ELECTROMAGNETIC INDUCTION

20

1. A solenoid has 2000 turns wound over a length of 0.3 m. Its cross-sectional area is 1.2×10^{-3} m^2. Around its central section a coil of 300 turns is wound. If an initial current of 2 A flowing in the solenoid is reversed in 0.25 s, the emf induced in the coil will be

   (a) 2.4×10^{-4} V (b) 2.4×10^{-2} V

   (c) 4.8×10^{-4} V (d) 4.8×10^{-2} V

2. A boat is moving due east in a region where the earth's magnetic field is 5.0×10^{-5} NA^{-1} m^{-1} due north and horizontal. The boat carries a vertical aerial 2 m long. If the speed of the boat is 1.50 ms^{-1}, the magnitude of the induced emf in the wire of aerial is:

   (a) 0.75mV (b) 0.50mV

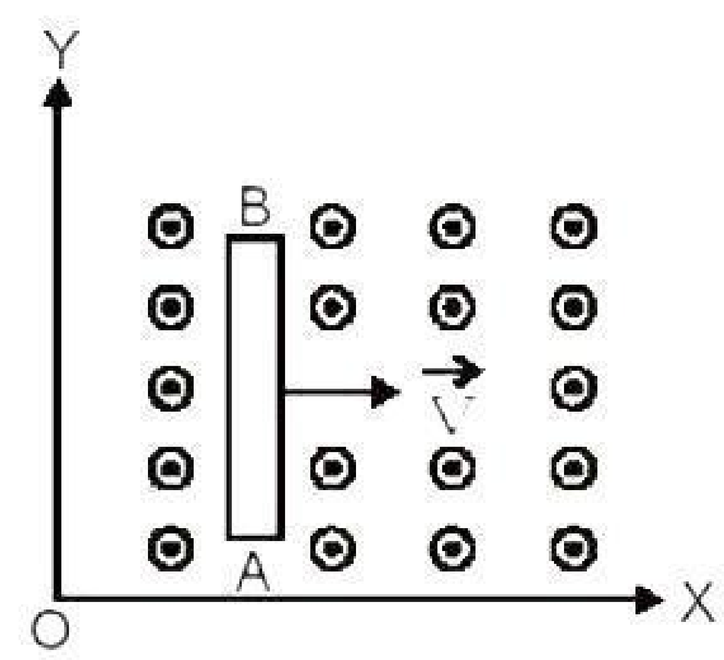
   (c) 0.15mV (d) 1mV

3. A coil having n turns and resistance R Ω is connected with a galvanometer of resistance 4R Ω. This combination is moved in time t seconds from a magnetic field W_1 weber to W_2 weber. The induced current in the circuit is

   (a) $-\frac{(W_1 - W_2)}{Rnt}$ (b) $-\frac{n(W_2 - W_1)}{5\ Rt}$

   (c) $-\frac{(W_2 - W_1)}{3\ Rnt}$ (d) $-\frac{n(W_2 - W_1)}{Rt}$

4. A conducting rod AB moves parallel to X-axis in a uniform magnetic field, pointing in the positive X-direction. The end A of the rod gets



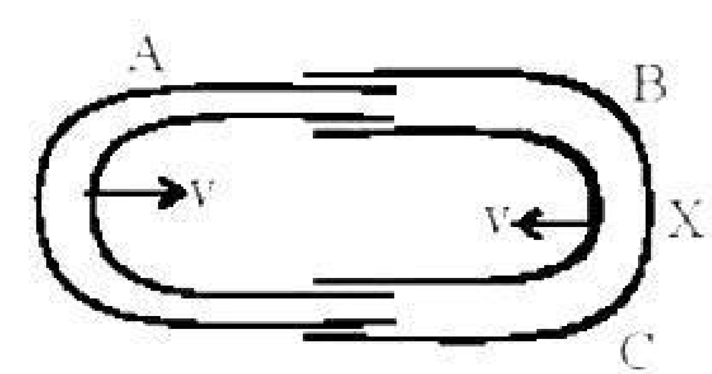
   (a) positively charged

   (b) negatively charged

   (c) neutral

   (d) first positively charged and then negatively charged

5. One conducting U tube can slide inside another as shown in figure, maintaining electrical contacts between the tubes. The magnetic field B is perpendicular to the plane of the figure. If each tube moves towards the other at a constant speed v, then the emf induced in the circuit in terms of B, l and v where l is the width of each tube, will be



