ELECTROMAGNETIC INDUCTION
CHAPTER - 38

1. (a) $\int E.dl = MLT^{-3}I^{-1} \times L = ML^2I^{-1}T^{-3}$

   (b) $\Im BI = LT^{-1} \times MI^{-1}T^{-2} \times L = ML^2I^{-1}T^{-3}$

   (c) $d\phi_s / dt = MI^{-1}T^{-2} \times L^2 = ML^2I^{-1}T^{-2}$

2. $\phi = at^2 + bt + c$

   (a) $a = \left[\frac{\phi}{t^2}\right] = \left[\frac{\phi/t}{t}\right] = \frac{\text{Volt}}{\text{Sec}}$

   $b = \left[\frac{\phi}{t}\right] = \text{Volt}$

   $c = [\phi] = \text{Weber}$

   (b) $E = \frac{d\phi}{dt}$ [a = 0.2, b = 0.4, c = 0.6, t = 2s]

   $= 2at + b$

   $= 2 \times 0.2 \times 2 + 0.4 = 1.2$ volt

3. (a) $\phi_2 = B.A. = 0.01 \times 2 \times 10^{-3} = 2 \times 10^{-5}$.

   $\phi_1 = 0$

   $e = -\frac{d\phi}{dt} = \frac{-2\times10^{-5}}{10\times10^{-3}} = -2$ mV

   $\phi_3 = B.A. = 0.03 \times 2 \times 10^{-3} = 6 \times 10^{-5}$

   $d\phi = 4 \times 10^{-5}$

   $e = -\frac{d\phi}{dt} = -4$ mV

   $\phi_4 = B.A. = 0.01 \times 2 \times 10^{-3} = 2 \times 10^{-5}$

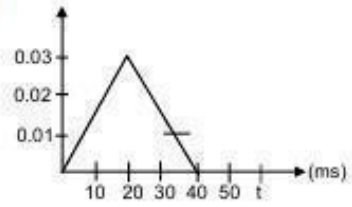
   $d\phi = -4 \times 10^{-5}$

   $e = -\frac{d\phi}{dt} = 4$ mV

   $\phi_5 = B.A. = 0$

   $d\phi = -2 \times 10^{-5}$

   $e = -\frac{d\phi}{dt} = 2$ mV



   (b) emf is not constant in case of → 10 – 20 ms and 20 – 30 ms as –4 mV and 4 mV.

4. $\phi_1 = BA = 0.5 \times \pi(5 \times 10^{-2})^2 = 5\pi\ 25 \times 10^{-5} = 125 \times 10^{-5}$

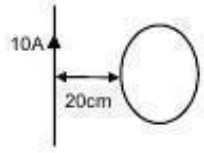
   $\phi_2 = 0$

   $E = \frac{\phi_1 - \phi_2}{t} = \frac{125\pi\times10^{-5}}{5\times10^{-1}} = 25\pi \times 10^{-4} = 7.8 \times 10^{-3}$.

5. A = 1 mm^2 ; i = 10 A, d = 20 cm ; dt = 0.1 s

   $e = \frac{d\phi}{dt} = \frac{BA}{dt} = \frac{\mu_0 i}{2\pi d} \times \frac{A}{dt}$

   $= \frac{4\pi\times10^{-7}\times10}{2\pi\times2\times10^{-1}} \times \frac{10^{-6}}{1\times10^{-1}} = 1\times10^{-10}$ V.



6. (a) During removal,

   $\phi_1 = B.A. = 1 \times 50 \times 0.5 \times 0.5 - 25 \times 0.5 = 12.5$ Tesla-m^2

   $\phi_2 = 0$, $\tau = 0.25$

   $e = -\frac{d\phi}{dt} = \frac{\phi_2 - \phi_1}{dt} = \frac{12.5}{0.25} = \frac{125\times10^{-1}}{25\times10^{-2}} = 50V$

   (b) During its restoration

   $\phi_1 = 0$; $\phi_2 = 12.5$ Tesla-m^2 ; t = 0.25 s

   $E = \frac{12.5 - 0}{}$ = 50 V

$$\frac{}{0.25} = 50\ V.$$

(c) During the motion

$\phi_1 = 0, \phi_2 = 0$

$$E = \frac{d\phi}{dt} = 0$$

7. $R = 25\ \Omega$

(a) $e = 50\ V, T = 0.25\ s$

$i = e/R = 2A, H = i^2 RT$

$= 4 \times 25 \times 0.25 = 25\ J$

(b) $e = 50\ V, T = 0.25\ s$

$i = e/R = 2A, H = i^2 RT = 25\ J$

(c) Since energy is a scalar quantity

Net thermal energy developed = 25 J + 25 J = 50 J.

8. $A = 5\ cm^2 = 5 \times 10^{-4}\ m^2$

$B = B_0 \sin \omega t = 0.2 \sin(300\ t)$

$\theta = 60°$

a) Max emf induced in the coil

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

$$= \frac{d}{dt}(B_0 \sin\omega t \times 5 \times 10^{-4} \times \frac{1}{2})$$

$$= B_0 \times \frac{5}{2} \times 10^{-4} \frac{d}{dt}(\sin\omega t) = \frac{B_0 5}{2} \times 10^{-4} \cos\omega t \cdot \omega$$

$$= \frac{0.2 \times 5}{2} \times 300 \times 10^{-4} \times \cos\omega t = 15 \times 10^{-3} \cos\omega t$$

$E_{max} = 15 \times 10^{-3} = 0.015\ V$

b) Induced emf at $t = (\pi/900)\ s$

$E = 15 \times 10^{-3} \times \cos \omega t$

$= 15 \times 10^{-3} \times \cos(300 \times \pi/900) = 15 \times 10^{-3} \times ½$

$= 0.015/2 = 0.0075 = 7.5 \times 10^{-3}\ V$

c) Induced emf at $t = \pi/600\ s$

$E = 15 \times 10^{-3} \times \cos(300 \times \pi/600)$

$= 15 \times 10^{-3} \times 0 = 0\ V.$

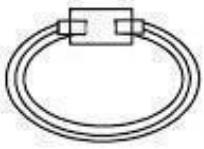
9. $\vec{B} = 0.10\ T$

$A = 1\ cm^2 = 10^{-4}\ m^2$

$T = 1\ s$

$\phi = B.A. = 10^{-1} \times 10^{-4} = 10^{-5}$

$$e = \frac{d\phi}{dt} = \frac{10^{-5}}{1} = 10^{-5} = 10\ \mu V$$



10. $E = 20\ mV = 20 \times 10^{-3}\ V$

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

$Dt = 0.2\ s, \theta = 180°$

$\phi_1 = BA, \phi_2 = -BA$

$d\phi = 2BA$

$$E = \frac{d\phi}{dt} = \frac{2BA}{dt}$$

$$\Rightarrow 20 \times 10^{-3} = \frac{2 \times B \times 2 \times 10^{-4}}{2 \times 10^{-1}}$$

$$\Rightarrow 20 \times 10^{-3} = 4 \times B \times 10^{-3}$$

$$\Rightarrow B = \frac{20 \times 10^{-3}}{42 \times 10^{-3}} = 5T$$

11. Area = A, Resistance = R, B = Magnetic field

$\phi = BA = Ba \cos 0° = BA$

$e = \frac{d\phi}{dt} = \frac{BA}{1}$; $i = \frac{e}{R} = \frac{BA}{R}$

$\phi = iT = BA/R$

12. $r = 2 \text{ cm} = 2 \times 10^{-2} \text{ m}$

$n = 100 \text{ turns / cm} = 10000 \text{ turns/m}$

$i = 5 \text{ A}$

$B = \mu_0 ni$

$= 4\pi \times 10^{-7} \times 10000 \times 5 = 20\pi \times 10^{-3} = 62.8 \times 10^{-3} \text{ T}$

$n_2 = 100 \text{ turns}$

$R = 20 \Omega$

$r = 1 \text{ cm} = 10^{-2} \text{ m}$

Flux linking per turn of the second coil = $B\pi r^2 = B\pi \times 10^{-4}$

ϕ_1 = Total flux linking = $Bn_2 \pi r^2 = 100 \times \pi \times 10^{-4} \times 20\pi \times 10^{-3}$

When current is reversed.

$\phi_2 = -\phi_1$

$d\phi = \phi_2 - \phi_1 = 2 \times 100 \times \pi \times 10^{-4} \times 20\pi \times 10^{-3}$

$E = -\frac{d\phi}{dt} = \frac{4\pi^2 \times 10^{-4}}{dt}$

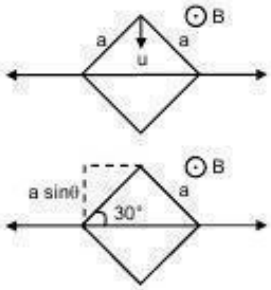
$I = \frac{E}{R} = \frac{4\pi^2 \times 10^{-4}}{dt \times 20}$

$q = Idt = \frac{4\pi^2 \times 10^{-4}}{dt \times 20} \times dt = 2 \times 10^{-4} \text{ C.}$

13. Speed = u

Magnetic field = B

Side = a



a) The perpendicular component i.e. a sinθ is to be taken which is ⊥r to velocity.

So, $l = a \sin \theta \, 30° = a/2$.

Net 'a' charge = $4 \times a/2 = 2a$

So, induced emf = $B\vartheta l = 2auB$

b) Current = $\frac{E}{R} = \frac{2auB}{R}$

14. $\phi_1 = 0.35$ weber, $\phi_2 = 0.85$ weber

$D\phi = \phi_2 - \phi_1 = (0.85 - 0.35)$ weber = 0.5 weber

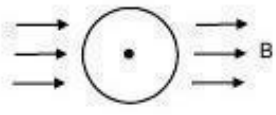
$dt = 0.5$ sec

$E = \frac{d\phi}{dt'} = \frac{0.5}{0.5} = 1 \text{ v.}$

The induced current is anticlockwise as seen from above.

15. $i = v(B \times l)$

$= v B l \cos\theta$



θ is angle between normal to plane and $\vec{B} = 90°$.

$= v B l \cos 90° = 0.$

16. $u = 1 \text{ cm/'}, B = 0.6 \text{ T}$

a) At t = 2 sec, distance moved = 2 × 1 cm/s = 2 cm

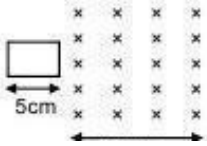
$E = \frac{d\phi}{dt} = \frac{0.6 \times (2 \times 5 - 0) \times 10^{-4}}{2} = 3 \times 10^{-4} \text{ V}$

b) At t = 10 sec

distance moved = 10 × 1 = 10 cm

The flux linked does not change with time

$\therefore E = 0$



c) At t = 22 sec

distance = 22 × 1 = 22 cm

The loop is moving out of the field and 2 cm outside.

$$E = \frac{d\phi}{dt} = B \times \frac{dA}{dt}$$

$$= \frac{0.6 \times (2 \times 5 \times 10^{-4})}{2} = 3 \times 10^{-4} \text{ V}$$

d) At t = 30 sec

The loop is total outside and flux linked = 0

$\therefore$ E = 0.

