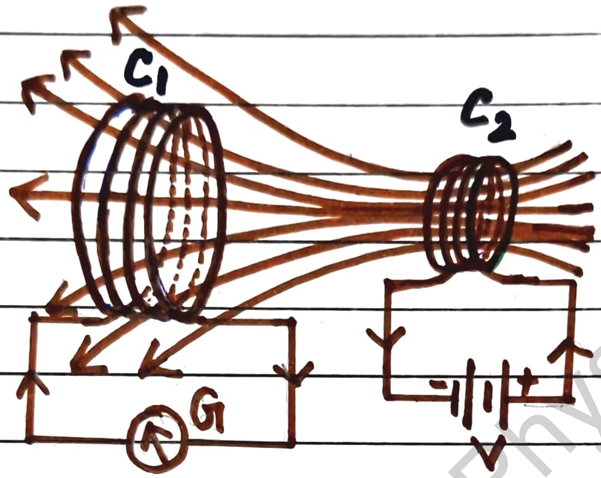
Example 6.1

Consider experiment 6.2 - - - - - of a galvanometer?

Solution:



We know

Magnitude of induced emf

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

and mag. flux

$$\phi_B = BA\cos\theta$$

where $B = \mu_0 n I$

$\mu_0 \rightarrow$ Permeability of free space

$n \rightarrow$ number of turns per unit length

$I \rightarrow$ current in coil C_2

By above relations it is clear that to obtain large deflection in galvanometer following steps can be taken-

(1) Insert the soft iron rod inside the coil C_2 to increase the permeability of the medium.

(ii) Increase the current I of coil C_2 by connecting the powerful battery.

(iii) Move the coil faster to increase the rate of changing mag. flux.

(b) In absence of galvanometer a small bulb or LED light can be connected to show the presence of an induced current.

Example 6.2

A square loop - - - - - - - - - - - this time interval.

Solution:

Given,

Side of square loop $a = 10 cm = 10 \times 10^{-2} m = 10^{-1} m$

Resistance $R = 0.5 \Omega$

Magnetic field $B_1 = 0.10 T$

$B_2 = 0$

time interval $\Delta t = 0.70$ sec

$\theta = 45^\circ$

Initially magnetic flux $\phi_1 = B_1 A \cos\theta$

$\phi_1 = 0.10 \times (10^{-1})^2 \times \cos 45^\circ$

or $\phi_1 = 0.10 \times 10^{-2} \times \frac{1}{\sqrt{2}}$

or $\phi_1 = \frac{10^{-3}}{\sqrt{2}}$

and $\phi_2 = 0$ $[\because B_2 = 0]$

We know, iduced emf

$|\varepsilon| = \frac{\Delta\phi}{\Delta t} = \frac{10^{-3}/\sqrt{2}}{0.70}$ $[\because \Delta\phi = \phi_1 - \phi_2]$

or $|\varepsilon| = \frac{10^{-3} \times 100}{\sqrt{2} \times 0.70} = \frac{10^{-1}}{1.41 \times 70}$

$= \frac{10^{-1}}{98.7} = \frac{100 \times 10^{-3}}{98.7}$

$= 1.01 \times 10^{-3} V$

$\simeq 1 mV$ Ans

Now current

$$I = \frac{\mathcal{E}}{R}$$

$$= \frac{1.0 \times 10^{-3}}{0.5}$$

$$= 2 \times 10^{-3} A$$

$$I = 2 mA$$

i.e. emf = 1 mV

current = 2 mA **Ans**

Example 6.3

A circular coil .... is 3×10^{-5} T.