   (a) – Blv

   (b) Blv

   (c) 2 Blv

   (d) zero

6. A coil 10 turns and a resistance of 20Ω is connected in series with B.G of resistance 30Ω. The coil is placed with its plane perpendicular to the direction of a uniform magnetic field of induction 10^{-2} T. If it is now turned through an angle of $60°$ about an axis in its plane. Find the charge induced in the coil.

(Area of a coil $= 10^{-2}$ m^2)

(a) 10^{-5}C (b) 10^{-7}C

(c) 10^{-9}C (d) 10^{-10}C

7. A flexible wire loop in the shape of a circle has radius that grown linearly with time. There is a magnetic field perpendicular to the plane of the loop that has a magnitude inversely proportional to the distance from the center of the loop, $B(r) \propto \frac{1}{r}$. How does the emf E vary with time?

(a) $E \propto t^2$ (b) $E \propto t$

(c) $E \propto \sqrt{t}$ (d) E is constant

8. Magnetic flux linked with a stationary loop of resistance R varies with respect to time during the time period T as follows: $\phi = at(T - t)$. The amount of heat generated in the loop during that time (inductance of the coil is negligible) is

(a) $\frac{aT}{3R}$ (b) $\frac{a^2T^2}{3R}$

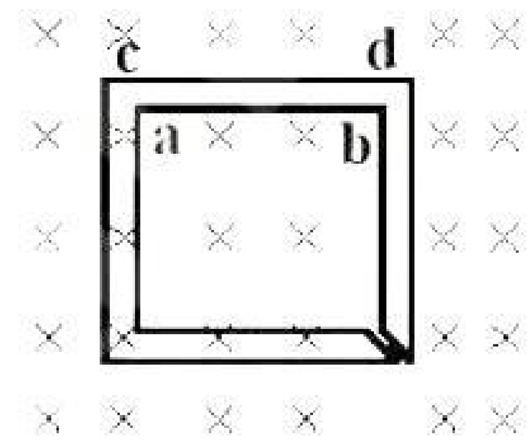
(c) $\frac{a^2T^2}{R}$ (d) $\frac{a^2T^3}{3R}$

9. A copper wire of length 40cm, diameter 2mm and resistivity 1.7×10^{-8} Ωm forms a square frame. If a uniform magnetic field B exists in a direction perpendicular to the plane of square frame and it changes at a steady rate $\frac{dB}{dt} = 0.02$ T/s, then find the current induced in the frame.

(a) 9.3×10^{-2} amp (b) 9.3×10^{-5} amp

(c) 3.3×10^{-2} amp (d) 19.3×10^{-6} amp

10. The figure shows certain wire segments joined together to form a coplanar loop. The loop is placed in a perpendicular magnetic field in the direction going into the plane of the figure.



The magnitude of the field increases with time. I_1 and I_2 are the currents in the segments ab and cd. Then,

(a) $I_1 > I_2$

(b) $I_1 + I_2 = 0$

(c) I_1 is in the direction ba and I_2 is in the direction cd

(d) I_1 is in the direction ab and I_2 is in the direction dc

11. A thin non-conductinging of mass m carrying a charge q can rotate freely about its axis. At $t = 0$, the ring was at rest and no magnetic field was present. Then suddenly a magnetic field B was set perpendicular to the plane. Find the angular velocity acquired by the ring.