17. As heat produced is a scalar prop.

So, net heat produced = $H_a + H_b + H_c + H_d$

R = 4.5 mΩ = 4.5×10^{-3} Ω

a) $e = 3 \times 10^{-4}$ V

$$i = \frac{e}{R} = \frac{3 \times 10^{-4}}{4.5 \times 10^{-3}} = 6.7 \times 10^{-2} \text{ Amp.}$$

$H_a = (6.7 \times 10^{-2})^2 \times 4.5 \times 10^{-3} \times 5$

$H_b = H_d = 0$ [since emf is induced for 5 sec]

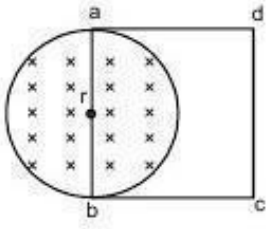
$H_c = (6.7 \times 10^{-2})^2 \times 4.5 \times 10^{-3} \times 5$

So Total heat = $H_a + H_c$

$= 2 \times (6.7 \times 10^{-2})^2 \times 4.5 \times 10^{-3} \times 5 = 2 \times 10^{-4}$ J.

18. r = 10 cm, R = 4 Ω

$$\frac{dB}{dt} = 0.010 \text{ T/'}, \quad \frac{d\phi}{dt} = \frac{dB}{dt} A$$



$$E = \frac{d\phi}{dt} = \frac{dB}{dt} \times A = 0.01 \left(\frac{\pi \times r^2}{2} \right)$$

$$= \frac{0.01 \times 3.14 \times 0.01}{2} = \frac{3.14}{2} \times 10^{-4} = 1.57 \times 10^{-4}$$

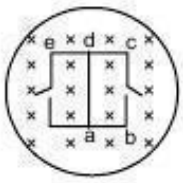
$$i = \frac{E}{R} = \frac{1.57 \times 10^{-4}}{4} = 0.39 \times 10^{-4} = 3.9 \times 10^{-5} \text{A}$$

19. a) S_1 closed S_2 open

net R = 4 × 4 = 16 Ω

$$e = \frac{d\phi}{dt} = A \frac{dB}{dt} = 10^{-4} \times 2 \times 10^{-2} = 2 \times 10^{-6} \text{ V}$$

$$\text{i through ad} = \frac{e}{R} = \frac{2 \times 10^{-6}}{16} = 1.25 \times 10^{-7} \text{ A along ad}$$



b) R = 16 Ω

$$e = A \times \frac{dB}{dt} = 2 \times 0^{-5} \text{ V}$$

$$i = \frac{2 \times 10^{-6}}{16} = 1.25 \times 10^{-7} \text{ A along d a}$$

c) Since both S_1 and S_2 are open, no current is passed as circuit is open i.e. i = 0

d) Since both S_1 and S_2 are closed, the circuit forms a balanced wheat stone bridge and no current will flow along ad i.e. i = 0.

20. Magnetic field due to the coil (1) at the center of (2) is $B = \frac{\mu_0 N i a^2}{2(a^2 + x^2)^{3/2}}$

Flux linked with the second,

$$= B.A_{(2)} = \frac{\mu_0 N i a^2}{2(a^2 + x^2)^{3/2}} \pi a'^2$$

$$\text{E.m.f. induced } \frac{d\phi}{dt} = \frac{\mu_0 N a^2 a'^2 \pi}{2(a^2 + x^2)^{3/2}} \frac{di}{dt}$$



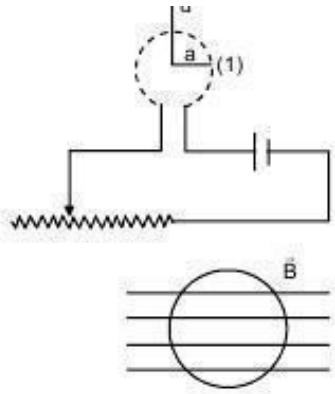
$$= \frac{\mu_0 N\pi a^2 a'^2}{2(a^2+x^2)^{3/2}} \frac{d}{dt} \frac{E}{((R/L)x+r)}$$

$$= \frac{\mu_0 N\pi a^2 a'^2}{2(a^2+x^2)^{3/2}} E \frac{-1.R/L.v}{((R/L)x+r)^2}$$

b) $= \frac{\mu_0 N\pi a^2 a'^2}{2(a^2+x^2)^{3/2}} \frac{ERV}{L(R/2+r)^2}$ (for x = L/2, R/L x = R/2)

a) For x = L

$$E = \frac{\mu_0 N\pi a^2 a'^2 RvE}{2(a^2+x^2)^{3/2}(R+r)^2}$$



21. N = 50, $\vec{B}$ = 0.200 T ; r = 2.00 cm = 0.02 m

$\theta = 60°$, t = 0.100 s

a) $e = \frac{Nd\phi}{dt} = \frac{N \times B.A}{T} = \frac{NBA\cos 60°}{T}$

$= \frac{50 \times 2 \times 10^{-1} \times \pi \times (0.02)^2}{0.1} = 5 \times 4 \times 10^{-3} \times \pi$

$= 2\pi \times 10^{-2}$ V = 6.28×10^{-2} V

b) $i = \frac{e}{R} = \frac{6.28 \times 10^{-2}}{4} = 1.57 \times 10^{-2}$ A

$Q = it = 1.57 \times 10^{-2} \times 10^{-1} = 1.57 \times 10^{-3}$ C

22. n = 100 turns, B = 4×10^{-4} T

A = 25 cm^2 = 25×10^{-4} m^2

a) When the coil is perpendicular to the field

ϕ = nBA

When coil goes through half a turn

ϕ = BA cos 18° = 0 – nBA

$d\phi$ = 2nBA

The coil undergoes 300 rev, in 1 min

300 × 2π rad/min = 10 π rad/sec

10π rad is swept in 1 sec.

π/π rad is swept 1/10π × π = 1/10 sec

$E = \frac{d\phi}{dt} = \frac{2nBA}{dt} = \frac{2 \times 100 \times 4 \times 10^{-4} \times 25 \times 10^{-4}}{1/10} = 2 \times 10^{-3}$ V

b) ϕ_1 = nBA, ϕ_2 = nBA (θ = 360°)

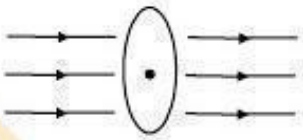
$d\phi$ = 0

c) $i = \frac{E}{R} = \frac{2 \times 10^{-3}}{4} = \frac{1}{2} \times 10^{-3}$

$= 0.5 \times 10^{-3} = 5 \times 10^{-4}$

$q = idt = 5 \times 10^{-4} \times 1/10 = 5 \times 10^{-5}$ C.

23. r = 10 cm = 0.1 m



R = 40 Ω, N = 1000

$\theta = 180°$, $B_H = 3 \times 10^{-5}$ T

ϕ = N(B.A) = NBA Cos 180° or = –NBA

$= 1000 \times 3 \times 10^{-5} \times \pi \times 1 \times 10^{-2} = 3\pi \times 10^{-4}$ where

$d\phi = 2NBA = 6\pi \times 10^{-4}$ weber

$e = \frac{d\phi}{dt} = \frac{6\pi \times 10^{-4} V}{dt}$

$i = \frac{6\pi \times 10^{-4}}{40dt} = \frac{4.71 \times 10^{-5}}{dt}$

$Q = \frac{4.71 \times 10^{-5} \times dt}{dt} = 4.71 \times 10^{-5}$ C.

24. $\text{emf} = \frac{d\phi}{dt} = \frac{dB.A\cos\theta}{dt}$

$= B\,A \sin\theta\,\omega = -BA\,\omega \sin\theta$

(dq/dt = the rate of change of angle between arc vector and B = ω)

a) emf maximum = $BA\omega = 0.010 \times 25 \times 10^{-4} \times 80 \times \frac{2\pi \times \pi}{6}$

$= 0.66 \times 10^{-3} = 6.66 \times 10^{-4}$ volt.

b) Since the induced emf changes its direction every time, so for the average emf = 0

25. $H = \int_0^t i^2 R dt = \int_0^t \frac{B^2A^2\omega^2}{R^2} \sin\omega t\, R\, dt$

$= \frac{B^2A^2\omega^2}{2R^2}\int_0^t (1-\cos 2\omega t)dt$

$= \frac{B^2A^2\omega^2}{2R}\left(t - \frac{\sin 2\omega t}{2\omega}\right)_0^{1\,\text{minute}}$

$= \frac{B^2A^2\omega^2}{2R}\left(60 - \frac{\sin 2\times 8 - \times 2\pi/60\times 60}{2\times 80\times 2\pi/60}\right)$

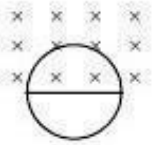
$= \frac{60}{200}\times\pi^2 r^4 \times B^2 \times \left(80^4 \times \frac{2\pi}{60}\right)^2$

$= \frac{60}{200}\times 10 \times \frac{64}{9}\times 10 \times 625 \times 10^{-8} \times 10^{-4} = \frac{625\times 6\times 64}{9\times 2}\times 10^{-11} = 1.33 \times 10^{-7}$ J.

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26. $\phi_1 = BA$, $\phi_2 = 0$

$= \frac{2\times 10^{-4} \times \pi(0.1)^2}{2} = \pi \times 10^{-5}$



$E = \frac{d\phi}{dt} = \frac{\pi \times 10^{-6}}{2} = 1.57 \times 10^{-6}$ V

27. l = 20 cm = 0.2 m

v = 10 cm/s = 0.1 m/s

B = 0.10 T

a) $F = q\,v\,B = 1.6 \times 10^{-19} \times 1 \times 10^{-1} \times 1 \times 10^{-1} = 1.6 \times 10^{-21}$ N

b) $qE = qvB$

$\Rightarrow E = 1 \times 10^{-1} \times 1 \times 10^{-1} = 1 \times 10^{-2}$ V/m

This is created due to the induced emf.

c) Motional emf = $Bv\ell$

$= 0.1 \times 0.1 \times 0.2 = 2 \times 10^{-3}$ V

28. ℓ = 1 m, B = 0.2 T, v = 2 m/s, $e = B\ell v$

$= 0.2 \times 1 \times 2 = 0.4$ V

29. ℓ = 10 m, $v = 3 \times 10^7$ m/s, $B = 3 \times 10^{-10}$ T

Motional emf = $Bv\ell$

$= 3 \times 10^{-10} \times 3 \times 10^7 \times 10 = 9 \times 10^{-3} = 0.09$ V

30. v = 180 km/h = 50 m/s

$B = 0.2 \times 10^{-4}$ T, L = 1 m

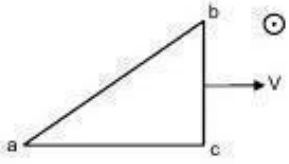
$E = Bv\ell = 0.2\ l\ 10^{-4} \times 50 = 10^{-3}$ V

$\therefore$ The voltmeter will record 1 mv.