Solution: Given

Radius of coil $r = 10 cm = 10 \times 10^{-2} m$

$= 10^{-1} m$

turns $n = 500$

resistance $R = 2 \Omega$

$\theta_1 = 0°$ and $\theta_2 = 180°$

magnetic field $B = 3 \times 10^{-5}$

$$\phi_1 = BA \cos\theta$$

$$= BA \cos 0° = BA$$

$$\phi_2 = BA \cos 180° \quad [\cos 180° = -1]$$

$$= -BA$$

so

$$\Delta\phi = 2BA \quad [\Delta\phi = \phi_1 - \phi_2]$$

$$= 2 \times 3 \times 10^{-5} \times \pi (10^{-1})^2 \quad [\because A = \pi r^2]$$

or $\Delta\phi = 6\pi \times 10^{-7}$ Wb

Therefore, the estimated induced emf $\mathcal{E} = N\frac{\Delta\phi}{\Delta t}$

$$= \frac{500 \times 6\pi \times 10^{-7}}{0.25}$$

$$= \frac{5 \times 6 \times 3.14 \times 10^{-5}}{0.25}$$

$$= \frac{3 \times 314 \times 10^{-4}}{25}$$

$$= 37.68 \times 10^{-4}$$

or $\mathcal{E} = 3.8 \times 10^{-3}$ V Ans

and $I = \frac{\mathcal{E}}{R}$

$$= \frac{3.8 \times 10^{-3}}{2}$$

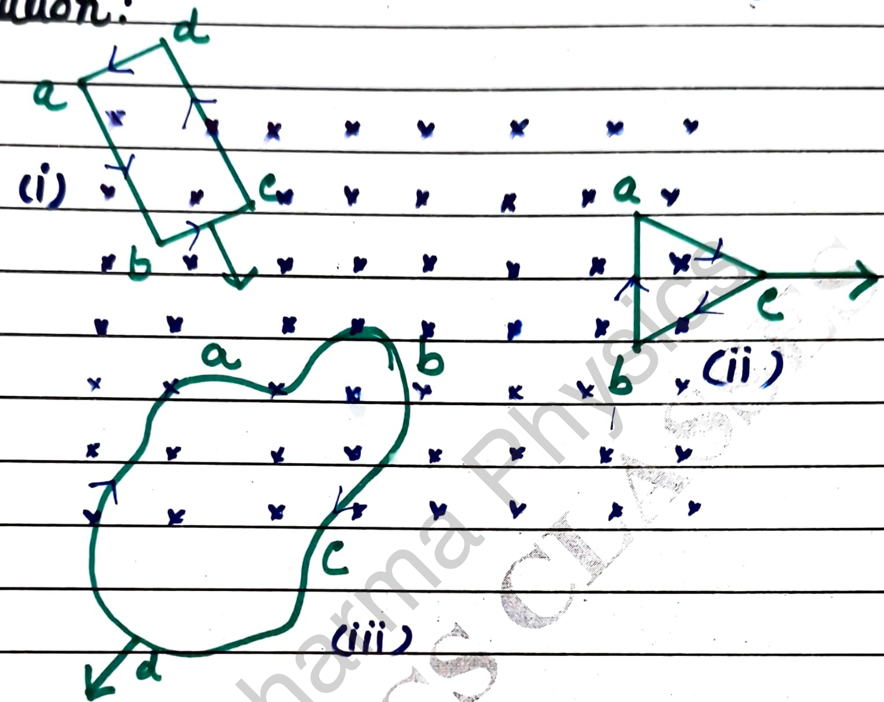
$$= 1.9 \times 10^{-3} \text{ A}$$

Ans

Example 6.4

Figure 6.7 shows - - - - - using Lenz's law.

Solution:



(i) The magnetic flux through the rectangular loop abcd increases, as the loop is moving into the magnetic field. Therefore the induced current must flow along the path bcdab to opposes the increasing flux.

(ii) Due to the outward motion, magnetic flux through the rectangular abc decreases due to which the induced current flows along bacb to oppose the change in flux.

(iii) As the magnetic flux linked with the loop abcd decreases due to the outward

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outward motion, the induced current flows along cdabc so as to oppose the change in magnetic flux.

Example 6.5

A closed loop - - - - - to the loop.