(a) $\frac{3qB}{2m}$ (b) $\frac{2qB}{3m}$

(c) $\frac{qB}{2m}$ (d) $\frac{q}{Bm}$

12. A circular and an elliptical loop, all in the (x – y) plane, are moving out of a uniform magnetic field with a constant velocity, $\vec{V} = v\hat{i}$. The magnetic field is directed along the negative z axis direction. The induced emf, during the passage of these loops, out of the field region, will not remain constant for

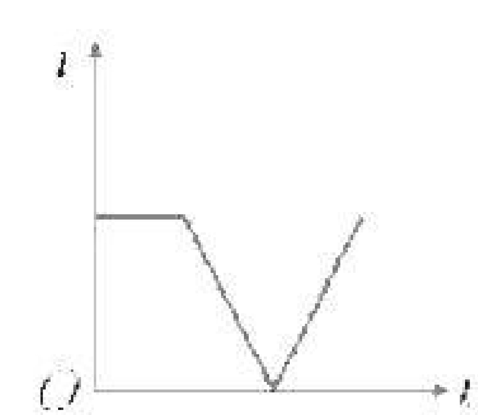
(a) both circular and elliptical loops

(b) only elliptical loop

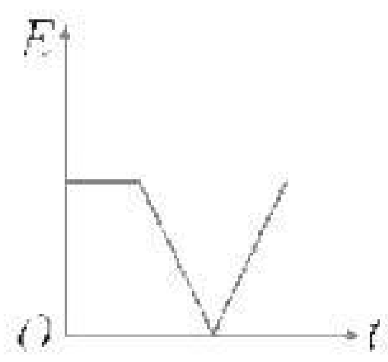
(c) only circular loop

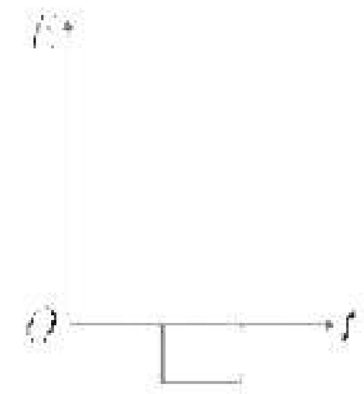
(d) none of these

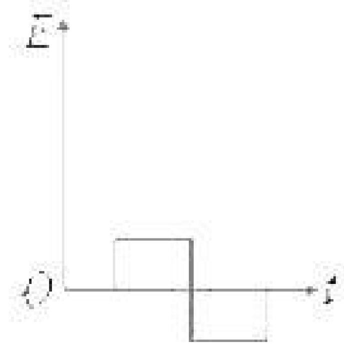
13. The current i in an induction coil varies with time t according to the graph shown in figure.

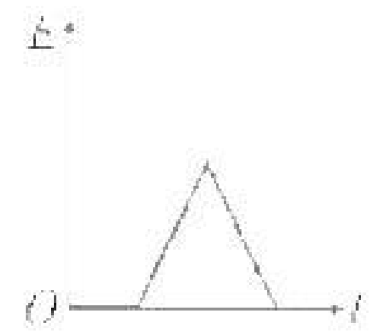


Which of the following graphs shows the induced emf (E) in the coil with time?

(a) 

(b) 

(c) 

(d) 

14. The total number of turns and cross-section area in a solenoid is fixed. However, its length L is varied by adjusting the separation between windings. The inductance of solenoid will be proportional to:

(a) L (b) L^2

(c) $1/L^2$ (d) 1/L

15. Two coils 'P' and 'Q' are separated by some distance. When a current of 3A flows through coil 'P', a magnetic flux of 10^{-3} Wb passes through 'Q'. No current is passed through 'Q'. When no current passes through 'P' and a current of 2A passes through 'Q', the flux through 'P' is:

