Solution

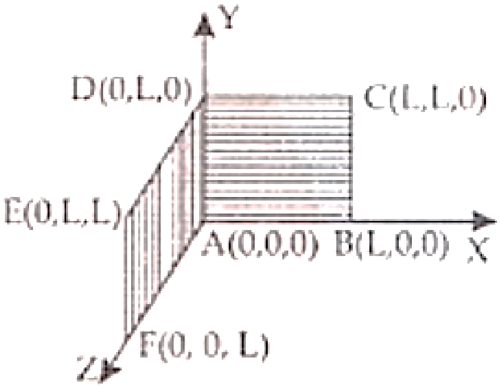
ELECTROMAGNETIC INDUCTION

Class 12 - Physics

1.
   (c) Lenz's law
   Explanation:
   According to Lenz's law, the direction of an induced e.m.f always opposes the change in magnetic flux that causes the e.m.f.

2.
   (c) 2 L
   Explanation:
   $e = e_1 + e_2$
   $L_f \frac{di}{dt} = L_1 \frac{di}{dt} + L_2 \frac{di}{dt}$
   $L_f = L_1 + L_2$ = L + L = 2L

3.
   (d) 2 B_0L^2Wb
   Explanation:
   The loop can be considered in two planes:



   i. Plane of ABCDA is in X-Y plane So its vector $\vec{A}$ is in Z-direction so
   $A_1 = |A|\hat{k} = L^2\hat{k}$
   ii. Plane of DEFAD is in Y-Z plane
   So $\mathrm{A_2 = |A|i = L^2i}$
   $\therefore A = A_1 + A_2 = L^2(\hat{i} + \hat{k})$
   B = B_0 (i + k)
   the magnetic flux linked with uniform surface of area A in uniform magnetic field is given by,
   $\phi = B \cdot A = B_0(i+k) \cdot L^2(i+k)$ $= \mathrm{B_0L^2[i.i + i.k + k.i + k.k]}$
   = B_0L^2[1 + 0 + 0 + 1] $\because \cos 90^\circ = 0$
   = 2 B_0L^2Wb

4. **(a)** 2 L
   Explanation:
   When the two inductors are joined in series,
   $L_{eq} = L_1 + L_2$ = L + L
   = 2L

5. **(a)** Electromagnetic induction
   Explanation:

6.
(c) $\pi\mu\mathrm{V}$
Explanation:
$\phi = B\pi r^2 \cos 0^\circ = B\pi r^2$
$|\varepsilon| = \frac{d\phi}{dt} = \frac{d}{dt}\left(\pi r^2 B\right) = 2\pi r B \frac{dr}{dt}$
When r = 2cm $= 2 \times 10^{-2}$ m
$\frac{dr}{dt} = 1$ mm s^{-1} = 10^{-3}ms^{-1}
$|\varepsilon| = 0.025 \times \pi \times 2 \times 2 \times 10^{-2} \times 10^{-3}$
$= 0.100 \times \pi \times 10^{-5} = \pi\mu\mathrm{V}$

7. **(a)** the resistance of the coil
Explanation:
Because induced e.m.f. is given by $E = -N\frac{d\varphi}{dt}$

8.
(b) Weber
Explanation:
Weber

9.
(d) $\frac{AB}{R}$
Explanation:
$\frac{AB}{R}$

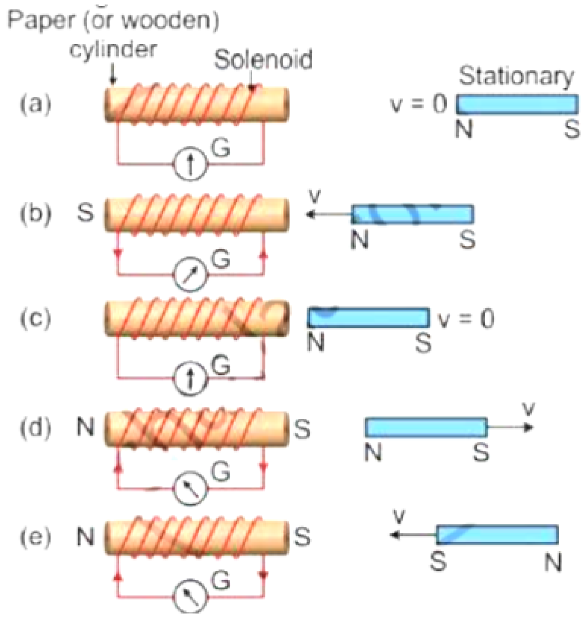
10.
(b) Zero
Explanation:
Induced EMF is zero because flux linked with it remains constant.