31. a) Zero as the components of ab are exactly opposite to that of bc. So they cancel each other. Because velocity should be perpendicular to the length.

b) $e = Bv \times \ell$

$= Bv$ (bc) +ve at C



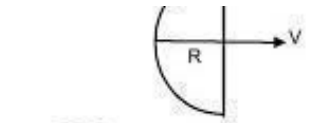
c) e = 0 as the velocity is not perpendicular to the length.

d) e = Bv (bc) positive at 'a'.

i.e. the component of 'ab' along the perpendicular direction.

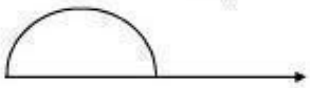
32. a) Component of length moving perpendicular to V is 2R

$\therefore$ E = B v 2R



b) Component of length perpendicular to velocity = 0

$\therefore$ E = 0



33. ℓ = 10 cm = 0.1 m ;

$\theta = 60°$; B = 1T

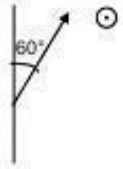
V = 20 cm/s = 0.2 m/s

$E = B\ell \sin 60°$

[As we have to take that component of length vector which is $\perp$r to the velocity vector]

$= 1 \times 0.2 \times 0.1 \times \sqrt{3}/2$

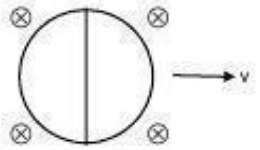
$= 1.732 \times 10^{-2} = 17.32 \times 10^{-3}$ V.



34. a) The e.m.f. is highest between diameter $\perp$r to the velocity. Because here length $\perp$r to velocity is highest.

$E_{max} = VB2R$

b) The length perpendicular to velocity is lowest as the diameter is parallel to the velocity $E_{min} = 0$.



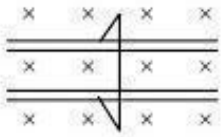
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35. $F_{magnetic} = i\ell B$

This force produces an acceleration of the wire.

But since the velocity is given to be constant.

Hence net force acting on the wire must be zero.

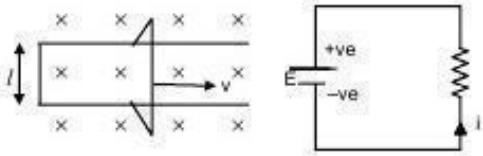


36. $E = B\nu\ell$

Resistance = r × total length

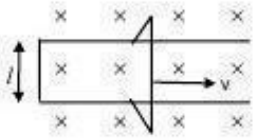
$= r \times 2(\ell + vt) = 24(\ell + vt)$

$$i = \frac{B\nu\ell}{2r(\ell + vt)}$$



37. $e = B\nu\ell$

$$i = \frac{e}{R} = \frac{B\nu\ell}{2r(\ell + vt)}$$



a) $$F = i\ell B = \frac{B\nu\ell}{2r(\ell + vt)} \times \ell B = \frac{B^2\ell^2\nu}{2r(\ell + vt)}$$

b) Just after t = 0

$$F_0 = i\ell B = \ell B\left(\frac{\ell B\nu}{2r\ell}\right) = \frac{\ell B^2\nu}{2r}$$

$$\frac{F_0}{2} = \frac{\ell B^2\nu}{4r} = \frac{\ell^2 B^2\nu}{2r(\ell + vt)}$$

$\Rightarrow 2\ell = \ell + vt$

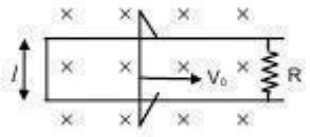
$\Rightarrow T = \ell/v$

38. a) When the speed is V

Emf = $B\ell v$

Resistance = r + r

$$\text{Current} = \frac{B\ell\nu}{r + R}$$



b) Force acting on the wire = $i\ell B$

$$= \frac{B\ell\nu\ell B}{R + r} = \frac{B^2\ell^2\nu}{R + r}$$

$$\text{Acceleration on the wire} = \frac{B^2\ell^2\nu}{m(R + r)}$$

c) $$v = v_0 + at = v_0 - \frac{B^2\ell^2\nu}{m(R + r)}t$$ [force is opposite to velocity]

$$= v_0 - \frac{B^2\ell^2 x}{m(R+r)}$$

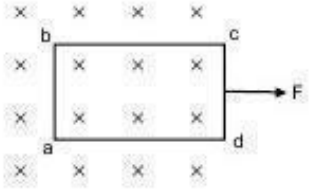
d) $a = v\frac{dv}{dx} = \frac{B^2\ell^2 v}{m(R+r)}$

$\Rightarrow dx = \frac{dvm(R+r)}{B^2\ell^2}$

$\Rightarrow x = \frac{m(R+r)v_0}{B^2\ell^2}$

39. $R = 2.0\ \Omega$, $B = 0.020$ T, $l = 32$ cm $= 0.32$ m

$B = 8$ cm $= 0.08$ m



a) $F = i\ell B = 3.2 \times 10^{-5}$ N

$= \frac{B^2\ell^2 v}{R} = 3.2 \times 10^5$

$\Rightarrow \frac{(0.020)^2 \times (0.08)^2 \times v}{2} = 3.2 \times 10^{-5}$

$\Rightarrow v = \frac{3.2\times10^{-5}\times2}{6.4\times10^{-3}\times4\times10^{-4}} = 25$ m/s

b) Emf $E = vB\ell = 25 \times 0.02 \times 0.08 = 4 \times 10^{-2}$ V

c) Resistance per unit length $= \frac{2}{0.8}$

Resistance of part ad/cb $= \frac{2\times0.72}{0.8} = 1.8\ \Omega$

$V_{ab} = iR = \frac{B\ell v}{2}\times1.8 = \frac{0.02\times0.08\times25\times1.8}{2} = 0.036$ V $= 3.6 \times 10^{-2}$ V

d) Resistance of cd $= \frac{2\times0.08}{0.8} = 0.2\ \Omega$

$V = iR = \frac{0.02\times0.08\times25\times0.2}{2} = 4 \times 10^{-3}$ V

40. $\ell = 20$ cm $= 20 \times 10^{-2}$ m

$v = 20$ cm/s $= 20 \times 10^{-2}$ m/s

$B_H = 3 \times 10^{-5}$ T

$i = 2\ \mu A = 2 \times 10^{-6}$ A

$R = 0.2\ \Omega$

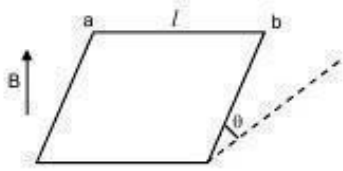
$i = \frac{B_v \ell v}{R}$

$\Rightarrow B_v = \frac{iR}{\ell v} = \frac{2\times10^{-6}\times2\times10^{-1}}{20\times10^{-2}\times20\times10^{-2}} = 1 \times 10^{-5}$ Tesla

$\tan\delta = \frac{B_v}{B_H} = \frac{1\times10^{-5}}{3\times10^{-5}} = \frac{1}{3} \Rightarrow \delta(\text{dip}) = \tan^{-1}(1/3)$

41. $I = \frac{B\ell v}{R} = \frac{B\times\ell\cos\theta\times v\cos\theta}{R}$

$= \frac{B\ell v}{R}\cos^2\theta$

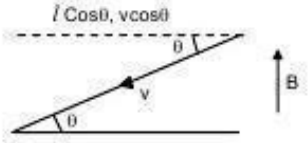


$F = i\ell B = \frac{B\ell v\cos^2\theta\times\ell B}{R}$

Now, $F = mg\sin\theta$ [Force due to gravity which pulls downwards]

Now, $\frac{B^2\ell^2 v\cos^2\theta}{R} = mg\sin\theta$

$\Rightarrow B = \sqrt{\frac{Rmg\sin\theta}{\ell^2 v\cos^2\theta}}$



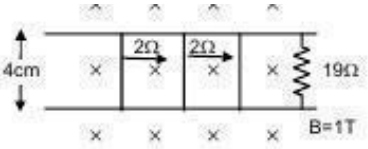
42. a) The wires constitute 2 parallel emf

42. a) The wires constitute 2 parallel emf.

$\therefore$ Net emf = $B\ell v = 1 \times 4 \times 10^{-2} \times 5 \times 10^{-2} = 20 \times 10^{-4}$

Net resistance = $\frac{2\times2}{2+2} + 19 = 20\ \Omega$

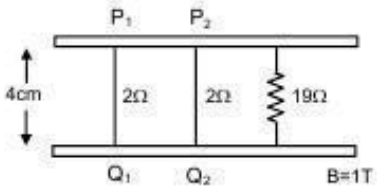
Net current = $\frac{20\times10^{-4}}{20} = 0.1$ mA.



b) When both the wires move towards opposite directions then not emf = 0

$\therefore$ Net current = 0

43.



a) No current will pass as circuit is incomplete.

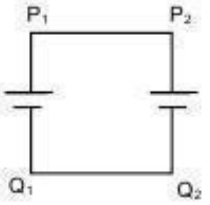
b) As circuit is complete

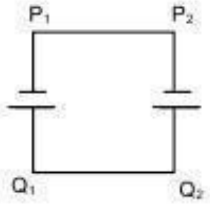
$VP_2Q_2 = B\ell v$

$= 1 \times 0.04 \times 0.05 = 2 \times 10^{-3}$ V

$R = 2\Omega$

$i = \frac{2\times10^{-3}}{2} = 1 \times 10^{-3}$ A = 1 mA.