(a) 6.67×10^{-4} Wb (b) 3.67×10^{-3} Wb

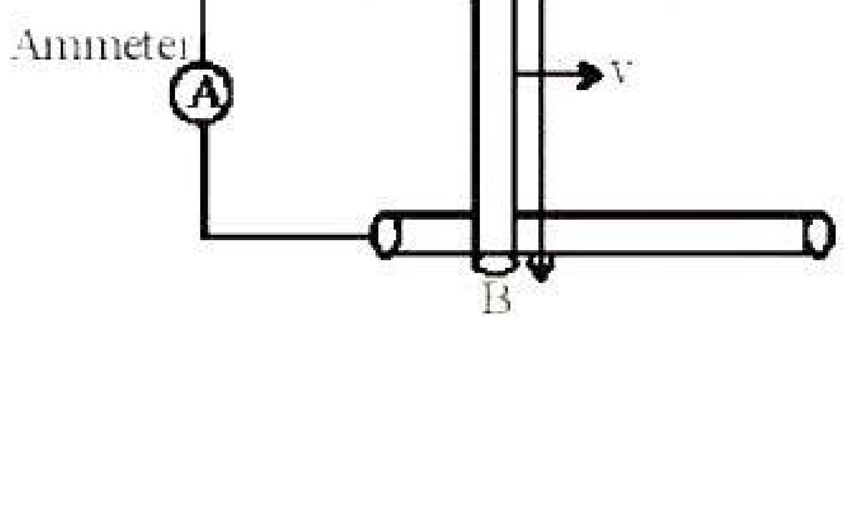
(c) 6.67×10^{-3} Wb (d) 3.67×10^{-4} Wb

16. A planar loop of wire rotates in a uniform magnetic field. Initially, at $t = 0$, the plane of the loop is perpendicular to the magnetic field. If it rotates with a period of 10 s about an axis in its plane then the magnitude of induced emf will be maximum and minimum, respectively at:

(a) 2.5 s and 7.5 s (b) 2.5 s and 5.0 s

(c) 5.0 s and 7.5 s (d) 5.0 s and 10.0 s

17. If the rod is moving with a constant velocity of 12 cm/s then the power that must be supplied by an external force in maintaining the speed and the reading of ammeter are respectively.



(Given B = 0.5 Tesla, l = 15 cm, v = 12 cm/s, Resistance of rod $R_{AB} = 9.0\ m\Omega$)

(a) 9×10^{-5} W, 0.5A (b) 0.5×10^{-5} W, 1A

(c) 9×10^{-3} W, 1A (d) 1×10^{-3} W, 3A

18. The number of turns in the coil of an AC generator is 5000 and the area of the coil is 0.25 m^2, the coil is rotated at the rate of 100 cycle per second in a magnetic field of 0.2

Weber/m^2. The peak value of the emf generated is nearly

(a) 786kV (b) 440kV

(c) 220kV (d) 157kV

19. A 100 turns coil of area of cross section 200 cm^2 having 2 Ω resistance is held perpendicular to a magnetic field of 0.1 T. If it is removed from the magnetic field in one second, find the charge flows in it during this process.

(a) 0.2 C (b) 2 C

(c) 0.1 C (d) 1 C

20. The coefficient of self inductance of a solenoid is 0.18 mH. If a core of soft iron of relative permeability 900 is inserted, then the coefficient of self inductance will become nearly.

(a) 5.4 mH (b) 162 mH

(c) 0.006 mH (d) 0.0002 mH

21. Two coaxial solenoids are made by winding thin insulated wire over a pipe of cross-sectional area A = 10 cm^2 and length = 20 cm. If one of the solenoids has 300 turns and the other 400 turns, their mutual inductance is

($\mu_0 = 4\pi \times 10^{-7}\ TmA^{-1}$)

(a) $4.8\pi \times 10^{-4}$ H (b) $4.8\pi \times 10^{-5}$ H

(c) $2.4\pi \times 10^{-4}$ H (d) $4.8\pi \times 10^{4}$ H

22. A copper wire is wound on a wooden frame, whose shape is that of an equilateral triangle. If the linear dimension of each side of the frame is increased by a factor of 3, keeping the number of turns of the coil per unit length of the frame the same, then the self inductance of the coil:

(a) decreases by a factor of 9

(b) increases by a factor of 27

(c) increases by a factor of 3

(d) decreases by a factor of $9\sqrt{3}$

23. Two coaxial solenoids are made by winding thin insulated wire over a pipe of cross-sectional area $A = 10\ cm^2$ and length = 20 cm. If one of the solenoid has 300 turns and the other 400 turns, their mutual inductance is

$(\mu_0 = 4\pi \times 10^{-7}\ TmA^{-1})$

(a) $2.4\pi \times 10^{-5}$ H (b) $4.8\pi \times 10^{-4}$ H

(c) $4.8\pi \times 10^{-5}$ H (d) $2.4\pi \times 10^{-4}$ H

24. When the current changes from +2 A to –2A in 0.05 second, an e.m.f. of 8 V is induced in a coil. The coefficient of self-induction of the coil is