11. According to Faraday's law of electromagnetic induction, the magnitude of induced emf is equal to the rate of change of magnetic flux linked with the closed circuit (or coil). Mathematically,
$E = -N\frac{d\phi_B}{dt}$
where N is the number of turns in the circuit and ϕ_B is the magnetic flux linked with each turn.
Suppose the conducting rod completes one revolution in time T. Then
Change in flux $= B \times Area\ swept = B \times \pi l^2$
Induced emf $= \frac{\text{Change in flux}}{\text{Time}}$
$\varepsilon = \frac{B \times \pi l^2}{T}$
But $T = \frac{2\pi}{\omega}$
$\therefore \varepsilon = \frac{B \times \pi l^2}{\frac{2\pi}{\omega}} = \frac{1}{2} B l^2 \omega$

12. Electromagnetic induction is the production of an electromotive force across a conductor when it is exposed to a varying magnetic field.
   i. When the magnet is stationary there is no deflection in the galvanometer. The pointer read zero. [Fig. (a)]
   ii. when the magnet with the north pole facing the solenoid is moved towards the solenoid, the galvanometer shows a deflection towards the right showing that a current flows in the solenoid in the direction as shown in [Fig (b)]
   iii. As the motion of the magnet stops, the pointer of the galvanometer comes to the zero position [Fig (c)]. This shows that the current in the solenoid flows as long as the magnet is moving.
   iv. If the magnet is moved away from the solenoid, the current again flows in the solenoid, but now in a direction opposite to that shown in [Fig. (b)] and therefore the pointer of the galvanometer deflects towards the left[Fig. (d)].

v. If the magnet is moved away rapidly i.e. with more velocity, the extent of deflection in the galvanometer increases although the direction of deflection remains the same. It shows that more current flows now.

vi. If the polarity of the magnet is reversed and then the magnet is brought towards the solenoid, the current in the solenoid flows in the direction opposite to that shown in Fig (b) and so the pointer of the galvanometer deflects towards the left [Fig. (e)].

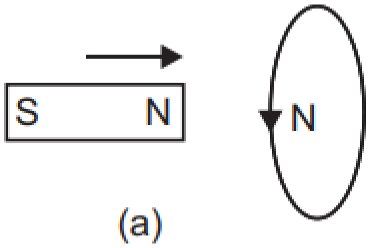


13. According to Lenz's law, the direction of the induced current (caused by induced emf) is always such as to oppose the change causing it.

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

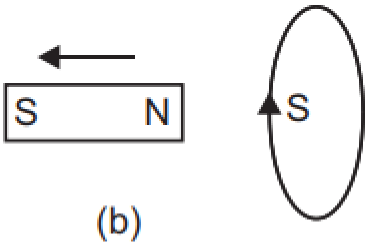
where k is a positive constant. The negative sign expresses Lenz's law. It means that the induced emf is such that, if the circuit is closed, the induced current opposes the change in flux.

Example: When the north pole of a coil is brought near a closed coil, the direction of current induced in the coil is such as to oppose the approach of north pole. For this the nearer face of coil behaves as north pole. This necessitates an anticlockwise current in the coil, when seen from the magnet side [fig. (a)]



(a)

Similarly when north pole of the magnet is moved away from the coil, the direction of current in the coil will be such as to attract the magnet. For this the nearer face of coil behaves as south pole. This necessitates a clockwise current in the coil, when seen from the magnet side (fig. b).



(b)

Thus, in each case whenever there is a relative motion between a coil and the magnet, a force begins to act which opposes the relative motion. Therefore to maintain the relative motion, a mechanical work must be done. This work appears in the form of electric energy of coil. Thus Lenz's law is based on conservation of energy.