44. B = 1 T, V = 5 l 10^{-2} m/', R = 10 Ω

a) When the switch is thrown to the middle rail

$E = Bv\ell$

$= 1 \times 5 \times 10^{-2} \times 2 \times 10^{-2} = 10^{-3}$

Current in the 10 Ω resistor = E/R

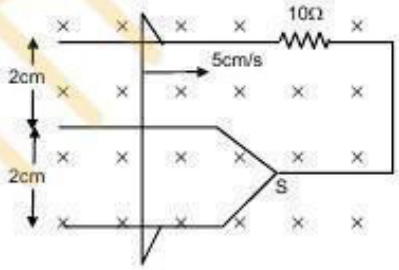
$= \frac{10^{-3}}{10} = 10^{-4} = 0.1$ mA

b) The switch is thrown to the lower rail

$E = Bv\ell$

$= 1 \times 5 \times 10^{-2} \times 2 \times 10^{-2} = 20 \times 10^{-4}$

Current = $\frac{20\times10^{-4}}{10} = 2 \times 10^{-4} = 0.2$ mA



45. Initial current passing = i

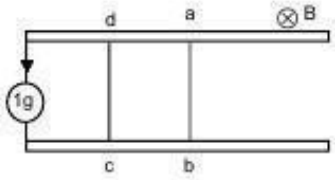
Hence initial emf = ir

Emf due to motion of ab = $B\ell v$

Net emf = $ir - B\ell v$

Net resistance = 2r

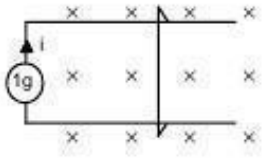
Hence current passing = $\frac{ir - B\ell v}{2r}$



46. Force on the wire = $i\ell B$

Acceleration = $\frac{i\ell B}{m}$

Velocity = $\frac{i\ell Bt}{m}$



47. Given $B\ell v = mg$ ...(1)

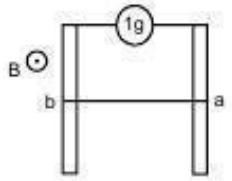
When wire is replaced we have

$2mg - B\ell v = 2ma$ [where a $\rightarrow$ acceleration]

$\Rightarrow a = \frac{2mg - B\ell v}{2m}$

Now, $s = ut + \frac{1}{2}at^2$

$\frac{1}{\quad} \frac{2mg - B\ell v}{\quad}$

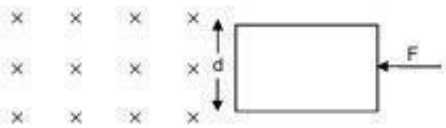


$\Rightarrow \ell = \frac{1}{2} \times \frac{\text{[illegible]}}{2m} \times t^2$ [$\because s = \ell$]

$\Rightarrow t = \sqrt{\frac{4ml}{2mg - B\ell v}} = \sqrt{\frac{4ml}{2mg - mg}} = \sqrt{2\ell / g}$. [from (1)]

---

48. a) emf developed = Bdv (when it attains a speed v)



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

Force = $\frac{Bd^2v^2}{R}$

This force opposes the given force

Net F = $F - \frac{Bd^2v^2}{R} = RF - \frac{Bd^2v^2}{R}$

Net acceleration = $\frac{RF - B^2d^2v}{mR}$

b) Velocity becomes constant when acceleration is 0.

$\frac{F}{m} - \frac{B^2d^2v_0}{mR} = 0$

$\Rightarrow \frac{F}{m} = \frac{B^2d^2v_0}{mR}$

$\Rightarrow V_0 = \frac{FR}{B^2d^2}$

c) Velocity at line t

$a = -\frac{dv}{dt}$

$\Rightarrow \int_0^v \frac{dv}{RF - I^2B^2v} = \int_0^t \frac{dt}{mR}$

$\Rightarrow \left[I_n[RF - I^2B^2v] \frac{1}{-I^2B^2} \right]_0^v \quad \left[\frac{t}{Rm} \right]_0^t$

$\Rightarrow \left[I_n(RF - I^2B^2v) \right]_0^v = \frac{-tI^2B^2}{Rm}$

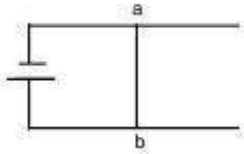
$\Rightarrow I_n(RF - I^2B^2v) - \ln(RF) = \frac{-t^2B^2t}{Rm}$

$\Rightarrow 1 - \frac{I^2B^2v}{RF} = e^{\frac{-I^2B^2t}{Rm}}$

$\Rightarrow \frac{I^2B^2v}{RF} = 1 - e^{\frac{-I^2B^2t}{Rm}}$

$\Rightarrow v = \frac{FR}{I^2B^2}\left(1 - e^{\frac{-I^2B^2v_0t}{Rv_0m}} \right) = v_0(1 - e^{-Fv_0m})$

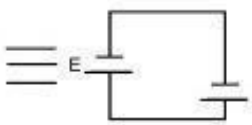
49. Net emf = E – Bvℓ



$I = \frac{E - Bv\ell}{r}$ from b to a

$F = I\ell B$

$= \left(\frac{E - Bv\ell}{r} \right) \ell B = \frac{\ell B}{r}(E - Bv\ell)$ towards right.



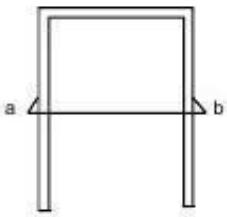
After some time when E = Bvℓ,

Then the wire moves constant velocity v

Hence v = E / Bℓ.

50. a) When the speed of wire is V

emf developed = $B\ell V$



b) Induced current is the wire = $\frac{B\ell v}{R}$ (from b to a)

c) Down ward acceleration of the wire

$= \frac{mg-F}{m}$ due to the current

$= mg - i\ell B/m = g - \frac{B^2\ell^2V}{Rm}$

d) Let the wire start moving with constant velocity. Then acceleration = 0

$\frac{B^2\ell^2v}{Rm}m = g$

$\Rightarrow V_m = \frac{gRm}{B^2\ell^2}$

e) $\frac{dV}{dt} = a$

$\Rightarrow \frac{dV}{dt} = \frac{mg - B^2\ell^2v/R}{m}$

$\Rightarrow \frac{dv}{\frac{mg - B^2\ell^2v/R}{m}} = dt$

$\Rightarrow \int_0^v \frac{mdv}{mg - \frac{B^2\ell^2v}{R}} = \int_0^t dt$

$\Rightarrow \frac{m}{\frac{-B^2\ell^2}{R}}\left(\log(mg - \frac{B^2\ell^2v}{R}\right)_0^v = t$

$\Rightarrow \frac{-mR}{B^2\ell^2} = \log\left[\log\left(mg - \frac{B^2\ell^2v}{R}\right) - \log(mg)\right] = t$

$\Rightarrow \log\left[\frac{mg - \frac{B^2\ell^2v}{R}}{mg}\right] = \frac{-tB^2\ell^2}{mR}$

$\Rightarrow \log\left[1 - \frac{B^2\ell^2v}{Rmg}\right] = \frac{-tB^2\ell^2}{mR}$

$\Rightarrow 1 - \frac{B^2\ell^2v}{Rmg} = e^{\frac{-tB^2\ell^2}{mR}}$

$\Rightarrow (1 - e^{-B^2\ell^2/mR}) = \frac{B^2\ell^2v}{Rmg}$

$\Rightarrow v = \frac{Rmg}{B^2\ell^2}\left(1 - e^{-B^2\ell^2/mR}\right)$

$\Rightarrow v = v_m(1 - e^{-gt/Vm}) \quad \left[v_m = \frac{Rmg}{B^2\ell^2}\right]$

f) $\frac{ds}{dt} = v \Rightarrow ds = v\,dt$

$\Rightarrow s = vm \int_0^t (1 - e^{-gt/vm})dt$

$= V_m\left(t - \frac{V_m}{g}e^{-gt/vm}\right) = \left(V_m t + \frac{V_m^2}{g}e^{-gt/vm}\right) - \frac{V_m^2}{g}$

$= V_m t - \frac{V_m^2}{g}\left(1 - e^{-gt/vm}\right)$

g) $\frac{d}{dt} mgs = mg\frac{ds}{dt} = mgV_m(1 - e^{-gt/vm})$

$\frac{d_H}{dt} = i^2R = R\left(\frac{\ell BV}{R}\right)^2 = \frac{\ell^2 B^2 v^2}{R}$

$\Rightarrow \frac{\ell^2 B^2}{R} V_m^2 (1 - e^{-gt/vm})^2$

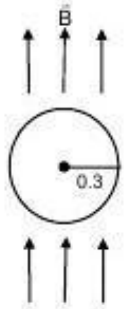
After steady state i.e. $T \to \infty$

$\frac{d}{dt} mgs = mgV_m$

$\frac{d_H}{dt} = \frac{\ell^2 B^2}{R} V_m^2 = \frac{\ell^2 B^2}{R} V_m \frac{mgR}{\ell^2 B^2} = mgV_m$

Hence after steady state $\frac{d_H}{dt} = \frac{d}{dt} mgs$

51. $\ell = 0.3$ m, $\vec{B} = 2.0 \times 10^{-5}$ T, $\omega = 100$ rpm



$v = \frac{100}{60} \times 2\pi = \frac{10}{3}\pi$ rad/s

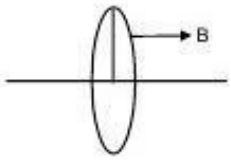
$v = \frac{\ell}{2} \times \omega = \frac{0.3}{2} \times \frac{10}{3}\pi$

Emf = $e = B\ell v$

$= 2.0 \times 10^{-5} \times 0.3 \times \frac{0.33}{2} \times \frac{10}{3}\pi$

$= 3\pi \times 10^{-6}$ V $= 3 \times 3.14 \times 10^{-6}$ V $= 9.42 \times 10^{-6}$ V.

52. V at a distance r/2



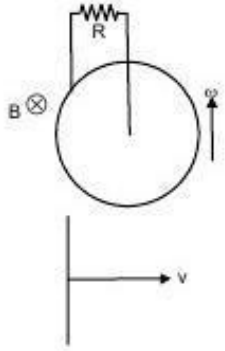
From the centre = $\frac{r\omega}{2}$

$E = B\ell v \Rightarrow E = B \times r \times \frac{r\omega}{2} = \frac{1}{2} Br^2\omega$

53. B = 0.40 T, $\omega = 10$ rad/', $r = 10\Omega$

r = 5 cm = 0.05 m

Considering a rod of length 0.05 m affixed at the centre and rotating with the same ω.



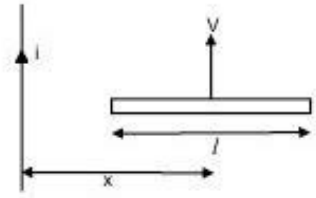
$v = \frac{\ell}{2} \times \omega = \frac{0.05}{2} \times 10$

$e = B\ell v = 0.40 \times \frac{0.05}{2} \times 10 \times 0.05 = 5 \times 10^{-3}$ V

$I = \frac{e}{R} = \frac{5 \times 10^{-3}}{10} = 0.5$ mA

It leaves from the centre.

54. $\vec{B} = \frac{B_0}{L} y\hat{K}$



L = Length of rod on y-axis

$V = V_0 \hat{i}$

Considering a small length by of the rod

dE = B V dy

$\Rightarrow dE = \frac{B_0}{L} y \times V_0 \times dy$

$\Rightarrow dE = \frac{B_0 V_0}{L} ydy$

$\Rightarrow E = \frac{B_0 V_0}{} \int^{L} ydy$

$$= \frac{B_0V_0}{L}\left[\frac{y^2}{2}\right]_0^L = \frac{B_0V_0}{L}\frac{L^2}{2} = \frac{1}{2}B_0V_0L$$

55. In this case $\vec{B}$ varies

Hence considering a small element at centre of rod of length dx at a dist x from the wire.