(a) 0.2 H (b) 0.4 H

(c) 0.8 H (d) 0.1 H

25. A conducting circular loop made of a thin wire, has area $3.5 \times 10^{-3} m^2$ and resistance 10Ω. It is placed perpendicular to a time dependent magnetic field B (t) = (0.4T) sin (50πt). The net charge flowing through the loop during t = 0 s and t = 10 ms is close to:

(a) 1.4×10^{-4} mC (b) 7.0×10^{-4} mC

(c) 21×10^{-4} mC (d) 6×10^{-4} mC

ANSWER KEY

1	(d)	4	(a)	7	(d)	10	(d)	13	(c)	16	(b)	19	(c)	22	(c)	25	(a)
2	(c)	5	(c)	8	(d)	11	(c)	14	(d)	17	(c)	20	(b)	23	(d)		
3	(b)	6	(a)	9	(a)	12	(a)	15	(a)	18	(d)	21	(c)	24	(d)		

20 Electromagnetic Induction

1. **(d)** Induced emf $e = \dfrac{\mu_0 N_1 N_2 A}{\ell}\dfrac{di}{dt}$

$= \dfrac{4 \times 3.14 \times 10^{-7} \times 2000 \times 300 \times 1.2 \times 10^{-3} \times [2-(-2)]}{0.30}$

$= 48.2 \times 10^{-3}\,V \approx 48\,mV$

2. **(c)** Induced emf $= vB_H l = 1.5 \times 5 \times 10^{-5} \times 2$

$= 15 \times 10^{-5} = 0.15\,mV$

3. **(b)** $\dfrac{d\phi}{dt} = \dfrac{(W_2 - W_1)}{t}$,

$R_{tot} = (R + 4R)\Omega = 5R\ \Omega$

$i = \dfrac{n d\varphi}{R_{tot}\,dt} = \dfrac{-n(W_2 - W_1)}{5Rt}$. ($\because W_2$ & W_1 are magnetic flux)

4. **(a)** According to right hand palm rule, the Lorentz force on free electrons in the conductor will be directed towards end B. Hence, the end A gets positively charged.

5. **(c)** Relative velocity $= v + v = 2v$

$\therefore$ emf. $= B.l(2v)$

6. **(a)** Given : n = 10 turns, $R_{coil} = 20\Omega$, $R_G = 30\Omega$, Total resistance in the circuit

$= 20 + 30 = 50\Omega$.

$A = 10^{-2}\,m^2$, $B = 10^{-2}\,T$, $\phi_1 = 0°$, $\phi_2 = 60°$

$q = \dfrac{\phi_1 - \phi_2}{R} = \dfrac{BnA\cos\theta_1 - BnA\cos\theta_2}{R}$

$= \dfrac{BnA(\cos 0 - \cos 60)}{R} = \dfrac{BnA(1 - 0.5)}{R}$

$= 1 \times 10^{-5}\,C$

7. **(d)**

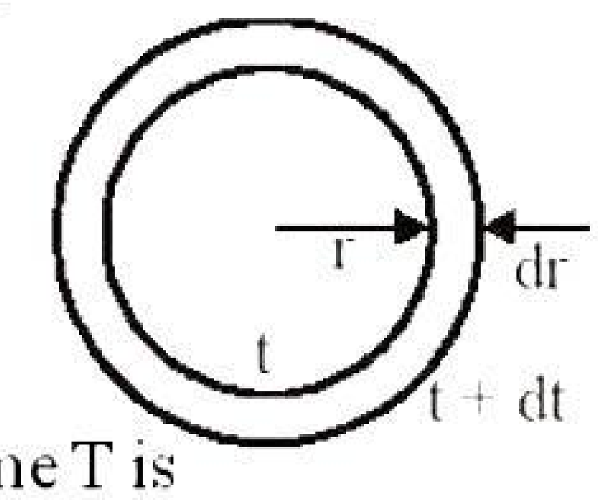
8. **(d)** Given that $\phi = at(T - t)$

Induced emf, $E = \dfrac{d\phi}{dt} = \dfrac{d}{dt}[at(T-t)]$

$= at(0-1) + a(T-t)$

$= a(T-2t)$

So, induced emf is also a function of time.