14. i. a. As per Fleming's left-hand rule, the free electrons of the rod experience a magnetic force in the direction from Y to X.

$\therefore$ The negative charge is developed at the end of X.

The positive charge is developed at the end of Y.

b. Magnetic force, F_m, experienced by the moving electrons, gets balanced by the electric force due to the electric field, caused by the charges developed at the ends of the rod. Hence net force on the electrons, inside the rod, (finally) becomes zero

ii. a. Force needed to move the rod XY at a uniform speed v in the perpendicular magnetic field B,

$F_m = lIB \sin 90^\circ = \frac{\varepsilon}{R} \cdot lB$

$= \frac{Blv}{R} \cdot lB = \frac{B^2 l^2 v}{R}$

The power, that needs to be delivered by the external agency, when key K is closed, is given by

$P = F_m v = \frac{B^2 l^2 v^2}{R}$

b. When the key K is open, there is induced emf, but no induced current. Hence the power that needs to be delivered is zero.

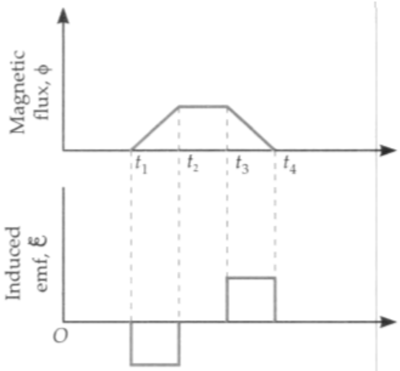
iii. The power dissipated as Joule heating loss is

$P_J = I^2 R = \left(\frac{Blv}{R}\right)^2 R$

$= \frac{B^2 l^2 v^2}{R}$

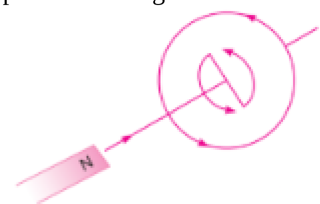
The source of this power is the mechanical work done by the external agency.

15. The graphs given in the figure show the variation of flux ϕ with time t and induced emf ε with time t, respectively.

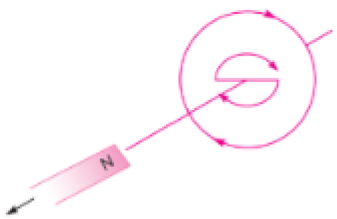


Explanation of variation of magnetic time. Magnetic flux is proportional to the coil linked with flux. Initially, the coil lies magnetic field, flux through it is zero. As the field at time t_1 the flux begins to increase. with time. Between times t_2 and t_3, in the magnetic field, so flux remains: After this the flux decreases linearly with reduces to zero at time t_4, when the coil co the magnetic field.

16. i. When the North pole of a bar magnet moves towards the closed coil, the magnetic flux through the coil increases. This produces an induced emf which produces (or tend to produce if the coil is open) an induced current in the anti-clockwise sense. The anti-clockwise sense corresponds to the generation of North pole which opposes the motion of the approaching N pole of the magnet. The face of the coil, facing the approaching magnet, then has the same polarity as that of the approaching pole of the magnet. The induced current, therefore, is seen to oppose the change of magnetic flux that produces it.



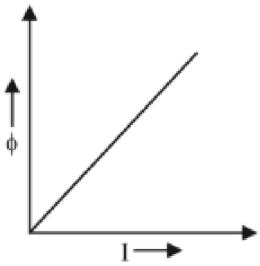
When a North pole of a magnet is moved away from the coil, the current (I) flows in the clock-wise sense which corresponds to the generation of South pole. The induced South pole opposes the motion of the receding North pole.



ii. a. ϕ = LI

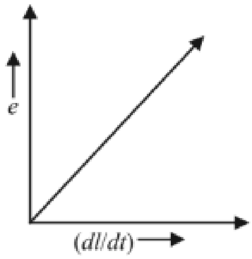
Where, l = Strength of current through the coil at any time