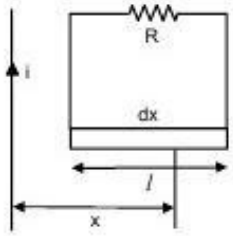
$$\vec{B} = \frac{\mu_0 i}{2\pi x}$$

So, $de = \frac{\mu_0 i}{2\pi x} \times vxdx$

$$e = \int_0^e de = \frac{\mu_0 iv}{2\pi} = \int_{x-t/2}^{x+t/2} \frac{dx}{x} = \frac{\mu_0 iv}{2\pi}[\ln(x + \ell/2) - \ell n(x - \ell/2)]$$

$$= \frac{\mu_0 iv}{2\pi}\ln\left[\frac{x+\ell/2}{x-\ell/2}\right] = \frac{\mu_0 iv}{2x}\ln\left(\frac{2x+\ell}{2x-\ell}\right)$$

56. a) emf produced due to the current carrying wire $= \frac{\mu_0 iv}{2\pi}\ln\left(\frac{2x+\ell}{2x-\ell}\right)$



Let current produced in the rod = $i' = \frac{\mu_0 iv}{2\pi R}\ln\left(\frac{2x+\ell}{2x-\ell}\right)$

Force on the wire considering a small portion dx at a distance x

$dF = i' B \ell$

$$\Rightarrow dF = \frac{\mu_0 iv}{2\pi R}\ln\left(\frac{2x+\ell}{2x-\ell}\right) \times \frac{\mu_0 i}{2\pi x} \times dx$$

$$\Rightarrow dF = \left(\frac{\mu_0 i}{2\pi}\right)^2 \frac{v}{R}\ln\left(\frac{2x+\ell}{2x-\ell}\right)\frac{dx}{x}$$

$$\Rightarrow F = \left(\frac{\mu_0 i}{2\pi}\right)^2 \frac{v}{R}\ln\left(\frac{2x+\ell}{2x-\ell}\right)\int_{x-t/2}^{x+t/2}\frac{dx}{x}$$

$$= \left(\frac{\mu_0 i}{2\pi}\right)^2 \frac{v}{R}\ln\left(\frac{2x+\ell}{2x-\ell}\right)\ln\left(\frac{2x+\ell}{2x-\ell}\right)$$

$$= \frac{v}{R}\left[\frac{\mu_0 i}{2\pi}\ln\left(\frac{2x+\ell}{2x-\ell}\right)\right]^2$$

b) Current $= \frac{\mu_0 \ln}{2\pi R}\ln\left(\frac{2x+\ell}{2x-\ell}\right)$

c) Rate of heat developed $= i^2R$

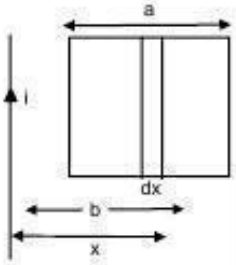
$$= \left[\frac{\mu_0 iv}{2\pi R}\left(\frac{2x+\ell}{2x-\ell}\right)\right]^2 R = \frac{1}{R}\left[\frac{\mu_0 iv}{2\pi}\ln\left(\frac{2x+\ell}{2x-\ell}\right)^2\right]$$

d) Power developed in rate of heat developed $= i^2R$

$$= \frac{1}{R}\left[\frac{\mu_0 iv}{2\pi}\ln\left(\frac{2x+\ell}{2x-\ell}\right)\right]^2$$

57. Considering an element dx at a dist x from the wire. We have

a) $\phi = B.A.$



$$d\phi = \frac{\mu_0 i \times adx}{2\pi x}$$

$$\phi = \int_0^a d\phi = \frac{\mu_0 ia}{2\pi}\int_b^{a+b}\frac{dx}{x} = \frac{\mu_0 ia}{2\pi}\ln\{1 + a/b\}$$

b) $e = \frac{d\phi}{dt} = \frac{d}{dt}\frac{\mu_0 ia}{2\pi}\ln[1 + a/b]$

$\frac{\mu_0 a}{\quad}$ $\frac{d}{\quad}$ $(\quad)$

$= \frac{}{2\pi} \ln[1+a/n] \frac{}{dt}(i_0 \sin\omega t)$

$= \frac{\mu_0 a i_0 \omega \cos\omega t}{2\pi} \ln[1+a/b]$

c) $i = \frac{e}{r} = \frac{\mu_0 a i_0 \omega \cos\omega t}{2\pi r} \ln[1+a/b]$

$H = i^2 rt$

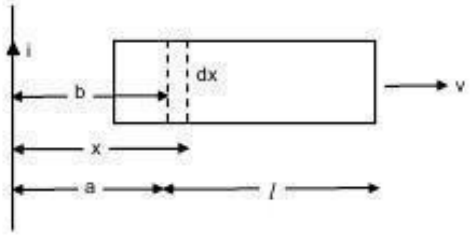
$= \left[\frac{\mu_0 a i_0 \omega \cos\omega t}{2\pi r} \ln(1+a/b)\right]^2 \times r \times t$

$= \frac{\mu_0^2 \times a^2 \times i_0^2 \times \omega^2}{4\pi \times r^2} \ln^2[1+a/b] \times r \times \frac{20\pi}{\omega}$

$= \frac{5\mu_0^2 a^2 i_0^2 \omega}{2\pi r} \ln^2[1+a/b] \quad [\because t = \frac{20\pi}{\omega}]$

58. a) Using Faraday'' law

Consider a unit length dx at a distance x



$B = \frac{\mu_0 i}{2\pi x}$

Area of strip = b dx

$d\phi = \frac{\mu_0 i}{2\pi x} dx$

$\Rightarrow \phi = \int_a^{a+l} \frac{\mu_0 i}{2\pi x} b dx$

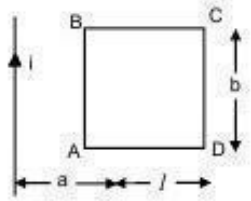
$= \frac{\mu_0 i}{2\pi} b \int_a^{a+l} \left(\frac{dx}{x}\right) = \frac{\mu_0 i b}{2\pi} \log\left(\frac{a+l}{a}\right)$

$Emf = \frac{d\phi}{dt} = \frac{d}{dt}\left[\frac{\mu_0 i b}{2\pi} \log\left(\frac{a+l}{a}\right)\right]$

$= \frac{\mu_0 i b}{2\pi} \frac{a}{a+l} \left(\frac{va-(a+l)v}{a^2}\right)$ (where da/dt = V)

$= \frac{\mu_0 i b}{2\pi} \frac{a}{a+l} \frac{vl}{a^2} = \frac{\mu_0 i b v l}{2\pi(a+l)a}$

The velocity of AB and CD creates the emf. since the emf due to AD and BC are equal and opposite to each other.



$B_{AB} = \frac{\mu_0 i}{2\pi a} \quad \Rightarrow \quad$ E.m.f. AB $= \frac{\mu_0 i}{2\pi a} bv$

Length b, velocity v.

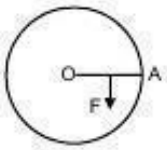
$B_{CD} = \frac{\mu_0 i}{2\pi(a+l)}$

$\Rightarrow$ E.m.f. CD $= \frac{\mu_0 i b v}{2\pi(a+l)}$

Length b, velocity v.

Net emf $= \frac{\mu_0 i}{2\pi a} bv - \frac{\mu_0 i b v}{2\pi(a+l)} = \frac{\mu_0 i b v l}{2\pi a(a+l)}$

59. $e = Bvl = \frac{B \times a \times \omega \times a}{2}$



$i = \frac{Ba^2\omega}{2R}$

$F = i\ell B = \frac{Ba^2\omega}{2R} \times a \times B = \frac{B^2 a^3 \omega}{2R}$ towards right of OA.

60. The 2 resistances r/4 and 3r/4 are in parallel.

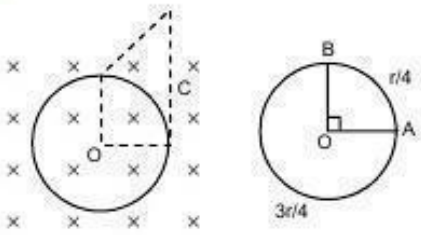
$$R' = \frac{r/4 \times 3r/4}{r} = \frac{3r}{16}$$

$$e = BV\ell$$

$$= B \times \frac{a}{2}\omega \times a = \frac{Ba^2\omega}{2}$$

$$i = \frac{e}{R'} = \frac{Ba^2\omega}{2R'} = \frac{Ba^2\omega}{2 \times 3r/16}$$

$$= \frac{Ba^2\omega 16}{2 \times 3r} = \frac{8}{3}\frac{Ba^2\omega}{r}$$

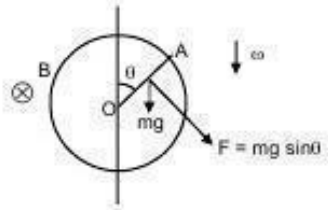


61. We know

$$F = \frac{B^2a^2\omega}{2R} = i\ell B$$

Component of mg along F = mg sin θ.

Net force = $\frac{B^2a^3\omega}{2R} - mg\sin\theta$.



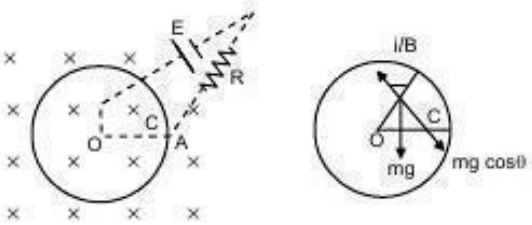
62. emf = $\frac{1}{2}B\omega a^2$ [from previous problem]

Current = $\frac{e+E}{R} = \frac{1/2 \times B\omega a^2 + E}{R} = \frac{B\omega a^2 + 2E}{2R}$

$\Rightarrow$ mg cos θ = iℓB [Net force acting on the rod is O]

$\Rightarrow$ mg cos θ = $\frac{B\omega a^2 + 2E}{2R} a \times B$

$\Rightarrow$ R = $\frac{(B\omega a^2 + 2E)aB}{2mg\cos\theta}$.



63. Let the rod has a velocity v at any instant,

Then, at the point,

e = Bℓv

Now, q = c × potential = ce = CBℓv

Current I = $\frac{dq}{dt} = \frac{d}{dt}$CBlv

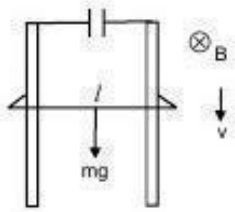
= CBl$\frac{dv}{dt}$ = CBla (where a → acceleration)

From figure, force due to magnetic field and gravity are opposite to each other.