$\therefore$ Heat generated in time T is

$H = \int_0^T \dfrac{E^2}{R}dt = \dfrac{a^2}{R}\int_0^T (T-2t)^2\,dt = \dfrac{a^2T^3}{3R}$

9. **(a)** Area of the loop $= 0.1 \times 0.1 = 0.01\,m^2$

$\varepsilon = -\dfrac{d\phi}{dt} = \dfrac{-d}{dt}(BA)$

Magnitude of emf

$\varepsilon = A\dfrac{dB}{dt} = (0.01 m^2)(0.02\,T/s) = 2 \times 10^{-4}\,V$

Resistance of the loop is

$R = \rho\dfrac{\ell}{A} = \dfrac{1.7 \times 10^{-8} \times 40 \times 10^{-2}}{3.14 \times 10^{-6}}$

$= 2.16 \times 10^{-3}\,\Omega$

Current induced in the loop

$I = \dfrac{\varepsilon}{R} = \dfrac{2 \times 10^{-4}\,V}{2.16 \times 10^{-3}\,\Omega} = 9.3 \times 10^{-2}$ amp.

10. **(d)** The magnetic field is increasing in the downward direction. Therefore, according to Lenz's law the current I_1 will flow in the direction ab and I_2 in the direction dc.

11. **(c)**

12. **(a)** In case of both the circular and the elliptical loops, the rate of change of area of the loops during their passage out of the field is not constant, hence induced emf will not remain constant for them.

13. **(c)** Induced emf in the coil, $e = -L\left(\frac{di}{dt}\right)$.

Initialy, $\frac{di}{dt} = 0$, then $\frac{di}{dt} = -ve$ and finally $\frac{di}{dt} = +ve$

Accordingly $e = 0$, $e = +$ve, and finally $e = -$ve.

14. **(d)** Inductance $= \frac{\mu_0 N^2 A}{L}$

15. **(a)** $Q_{coil} = (NQ) \propto i$

So, $\frac{Q_1}{Q_2} = \frac{i_1}{i_2} = \frac{3}{2}$

or $Q_2 = \frac{2}{3}Q_1 = \frac{2}{3} \times 10^{-3} = 6.67 \times 10^{-4}$Wb

16. **(b)** We have given, time period, $T = 10$s

$\therefore$ Angular velocity, $\omega = \frac{2\pi}{10} = \frac{\pi}{5}$

Magnetic flux, $\phi(t) = BA\cos\omega t$

Emf induced,

$$E = \frac{-d\phi}{dt} = BA\omega\sin\omega t = BA\omega\sin(\omega t)$$

Induced emf, $|\varepsilon|$ is maximum when $\omega t = \frac{\pi}{2}$

$$\Rightarrow t = \frac{\frac{\pi}{2}}{\frac{\pi}{5}} = 2.5 \text{ s}$$

For induced emf to be minimum i.e zero

$$\omega t = \pi \Rightarrow t = \frac{\pi}{\frac{\pi}{5}} = 5 \, s$$

$\therefore$ Induced emf is zero at t = 5 s

17. **(c)** Power $= \frac{B^2 v^2 l^2}{R}$

$$= \frac{0.5 \times 0.5 \times 12 \times 12 \times 15 \times 15 \times 10^{-8}}{9 \times 10^{-3}}$$

$= 9 \times 10^{-3}$ watt

Current $= \frac{Bvl}{R}$

$$= \frac{0.5 \times 12 \times 10^{-2} \times 15 \times 10^{-2}}{9 \times 10^{-3}} = 1\text{A}$$

18. **(d)** $e_0 = \omega NBA = (2\pi v)NBA$

$= 2 \times 3.14 \times 100 \times 5000 \times 0.2 \times 0.25 = 157$kV

19. **(c)** $A = 200\text{ cm}^2 = 200 \times 10^{-4}\text{ m}^2$; $N = 100$; $R = 2\Omega$