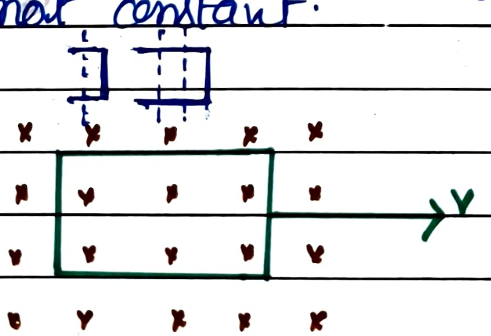
Solution:

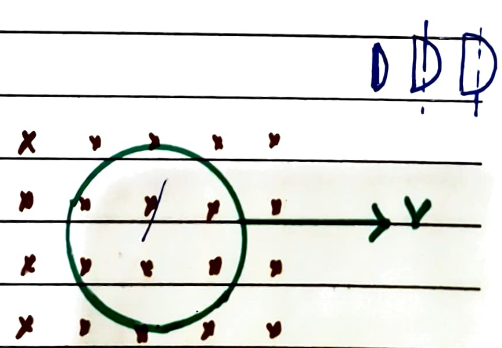
(a) No.
Constant magnetic field passing through a stationary loop will result no change in magnetic flux. Therefore no emf is generated. Hence no current can be generated.

(b) No current is induced in either case. Since the current is induced by changing magnetic flux not by changing electric flux.

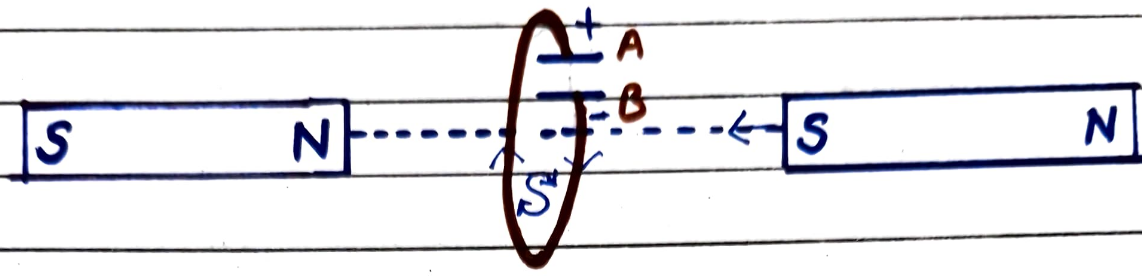
(∵ There is a constant electric field between the plates of the capacitor.)

(c) Induced emf is expected to be constant in case of rectangular loop only.
Because in case of rectangular loop equal area will move out in equal interval of time but in case of circular loop it is not constant.





(d)



If we see from the right side of the loop the direction of induced is clockwise. Therefore the polarity of the plate 'A' will be positive with respect to the plate 'B' in the capacitor.

Example 6·6

A metallic rod of 1 m - - - - - - - - metallic ring ?

Solution :