So, mg – IℓB = ma

$\Rightarrow$ mg – CBℓa × ℓB = ma $\Rightarrow$ ma + $CB^2\ell^2$ a = mg

$\Rightarrow$ a(m + $CB^2\ell^2$) = mg $\Rightarrow$ a = $\frac{mg}{m + CB^2\ell 2}$



64. a) Work done per unit test charge

= ϕE. dl (E = electric field)

ϕE. dl = e

$\Rightarrow$ Eϕ dl = $\frac{d\phi}{dt}$ $\Rightarrow$ E 2πr = $\frac{dB}{dt} \times A$

$\Rightarrow$ E 2πr = $\pi r^2 \frac{dB}{dt}$

$\Rightarrow$ E = $\frac{\pi r^2}{2\pi}\frac{dB}{dt} = \frac{r}{2}\frac{dB}{dt}$



b) When the square is considered,

ϕE dl = e

$\Rightarrow E \times 2r \times 4 = \frac{dB}{dt}(2r)^2$

$\Rightarrow E = \frac{dB}{dt}\frac{4r^2}{8r} \Rightarrow E = \frac{r}{2}\frac{dB}{dt}$

$\therefore$ The electric field at the point p has the same value as (a).

65. $\frac{di}{dt} = 0.01$ A/s

For 2s $\frac{di}{dt} = 0.02$ A/s

n = 2000 turn/m, R = 6.0 cm = 0.06 m

r = 1 cm = 0.01 m

a) $\phi = BA$

$\Rightarrow \frac{d\phi}{dt} = \mu_0 nA\frac{di}{dt}$

$= 4\pi \times 10^{-7} \times 2 \times 10^3 \times \pi \times 1 \times 10^{-4} \times 2 \times 10^{-2}$ $[A = \pi \times 1 \times 10^{-4}]$

$= 16\pi^2 \times 10^{-10}\ \omega$

$= 157.91 \times 10^{-10}\ \omega$

$= 1.6 \times 10^{-8}\ \omega$

or, $\frac{d\phi}{dt}$ for 1 s = 0.785 ω.

b) $\int E.dl = \frac{d\phi}{dt}$

$\Rightarrow E\phi dl = \frac{d\phi}{dt} \Rightarrow E = \frac{0.785 \times 10^{-8}}{2\pi \times 10^{-2}} = 1.2 \times 10^{-7}$ V/m

c) $\frac{d\phi}{dt} = \mu_0 n\frac{di}{dt}A = 4\pi \times 10^{-7} \times 2000 \times 0.01 \times \pi \times (0.06)^2$

$E\phi dl = \frac{d\phi}{dt}$

$\Rightarrow E = \frac{d\phi/dt}{2\pi r} = \frac{4\pi \times 10^{-7} \times 2000 \times 0.01 \times \pi \times (0.06)^2}{\pi \times 8 \times 10^{-2}} = 5.64 \times 10^{-7}$ V/m

66. V = 20 V

$dI = I_2 - I_1 = 2.5 - (-2.5) = 5A$

dt = 0.1 s

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

$\Rightarrow 20 = L(5/0.1) \Rightarrow 20 = L \times 50$

$\Rightarrow L = 20 / 50 = 4/10 = 0.4$ Henry.

67. $\frac{d\phi}{dt} = 8 \times 10^{-4}$ weber

n = 200, I = 4A, $E = -nL\frac{dI}{dt}$

or, $\frac{-d\phi}{dt} = \frac{-LdI}{dt}$

or, $L = n\frac{d\phi}{dt} = 200 \times 8 \times 10^{-4} = 2 \times 10^{-2}$ H.

68. $E = \frac{\mu_0 N^2 A}{\ell}\frac{dI}{dt}$

$= \frac{4\pi \times 10^{-7} \times (240)^2 \times \pi(2 \times 10^{-2})^2}{12 \times 10^{-2}} \times 0.8$

$= \frac{4\pi \times (24)^2 \times \pi \times 4 \times 8}{12} \times 10^{-8}$

$= 60577.3824 \times 10^{-8} = 6 \times 10^{-4}$ V.

69. We know $i = i_0 (1 - e^{-t/r})$

a) $\frac{90}{100} i_0 = i_0 (1 - e^{-t/r})$

$\Rightarrow 0.9 = 1 - e^{-t/r}$

$\Rightarrow e^{-t/r} = 0.1$

Taking ℓn from both sides

ℓn $e^{-t/r}$ = ℓn 0.1 $\Rightarrow -t = -2.3 \Rightarrow t/r = 2.3$

b) $\frac{99}{100} i_0 = i_0 (1 - e^{-t/r})$

$\Rightarrow e^{-t/r} = 0.01$

ℓn$e^{-t/r}$ = ℓn 0.01

or, $-t/r = -4.6$ or $t/r = 4.6$

c) $\frac{99.9}{100} i_0 = i_0 (1 - e^{-t/r})$

$e^{-t/r} = 0.001$

$\Rightarrow$ ln$e^{-t/r}$ = ln 0.001 $\Rightarrow e^{-t/r} = -6.9 \Rightarrow t/r = 6.9$.

70. i = 2A, E = 4V, L = 1H

$R = \frac{E}{i} = \frac{4}{2} = 2$

$i = \frac{L}{R} = \frac{1}{2} = 0.5$

71. L = 2.0 H, R = 20 Ω, emf = 4.0 V, t = 0.20 S

$i_0 = \frac{e}{R} = \frac{4}{20}$, $\tau = \frac{L}{R} = \frac{2}{20} = 0.1$

a) $i = i_0 (1 - e^{-t/\tau}) = \frac{4}{20}\left(1 - e^{-0.2/0.1}\right)$

$= 0.17$ A

b) $\frac{1}{2} Li^2 = \frac{1}{2} \times 2 \times (0.17)^2 = 0.0289 = 0.03$ J.

72. R = 40 Ω, E = 4V, t = 0.1, i = 63 mA

$i = i_0 - (1 - e^{tR/2})$

$\Rightarrow 63 \times 10^{-3} = 4/40\ (1 - e^{-0.1 \times 40/L})$

$\Rightarrow 63 \times 10^{-3} = 10^{-1}\ (1 - e^{-4/L})$

$\Rightarrow 63 \times 10^{-2} = (1 - e^{-4/L})$

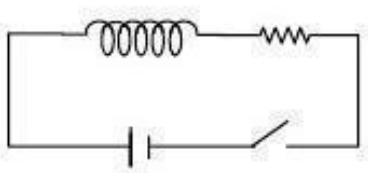
$\Rightarrow 1 - 0.63 = e^{-4/L} \Rightarrow e^{-4/L} = 0.37$

$\Rightarrow -4/L = \ln (0.37) = -0.994$

$\Rightarrow L = \frac{-4}{-0.994} = 4.024$ H = 4 H.

73. L = 5.0 H, R = 100 Ω, emf = 2.0 V

$t = 20$ ms $= 20 \times 10^{-3}$ s $= 2 \times 10^{-2}$ s



$i_0 = \frac{2}{100}$ now $i = i_0 (1 - e^{-t/\tau})$

$\tau = \frac{L}{R} = \frac{5}{100} \Rightarrow i = \frac{2}{100}\left(1 - e^{\frac{-2 \times 10^{-2} \times 100}{5}}\right)$

$\Rightarrow i = \frac{2}{100}(1 - e^{-2/5})$

$\Rightarrow 0.00659 = 0.0066.$

$V = iR = 0.0066 \times 100 = 0.66$ V

$V = iR = 0.0066 \times 100 = 0.66$ V.

74. $\tau = 40$ ms

$i_0 = 2$ A

a) $t = 10$ ms

$i = i_0 (1 - e^{-t/\tau}) = 2(1 - e^{-10/40}) = 2(1 - e^{-1/4})$

$= 2(1 - 0.7788) = 2(0.2211)^{A} = 0.4422$ A $= 0.44$ A

b) $t = 20$ ms

$i = i_0 (1 - e^{-t/\tau}) = 2(1 - e^{-20/40}) = 2(1 - e^{-1/2})$

$= 2(1 - 0.606) = 0.7869$ A $= 0.79$ A

c) $t = 100$ ms

$i = i_0 (1 - e^{-t/\tau}) = 2(1 - e^{-100/40}) = 2(1 - e^{-10/4})$

$= 2(1 - 0.082) = 1.835$ A $= 1.8$ A

d) $t = 1$ s

$i = i_0 (1 - e^{-t/\tau}) = 2(1 - e^{-1/40\times10^{-3}}) = 2(1 - e^{-10/40})$

$= 2(1 - e^{-25}) = 2 \times 1 = 2$ A

75. $L = 1.0$ H, $R = 20\ \Omega$, emf $= 2.0$ V

$\tau = \frac{L}{R} = \frac{1}{20} = 0.05$

$i_0 = \frac{e}{R} = \frac{2}{20} = 0.1$ A

$i = i_0 (1 - e^{-t}) = i_0 - i_0 e^{-t}$

$\Rightarrow \frac{di}{dt} = \frac{di_0}{dt}(i_0 x - 1/\tau \times e^{-t/\tau}) = i_0 / \tau\, e^{-t/\tau}$.

So,

a) $t = 100$ ms $\Rightarrow \frac{di}{dt} = \frac{0.1}{0.05} \times e^{-0.1/0.05} = 0.27$ A

b) $t = 200$ ms $\Rightarrow \frac{di}{dt} = \frac{0.1}{0.05} \times e^{-0.2/0.05} = 0.0366$ A

c) $t = 1$ s $\Rightarrow \frac{di}{dt} = \frac{0.1}{0.05} \times e^{-1/0.05} = 4 \times 10^{-9}$ A

76. a) For first case at $t = 100$ ms

$\frac{di}{dt} = 0.27$

Induced emf $= L\frac{di}{dt} = 1 \times 0.27 = 0.27$ V

b) For the second case at $t = 200$ ms

$\frac{di}{dt} = 0.036$

Induced emf $= L\frac{di}{dt} = 1 \times 0.036 = 0.036$ V

c) For the third case at $t = 1$ s

$\frac{di}{dt} = 4.1 \times 10^{-9}$ V

Induced emf $= L\frac{di}{dt} = 4.1 \times 10^{-9}$ V

77. $L = 20$ mH; $e = 5.0$ V, $R = 10\ \Omega$

$\tau = \frac{L}{R} = \frac{20\times10^{-3}}{10}$, $i_0 = \frac{5}{10}$

$i = i_0(1 - e^{-t/\tau})^2$

$\Rightarrow i = i_0 - i_0 e^{-t/\tau^2}$

$\Rightarrow iR = i_0R - i_0R\,e^{-t/\tau^2}$

a) $10 \times \frac{di}{dt} = \frac{d}{dt} i_0R + 10 \times \frac{5}{10} \times \frac{10}{20 \times 10^{-3}} \times e^{-0 \times 10/2 \times 10^{-2}}$

$= \frac{5}{2} \times 10^{-3} \times 1 = \frac{5000}{2} = 2500 = 2.5 \times 10^{-3}$ V/s.

b) $\frac{Rdi}{dt} = R \times i_0 \times \frac{1}{\tau} \times e^{-t/\tau}$

$t = 10$ ms $= 10 \times 10^{-3}$ s

$\frac{dE}{dt} = 10 \times \frac{5}{10} \times \frac{10}{20 \times 10^{-3}} \times e^{-0.01 \times 10/2 \times 10^{-2}}$

$= 16.844 = 17$ V/'

c) For $t = 1$ s

$\frac{dE}{dt} = \frac{Rdi}{dt} = \frac{5}{2} 10^3 \times e^{10/2 \times 10^{-2}} = 0.00$ V/s.