Initial magnetic flux linked with the coil is

$\phi_i = BA\cos\theta = 0.1 \times 200 \times 10^{-4} \times \cos 0°$
$= 2 \times 10^{-3}$ Wb

Final magnetic flux linked with the coil is $\phi_f = 0$

$$\varepsilon = -\frac{N\Delta\phi}{\Delta t} = \frac{-N(\phi_f - \phi_i)}{\Delta t}$$

$$= \frac{-100(0 - 2 \times 10^{-3})}{1} = 0.2\text{V}$$

Induced current $I = \frac{\varepsilon}{R} = \frac{0.2\text{V}}{2\Omega} = 0.1\text{A}$

Induced charge $q = It = 0.1 \times 1 = 0.1$ C

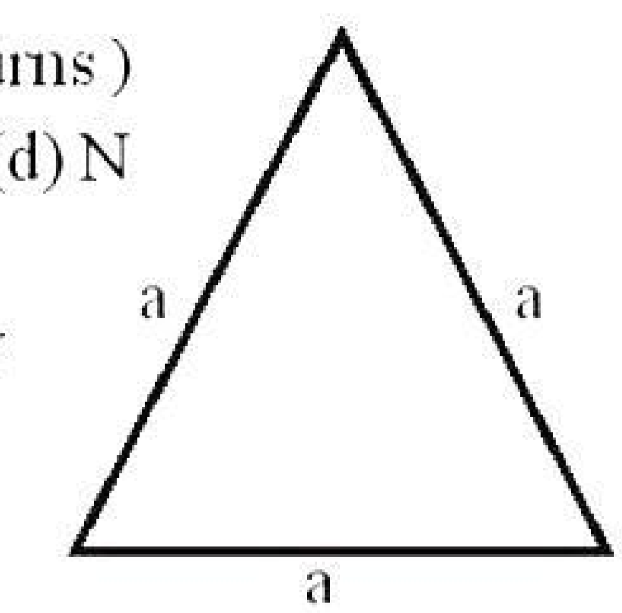
20. **(b)** $L = \mu_0 nI$

$\therefore \frac{L_2}{L_1} = \frac{\mu}{\mu_0}$ ----($\because$ n and I are same)

$\therefore L_2 = \mu_r L_1 = 900 \times 0.18 = 162$ mH

21. **(c)**

22. **(c)** As total length L of the wire will remain constant



L = (3a) N (N = total turns)

and length of winding = (d) N

(d = diameter of wire)

self inductance $= \mu_0 n^2 A \ell$

$$= \mu_0 n^2 \left(\frac{\sqrt{3}a^2}{4}\right) dN$$

$\propto a^2 N \propto a$ [as $N = L/3a \Rightarrow N \propto \frac{1}{a}$]

Now 'a' increased to '3a'

So self inductance will become 3 times

23. **(d)** Given, Area of cross-section of pipe, $A = 10\text{ cm}^2$

Length of pipe, $\ell = 20$ cm

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

$$= \frac{4\pi \times 10^{-7} \times 300 \times 400 \times 100 \times 10^{-4}}{0.2}$$

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

$$= 2.4\pi \times 10^{-4}\,\text{H}$$

24. **(d)** Induced emf,

$$e = -\frac{\Delta\phi}{\Delta t} = \frac{-\Delta(LI)}{\Delta t} = -L\frac{\Delta I}{\Delta t}$$

$$\therefore |e| = L\frac{\Delta I}{\Delta t}$$

$$\Rightarrow 8 = L \times \frac{[2-(-2)]}{0.05} \Rightarrow L = \frac{8 \times 0.05}{4} = 0.1\text{H}$$

25. **(a)** Net charge

$$\text{Q} = \frac{\Delta\phi}{\text{R}} = \frac{1}{10}\text{A}(\text{B}_\text{f} - \text{B}_\text{i}) = \frac{1}{10} \times 3.5 \times 10^{-3}$$

$$\left(0.4\sin\frac{\pi}{2} - 0\right) = \frac{1}{10}(3.5 \times 10^{-3})(0.4 - 0)$$

$$= 1.4 \times 10^{-4}\,\text{mC}$$