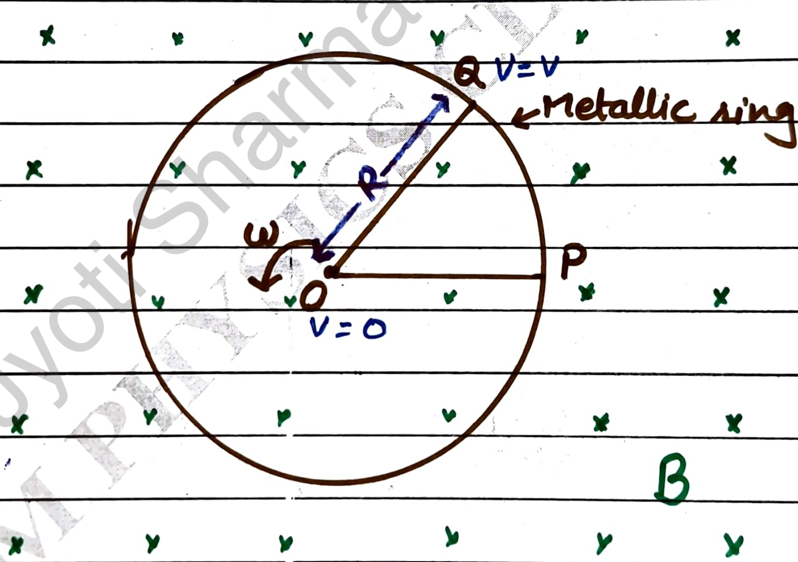
Given,

Length of the rod (= Radius) $R = 1\,m$

frequency $\nu = 50$ rev/s

Magnetic field $B = 1\,T$

One end of the rod is fixed at the centre of a metallic ring and other end is at the circumference of the ring. Shown in fig.



I Method

The average velocity of the rod.

$$v = \frac{0+v}{2} \quad [\because \text{at } O \text{ velocity is zero}]$$

$$= \frac{v}{2}$$

When rod rotates, it cuts the magnetic field and an emf is produced across its ends. Which is given by

$$e = B l V$$

here

$$e = BRV \quad [l = R]$$

$$= BR\frac{V}{2} \quad \left[\because V = \frac{v}{2}\right]$$

$$= \frac{BR(R\omega)}{2} \quad [\because v = R\omega]$$

$$= \frac{1}{2} BR^2\omega$$

$$= \frac{1}{2} \times 1 \times 1 \,(2\pi\nu) \quad [\because \omega = 2\pi\nu]$$

$$= \frac{1}{2} \times 2 \times 3.14 \times 50$$

$$e = 157 \text{ Volt}$$

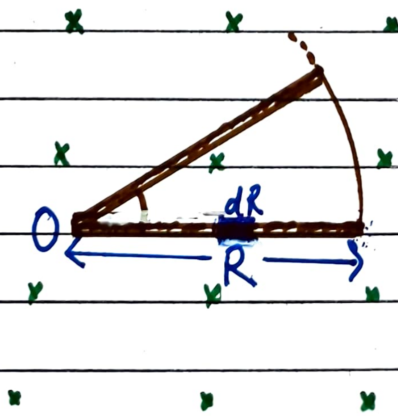
i.e emf between the centre and the ring is 157V.

II Method.

For small element dR

$$de = BvdR$$

$$e = \int de = \int_0^R BvdR$$



$$= \int_0^R B(R\omega)dR$$

$$= B\omega \int_0^R RdR$$

or $e = B\omega \frac{R^2}{2}$

$= \frac{1}{2} B \times (2\pi\nu) R^2$

$= \frac{1}{2} \times 1 \times 2 \times 3.14 \times 50 \times 1^2$

$= 157.00\ V$

Ans

Example 6.7

A wheel with ------ ---- .. $1G = 10^{-4} T$.

Solution: Given,

Number of spokes = 10

Length of each spoke $l = R = 0.5\ m$

frequency $\nu = 120$ rev/min

$= \frac{120}{60}$ rev/s

$\nu = 2$ rev/s

Magnetic field $B = 0.4\ G$

$= 0.4 \times 10^{-4}\ T$ $[\because 1G = 10^{-4} T]$

Now Induced emf

$e = \frac{1}{2} B R^2 \omega = \frac{1}{2} B R^2 (2\pi\nu)$

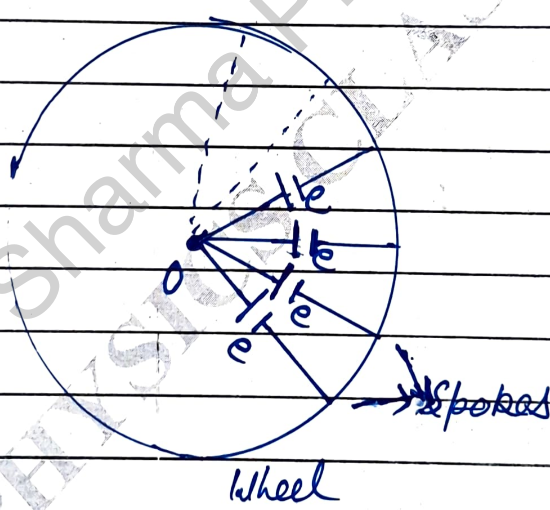
$= \frac{1}{2} \times 0.4 \times 10^{-4} \times (0.5)^2 \times 2 \times 3.14 \times 2$