78. $L = 500$ mH, $R = 25\ \Omega$, $E = 5$ V

a) $t = 20$ ms

$i = i_0 (1 - e^{-tR/L}) = \frac{E}{R}(1 - E^{-tR/L})$

$= \frac{5}{25}\left(1 - e^{-20 \times 10^{-3} \times 25/100 \times 10^{-3}}\right) = \frac{1}{5}(1 - e^{-1})$

$= \frac{1}{5}(1 - 0.3678) = 0.1264$

Potential difference $iR = 0.1264 \times 25 = 3.1606$ V $= 3.16$ V.

b) $t = 100$ ms

$i = i_0 (1 - e^{-tR/L}) = \frac{E}{R}(1 - E^{-tR/L})$

$= \frac{5}{25}\left(1 - e^{-100 \times 10^{-3} \times 25/100 \times 10^{-3}}\right) = \frac{1}{5}(1 - e^{-5})$

$= \frac{1}{5}(1 - 0.0067) = 0.19864$

Potential difference $= iR = 0.19864 \times 25 = 4.9665 = 4.97$ V.

c) $t = 1$ sec

$i = i_0 (1 - e^{-tR/L}) = \frac{E}{R}(1 - E^{-tR/L})$

$= \frac{5}{25}\left(1 - e^{-1 \times 25/100 \times 10^{-3}}\right) = \frac{1}{5}(1 - e^{-50})$

$= \frac{1}{5} \times 1 = 1/5$ A

Potential difference $= iR = (1/5 \times 25)$ V $= 5$ V.

79. $L = 120$ mH $= 0.120$ H

$R = 10\ \Omega$, emf $= 6$, $r = 2$

$i = i_0 (1 - e^{-t/\tau})$

Now, $dQ = idt$

$= i_0 (1 - e^{-t/\tau})\, dt$

$Q = \int dQ = \int_0^1 i_0(1 - e^{-t/\tau})dt$

$= i_0\left[\int_0^t dt - \int_0^1 e^{-t/\tau}dt\right] = i_0\left[t - (-\tau)\int_0^t e^{-t/\tau}dt\right]$

$= i_0[t + \tau(e^{-t/\tau - 1})] = i_0[t + \tau e^{-t/\tau}\tau]$

Now, $i_0 = \frac{6}{10+2} = \frac{6}{12} = 0.5$ A

$\tau = \frac{L}{R} = \frac{0.120}{12} = 0.01$

a) t = 0.01 s

So, Q $= 0.5[0.01 + 0.01\, e^{-0.01/0.01} - 0.01]$

$= 0.00183 = 1.8 \times 10^{-3}$ C = 1.8 mC

b) t = 20 ms = 2×10^{-2} ′ = 0.02 s

So, Q $= 0.5[0.02 + 0.01\, e^{-0.02/0.01} - 0.01]$

$= 0.005676 = 5.6 \times 10^{-3}$ C = 5.6 mC

c) t = 100 ms = 0.1 s

So, Q $= 0.5[0.1 + 0.01\, e^{-0.1/0.01} - 0.01]$

= 0.045 C = 45 mC

80. L = 17 mH, ℓ = 100 m, A = 1 mm^2 = 1×10^{-6} m^2, $f_{cu} = 1.7 \times 10^{-8}$ Ω-m

$R = \frac{f_{cu}\ell}{A} = \frac{1.7\times10^{-8}\times100}{1\times10^{-6}} = 1.7\ \Omega$

$i = \frac{L}{R} = \frac{0.17\times10^{-8}}{1.7} = 10^{-2}$ sec = 10 m sec.

81. τ = L/R = 50 ms = 0.05 ′

a) $\frac{i_0}{2} = i_0(1-e^{-t/0.06})$

$\Rightarrow \frac{1}{2} = 1-e^{-t/0.05} = e^{-t/0.05} = \frac{1}{2}$

$\Rightarrow \ell n\, e^{-t/0.05} = \ell n^{1/2}$

$\Rightarrow$ t = 0.05 × 0.693 = 0.3465 ′ = 34.6 ms = 35 ms.

b) $P = i^2R = \frac{E^2}{R}(1-E^{-tR/L})^2$

Maximum power = $\frac{E^2}{R}$

So, $\frac{E^2}{2R} = \frac{E^2}{R}(1-e^{-tR/L})^2$

$\Rightarrow 1 - e^{-tR/L} = \frac{1}{\sqrt{2}} = 0.707$

$\Rightarrow e^{-tR/L} = 0.293$

$\Rightarrow \frac{tR}{L} = -\ln 0.293 = 1.2275$

$\Rightarrow$ t = 50 × 1.2275 ms = 61.2 ms.

82. Maximum current = $\frac{E}{R}$

In steady state magnetic field energy stored = $\frac{1}{2}L\frac{E^2}{R^2}$

The fourth of steady state energy = $\frac{1}{8}L\frac{E^2}{R^2}$

One half of steady energy = $\frac{1}{4}L\frac{E^2}{R^2}$

$\frac{1}{8}L\frac{E^2}{R^2} = \frac{1}{2}L\frac{E^2}{R^2}(1-e^{-t_1R/L})^2$

$\Rightarrow 1 - e^{t_1R/L} = \frac{1}{2}$

$\Rightarrow e^{t_1R/L} = \frac{1}{2}$ $\Rightarrow t_1\frac{R}{L} = \ln 2$ $\Rightarrow t_1 = \frac{L}{R}\ln 2$

$\Rightarrow e^{\cdots} = \frac{1}{2} \Rightarrow t_1 \frac{\cdots}{L} = \ell n\, 2 \Rightarrow t_1 = \tau \ell n 2$

Again $\frac{1}{4} L \frac{E^2}{R^2} = \frac{1}{2} L \frac{E^2}{R^2} (1 - e^{-t_2 R/L})^2$

$\Rightarrow e^{t_2 R/L} = \frac{\sqrt{2}-1}{\sqrt{2}} = \frac{2-\sqrt{2}}{2}$

$\Rightarrow t_2 = \tau \left[\ell n \left(\frac{1}{2-\sqrt{2}} \right) + \ell n 2 \right]$

So, $t_2 - t_1 = \tau \ell n \frac{1}{2-\sqrt{2}}$

83. L = 4.0 H, R = 10 Ω, E = 4 V

a) Time constant = $\tau = \frac{L}{R} = \frac{4}{10} = 0.4$ s.

b) $i = 0.63\, i_0$

Now, $0.63\, i_0 = i_0 (1 - e^{-t/\tau})$

$\Rightarrow e^{-t/\tau} = 1 - 0.63 = 0.37$

$\Rightarrow \ell n e^{-t/\tau} = \ln 0.37$

$\Rightarrow -t/\tau = -0.9942$

$\Rightarrow t = 0.9942 \times 0.4 = 0.3977 = 0.40$ s.

c) $i = i_0 (1 - e^{-t/\tau})$

$\Rightarrow \frac{4}{10}(1 - e^{-0.4/0.4}) = 0.4 \times 0.6321 = 0.2528$ A.

Power delivered = VI

$= 4 \times 0.2528 = 1.01 = 1\ \omega$.

d) Power dissipated in Joule heating $= I^2 R$

$= (0.2528)^2 \times 10 = 0.639 = 0.64\ \omega$.

84. $i = i_0(1 - e^{-t/\tau})$

$\Rightarrow \mu_0 ni = \mu_0 n\, i_0 (1 - e^{-t/\tau}) \Rightarrow B = B_0 (1 - e^{-tR/L})$

$\Rightarrow 0.8\, B_0 = B_0 (1 - e^{-20\times10^{-5}\times R/2\times10^{-3}}) \Rightarrow 0.8 = (1 - e^{-R/100})$

$\Rightarrow e^{-R/100} = 0.2 \Rightarrow \ell n(e^{-R/100}) = \ell n(0.2)$

$\Rightarrow -R/100 = -1.609 \Rightarrow R = 16.9 = 160\ \Omega$.

85. Emf = E LR circuit

a) $dq = idt$

$= i_0 (1 - e^{-t/\tau})dt$

$= i_0 (1 - e^{-tR.L})dt \quad [\because \tau = L/R]$

$Q = \int_0^t dq = i_0 \left[\int_0^t dt - \int_0^t e^{-tR/L} dt \right]$

$= i_0 [t - (-L/R)(e^{-tR/L})\, t_0]$

$= i_0 [t - L/R\, (1 - e^{-tR/L})]$

$Q = E/R\, [t - L/R\, (1 - e^{-tR/L})]$

b) Similarly as we know work done = VI = EI

$= E\, i_0 [t - L/R\, (1 - e^{-tR/L})]$

$= \frac{E^2}{R} [t - L/R\, (1 - e^{-tR/L})]$

c) $H = \int_0^t i^2 R \cdot dt = \frac{E^2}{R^2} \cdot R \cdot \int_0^t (1 - e^{-tR/L})^2 \cdot dt$

$= \frac{E^2}{R} \int_0^t (1 + e^{(-2+B)/L} - 2e^{-tR/L}) \cdot dt$

$$= \frac{E^2}{R}\left(t - \frac{L}{2R}e^{-2tR/L} + \frac{L}{R}2\cdot e^{-tR/L}\right)_0^t$$

$$= \frac{E^2}{R}\left(t - \frac{L}{2R}e^{-2tR/L} + \frac{2L}{R}\cdot e^{-tR/L}\right) - \left(-\frac{L}{2R} + \frac{2L}{R}\right)$$

$$= \frac{E^2}{R}\left[\left(t - \frac{L}{2R}x^2 + \frac{2L}{R}\cdot x\right) - \frac{3}{2}\frac{L}{R}\right]$$

$$= \frac{E^2}{2}\left(t - \frac{L}{2R}(x^2 - 4x + 3)\right)$$

d) $E = \frac{1}{2}Li^2$

$$= \frac{1}{2}L\cdot\frac{E^2}{R^2}\cdot(1 - e^{-tR/L})^2 \quad [x = e^{-tR/L}]$$

$$= \frac{LE^2}{2R^2}(1-x)^2$$

e) Total energy used as heat as stored in magnetic field

$$= \frac{E^2}{R}T - \frac{E^2}{R}\cdot\frac{L}{2R}x^2 + \frac{E^2}{R}\frac{L}{r}\cdot 4x^2 - \frac{3L}{2R}\cdot\frac{E^2}{R} + \frac{LE^2}{2R^2} + \frac{LE^2}{2R^2}x^2 - \frac{LE^2}{R^2}x$$

$$= \frac{E^2}{R}t + \frac{E^2L}{R^2}x - \frac{LE^2}{R^2}$$

$$= \frac{E^2}{R}\left(t - \frac{L}{R}(1-x)\right)$$

= Energy drawn from battery.

