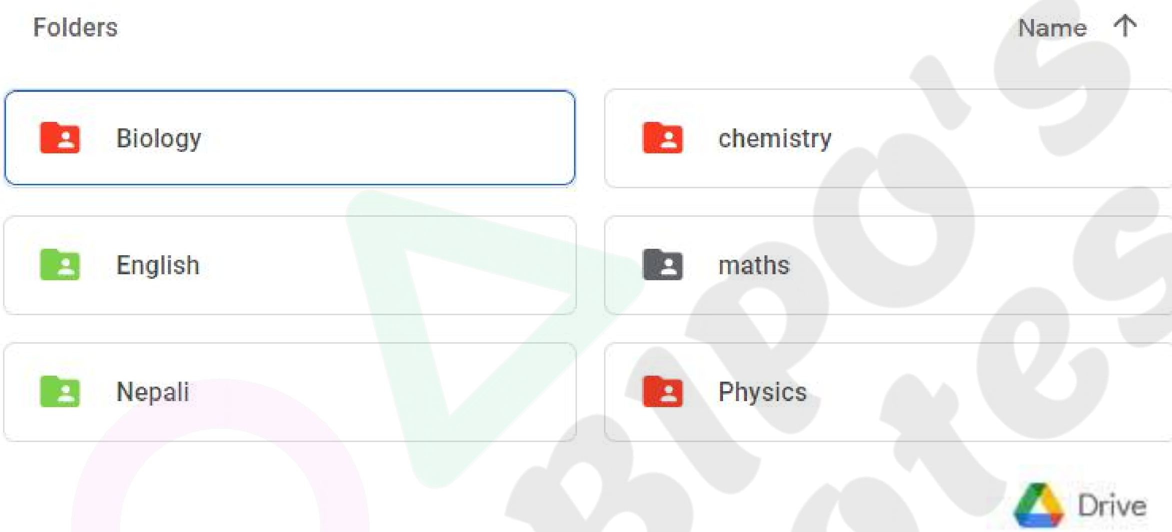
(Bipo)

Class 12 complete notes and paper collection.



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