or $e = 0.4 \times 10^{-4} \times 0.25 \times 3.14 \times 2$

$= 6.28 \times 10^{-5}$ V

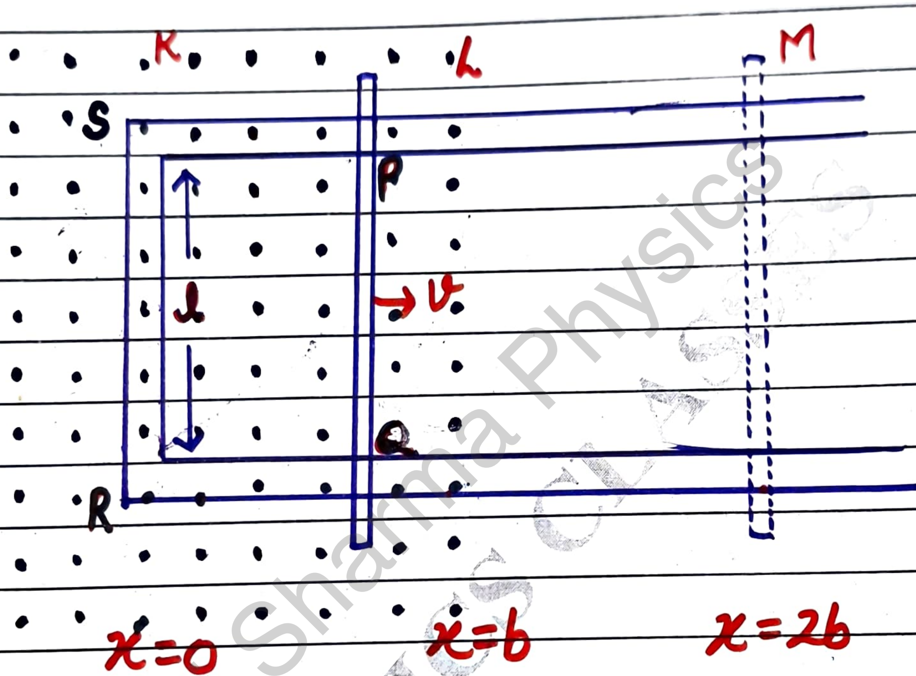
All the spokes are in parallel and emf across the parallel spokes remain same. Therefore for any numbers of spokes the emf is 6.28×10^{-5} V

Ans



Example 6.8

Refer to fig. - - - - - - - - - with distance.



Solution

For forward (outward) Motion-

	From $x=0$ to $x=b$ $(0 \leq x \leq b)$	From $x=b$ to $x=2b$ $(b \leq x \leq 2b)$
1. Flux -	$\phi = BA$ $= Blx$ [$\because A = lx$]	$\phi = BA$ $= Blb$
2. Induced emf	$\varepsilon = -\frac{d\phi}{dt}$ $= -\frac{d(Blx)}{dt} = -Bl\frac{dx}{dt}$ $\varepsilon = -Blv$ [$\because \frac{dx}{dt} = v$]	$\varepsilon = -\frac{d\phi}{dt}$ $= -\frac{d(Blb)}{dt}$ $\varepsilon = 0$ [$\because B, l$ and b are constants]