(Hence conservation of energy holds good).

86. L = 2H, R = 200 Ω, E = 2 V, t = 10 ms

a) $\ell = \ell_0(1 - e^{-t/\tau})$

$$= \frac{2}{200}\left(1 - e^{-10\times10^{-3}\times200/2}\right)$$

$= 0.01\ (1 - e^{-1}) = 0.01\ (1 - 0.3678)$

$= 0.01 \times 0.632 = 6.3$ A.

b) Power delivered by the battery

= VI

$$= EI_0(1 - e^{-t/\tau}) = \frac{E^2}{R}(1 - e^{-t/\tau})$$

$$= \frac{2\times2}{200}(1 - e^{-10\times10^{-3}\times200/2}) = 0.02\ (1 - e^{-1}) = 0.1264 = 12 \text{ mw.}$$

c) Power dissepited in heating the resistor = I^2R

$$= [i_0(1 - e^{-t/\tau})]^2R$$

$= (6.3 \text{ mA})^2 \times 200 = 6.3 \times 6.3 \times 200 \times 10^{-6}$

$= 79.38 \times 10^{-4} = 7.938 \times 10^{-3} = 8$ mA.

d) Rate at which energy is stored in the magnetic field

d/dt (1/2 LI^2]

$$= \frac{LI_0^2}{\tau}(e^{-t/\tau} - e^{-2t/\tau}) = \frac{2\times10^{-4}}{10^{-2}}(e^{-1} - e^{-2})$$

$= 2 \times 10^{-2}\ (0.2325) = 0.465 \times 10^{-2}$

$= 4.6 \times 10^{-3} = 4.6$ mW.

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87. $L_A = 1.0$ H ; $L_B = 2.0$ H ; R = 10 Ω

a) t = 0.1 s, $\tau_A = 0.1$, $\tau_B = L/R = 0.2$

$i_A = i_0(1 - e^{-t/\tau})$

$$2\left(\quad^{-0.1\times10}\right)$$

$= \frac{2}{10}\left(1-e^{-1}\right) = 0.2\,(1-e^{-1}) = 0.126424111$

$i_B = i_0(1-e^{-t/\tau})$

$= \frac{2}{10}\left(1-e^{\frac{-0.1\times10}{2}}\right) = 0.2\,(1-e^{-1/2}) = 0.078693$

$$\frac{i_A}{i_B} = \frac{0.12642411}{0.78693} = 1.6$$

b) $t = 200\text{ ms} = 0.2\text{ s}$

$i_A = i_0(1-e^{-t/\tau})$

$= 0.2(1-e^{-0.2\times10/1}) = 0.2 \times 0.864664716 = 0.172932943$

$i_B = 0.2(1-e^{-0.2\times10/2}) = 0.2 \times 0.632120 = 0.126424111$

$$\frac{i_A}{i_B} = \frac{0.172932943}{0.126424111} = 1.36 = 1.4$$

c) $t = 1\text{ s}$

$i_A = 0.2(1-e^{-1\times10/1}) = 0.2 \times 0.9999546 = 0.19999092$

$i_B = 0.2(1-e^{-1\times10/2}) = 0.2 \times 0.99326 = 0.19865241$

$$\frac{i_A}{i_B} = \frac{0.19999092}{0.19865241} = 1.0$$

88. a) For discharging circuit

$i = i_0\, e^{-t/\tau}$

$\Rightarrow 1 = 2\, e^{-0.1/\tau}$

$\Rightarrow (1/2) = e^{-0.1/\tau}$

$\Rightarrow \ell n\,(1/2) = \ell n\,(e^{-0.1/\tau})$

$\Rightarrow -0.693 = -0.1/\tau$

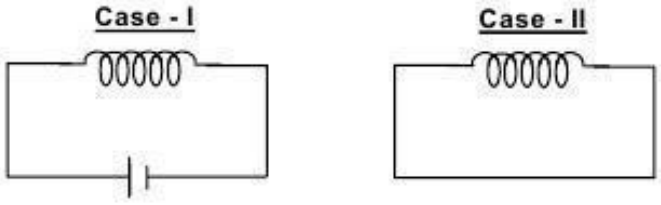
$\Rightarrow \tau = 0.1/0.693 = 0.144 = 0.14.$

b) $L = 4\text{ H}, i = L/R$

$\Rightarrow 0.14 = 4/R$

$\Rightarrow R = 4 / 0.14 = 28.57 = 28\ \Omega.$

89.



In this case there is no resistor in the circuit.

So, the energy stored due to the inductor before and after removal of battery remains same. i.e.

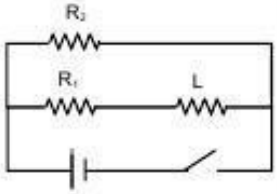
$$V_1 = V_2 = \frac{1}{2}Li^2$$

So, the current will also remain same.

Thus charge flowing through the conductor is the same.

---

90. a) The inductor does not work in DC. When the switch is closed the current charges so at first inductor works. But after a long time the current flowing is constant.



Thus effect of inductance vanishes.

$$i = \frac{E}{R_{net}} = \frac{E}{\frac{R_1R_2}{R_1+R_2}} = \frac{E(R_1+R_2)}{R_1R_2}$$

b) When the switch is opened the resistors are in series.

$$\tau = \frac{L}{R_{net}} = \frac{L}{R_1 + R_2}.$$

91. i = 1.0 A, r = 2 cm, n = 1000 turn/m

Magnetic energy stored = $\frac{B^2V}{2\mu_0}$

Where B → Magnetic field, V → Volume of Solenoid.

$$= \frac{\mu_0 n^2 i^2}{2\mu_0} \times \pi r^2 h$$

$$= \frac{4\pi \times 10^{-7} \times 10^6 \times 1 \times \pi \times 4 \times 10^{-4} \times 1}{2} \qquad [h = 1 \text{ m}]$$

$$= 8\pi^2 \times 10^{-5}$$

$$= 78.956 \times 10^{-5} = 7.9 \times 10^{-4} \text{ J}.$$

92. Energy density = $\frac{B^2}{2\mu_0}$

Total energy stored = $\frac{B^2V}{2\mu_0} = \frac{(\mu_0 i/2r)^2}{2\mu_0} V = \frac{\mu_0 i^2}{4r^2 \times 2} V$

$$= \frac{4\pi \times 10^{-7} \times 4^2 \times 1 \times 10^{-9}}{4 \times (10^{-1})^2 \times 2} = 8\pi \times 10^{-14} \text{ J}.$$

93. I = 4.00 A, V = 1 mm^3,
d = 10 cm = 0.1 m

$$\vec{B} = \frac{\mu_0 i}{2\pi r}$$

Now magnetic energy stored = $\frac{B^2}{2\mu_0} V$

$$= \frac{\mu_0^2 i^2}{4\pi r^2} \times \frac{1}{2\mu_0} \times V = \frac{4\pi \times 10^{-7} \times 16 \times 1 \times 1 \times 10^{-9}}{4 \times 1 \times 10^{-2} \times 2}$$

$$= \frac{8}{\pi} \times 10^{-14} \text{ J}$$

$$= 2.55 \times 10^{-14} \text{ J}$$

94. M = 2.5 H

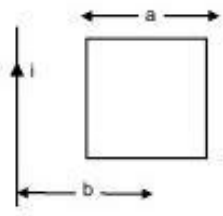
$$\frac{dI}{dt} = \frac{\ell A}{s}$$

$$E = -\mu \frac{dI}{dt}$$

$\Rightarrow$ E = 2.5 × 1 = 2.5 V

95. We know

$$\frac{d\phi}{dt} = E = M \times \frac{di}{dt}$$



From the question,

$$\frac{di}{dt} = \frac{d}{dt}(i_0 \sin \omega t) = i_0 \omega \cos \omega t$$

$$\frac{d\phi}{dt} = E = \frac{\mu_0 a i_0 \omega \cos \omega t}{2\pi} \ell n[1 + a/b]$$

Now, $E = M \times \frac{di}{dt}$

or, $\frac{\mu_0 a i_0 \omega \cos \omega t}{2\pi} \ell n[1 + a/b] = M \times i_0 \omega \cos \omega t$

$\Rightarrow$ $M = \frac{\mu_0 a}{2\pi} \ell n[1 + a/b]$

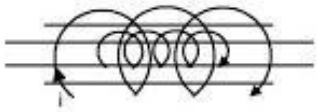
96. emf induced = $\dfrac{\pi\mu_0 N a^2 a'^2 ERV}{2L(a^2+x^2)^{3/2}(R/Lx+r)^2}$

$\dfrac{dI}{dt} = \dfrac{ERV}{L\left(\dfrac{Rx}{L}+r\right)^2}$ (from question 20)

$\mu = \dfrac{E}{di/dt} = \dfrac{N\mu_0\pi a^2 a'^2}{2(a^2+x^2)^{3/2}}$.

97. **Solenoid I :**

$a_1 = 4\ cm^2$; $n_1 = 4000/0.2$ m ; $\ell_1 = 20$ cm $= 0.20$ m



Solenoid II :

$a_2 = 8\ cm^2$; $n_2 = 2000/0.1$ m ; $\ell_2 = 10$ cm $= 0.10$ m

$B = \mu_0 n_2 i$ let the current through outer solenoid be i.

$\phi = n_1 B.A = n_1\, n_2\, \mu_0\, i \times a_1$

$= 2000 \times \dfrac{2000}{0.1} \times 4\pi \times 10^{-7} \times i \times 4 \times 10^{-4}$

$E = \dfrac{d\phi}{dt} = 64\pi \times 10^{-4} \times \dfrac{di}{dt}$

Now $M = \dfrac{E}{di/dt} = 64\pi \times 10^{-4}\ H = 2 \times 10^{-2}\ H.$ [As E = Mdi/dt]

98. a) B = Flux produced due to first coil

$= \mu_0\, n\, i$

Flux ϕ linked with the second

$= \mu_0\, n\, i \times NA = \mu_0\, n\, i\, N\, \pi\, R^2$

Emf developed

$= \dfrac{dI}{dt} = \dfrac{dt}{dt}(\mu_0 niN\pi R^2)$

$= \mu_0 nN\pi R^2 \dfrac{di}{dt} = \mu_0 nN\pi R^2 i_0 \omega \cos\omega t$.