ϕ = Amount of magnetic flux linked with all turns of the coil at that time and L = Constant of proportionality called coefficient of self induction



b. Induced emf,

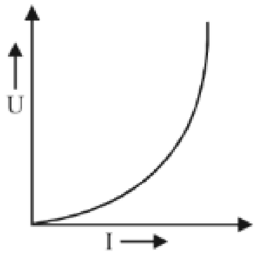
$e = \frac{-d\phi}{dt} = \frac{-d}{dt}(LI)$ i.e., $e = -L\frac{dI}{dt}$

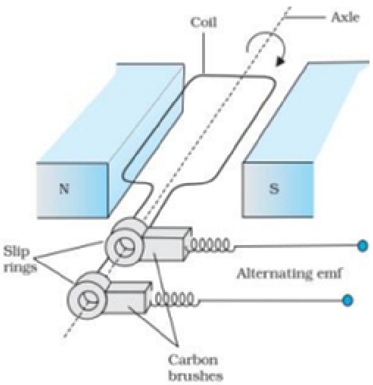


[The graph is drawn considering only magnitude of e]

c. Magnetic potential energy is given by,

$U = \frac{1}{2}LI^2$



17. 

i. The flux at any instant t is

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

From Faraday"s law

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

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

$\varepsilon = -NBA\omega\sin\omega t$

ii. $M = \frac{\mu_0\pi r_1^2}{2r_2} = \frac{4\pi\times10^{-7}\times\pi r_1^2}{2r_2}$

$= \frac{2\times10\times10^{-7}\times(10^{-2})^2}{100\times10^{-7}}$

$= 2\times10^{-10}H$

18. The self-inductance of a coil is equal to the induced emf set up in the coil when the current passing through it changes at the unit rate

The SI unit of self-inductance is henry. Consider a long solenoid of length l, area of crosssection A with N number of closely wound turns. If I is the amount of current flowing through the solenoid, then magnetic field B inside the solenoid will be:

B = $\frac{\mu_0 NI}{l}$

Now magnetic flux through each turn of the solenoid is:

$\phi = BA$ = $\frac{\mu_0 N^2 AI}{l}$

Since ϕ = LI

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

Hence, L = $\frac{\mu_0 N^2 A}{l}$

If a coil of wire with few turns around metal core carries a charge is passed through. The current will create a magnetic field that runs through the center of the coil pointing downward. If the current is stopped suddenly, then the magnitude of the magnetic field tends to be zero.

It is known that changing magnetic fields will influence the charges in loops of wire. If the magnitude of the magnetic field in the coil approaches to zero, it induces a voltage in the coil which creates the magnetic field. So as per Lenz's law, the voltage induced by changing the magnetic field gives rise to a current which counteracts the changes. Mathematically, the voltage across the inductor, the loop of coil, is

V_{Ind} = $L\frac{dI}{dt}$,

The force above expression looks similar to the expression of

F = $m\frac{dv}{dt}$

Now, E_{Ind} = $\frac{1}{2}LI^2$

$E_{Kinetic}$ = $\frac{1}{2}mv^2$

From the above description, there appears an analogy between mechanical motion and flow of electricity. Here, self-inductance L and mass m, both provide inertia that will resist in changing the current I or velocity v suddenly.

19. I. i. Current sensitivity of galvanometer is defined as the deflection per unit current.

$\frac{\phi}{I} = \frac{NBA}{K}$

Factors Number of turns in coil, Magnetic field intensity, Area of coil, Torsional Constant

ii. $R = \frac{V}{I} - G$ for (0-V) Range

$R_1 = \frac{V}{2I} - G$ for $\left(0 - \frac{V}{2}\right)$ Range

$\frac{V}{I} = R + G$

$R_1 = \left(\frac{R+G}{2}\right) - G$

$R_1 = \frac{R-\vec{G}}{2}$

II. $\phi = \left(2.0t^3 + 5.0t^2 + 6.0t\right) mWb$

$|\varepsilon| = \frac{d\phi}{dt} = 50 \times 10^{-3}\ V$

$I = \frac{|\varepsilon|}{R}$

$I = \frac{50\times10^{-3}}{5}\ A = 10\ mA$