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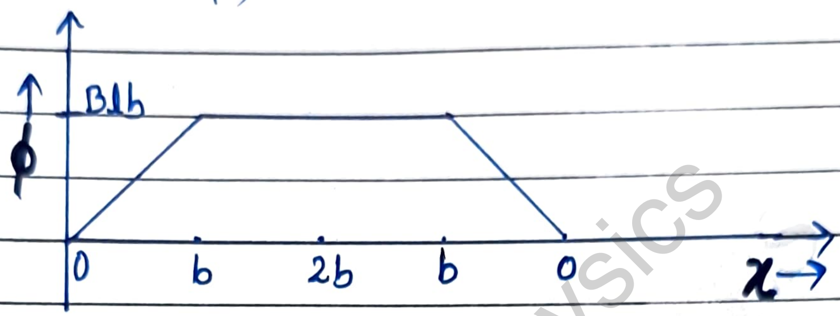
3. Force	$F = IlB$ $= \frac{\varepsilon}{R} lB$ $= -\frac{Blv}{r} lB$ $F = -\frac{B^2 l^2 v}{r}$	$F = Ilb$ here $I = 0$ as $\varepsilon = 0$ so $F = 0$
4 Power dissipated (Joule heat)	$P_J = I^2 R$ $= \left(-\frac{Blv}{r}\right)^2 \cdot r$ $P = \frac{B^2 l^2 v^2}{r}$	$P_J = 0$ $[\because I = 0]$

For Inward Motion.

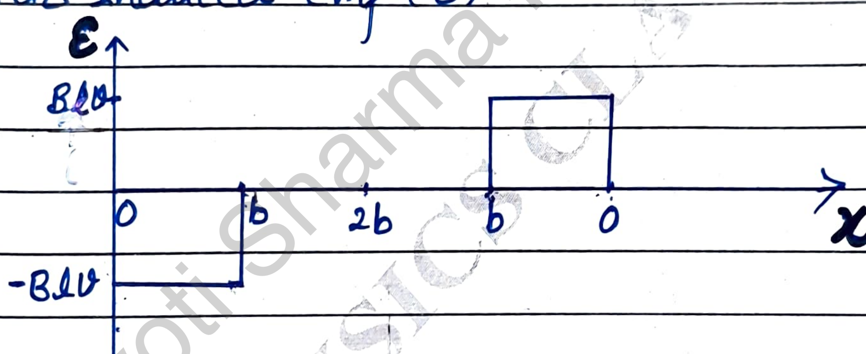
	from $x = 2b$ to b	from $x = b$ to 0
1 Flux	$\phi = Blb$	$\phi = Blx$
2 Induced emf	$\varepsilon = 0$	$\varepsilon = +Blv$
3. Force	$F = 0$	$F = +\frac{B^2 l^2 v}{r}$
4. Power dissipated	$P_J = 0$	$P = \frac{B^2 l^2 v^2}{r}$

Graph -

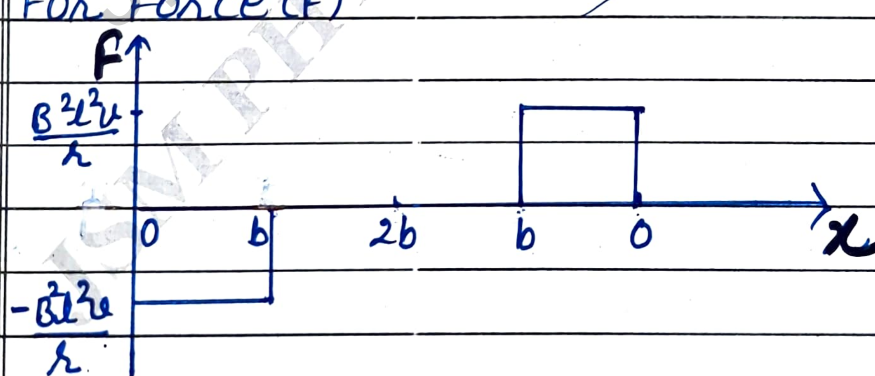
For Flux (ϕ)



For Induced emf (ε)



For force (F)



For Power Dissipated (P_J)