••11 A rectangular coil of N turns and of length a and width b is rotated at frequency f in a uniform magnetic field $\vec{B}$, as indicated in Fig. 30-38. The coil is connected to co-rotating cylinders, against which metal brushes slide to make contact. (a) Show that the emf induced in the coil is given (as a function of time t) by

$$\mathscr{E} = 2\pi f N a b B \sin(2\pi f t) = \mathscr{E}_0 \sin(2\pi f t).$$

This is the principle of the commercial alternating-current generator. (b) What value of Nab gives an emf with $\mathscr{E}_0 = 150$ V when the loop is rotated at 60.0 rev/s in a uniform magnetic field of 0.500 T?

$$60 \frac{\text{rev}}{\text{sec}} = 60 \frac{2\pi \text{ rad}}{\text{sec}}$$
$$= 120\pi \text{ rad/sec}$$

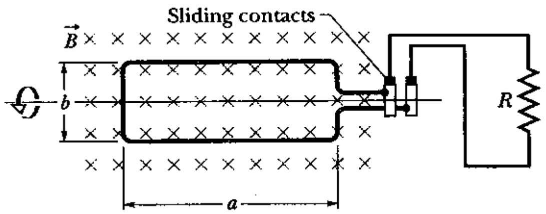
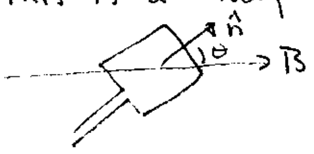


Fig. 30-38 Problem 11.

This is a loop of wire twirled in a magnetic field



$$\phi_B = \int \vec{B} \cdot d\vec{A} = B A \cos\theta$$

remember that there are actually N loops and $\theta \to \omega t$

$$\phi_B = N B A \cos \omega t$$

The Induced Emf is $(-)\frac{d\phi_B}{dt}$

$$\text{Induced Emf} = -\frac{d\phi_B}{dt} = (-)(-) N B A \omega \sin \omega t$$

Using $A = ab$ and $\omega = 2\pi f$, we produce the desired equation

$$\text{Induced Emf} = \underbrace{2\pi f N ab B}_{\mathcal{E}_0} \sin(2\pi f t)$$

$$\mathcal{E}_0 = \omega N ab B$$
$$150 = (120\pi) N ab (0.5)$$
$$Nab = 0.80 \text{ m}^2$$

•29 In Fig. 30-50, a metal rod is forced to move with constant velocity $\vec{v}$ along two parallel metal rails, connected with a strip of metal at one end. A magnetic field of magnitude $B = 0.350$ T points out of the page. (a) If the rails are separated by $L = 25.0$ cm and the speed of the rod is 55.0 cm/s, what emf is generated? (b) If the rod has a resistance of 18.0 Ω and the rails and connector have negligible resistance, what is the current in the rod? (c) At what rate is energy being transferred to thermal energy?

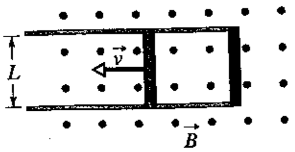


Fig. 30-50 Problems 29 and 35.

a) The B-field is parallel to the surface normal

$$\phi_B = \int \bar{B} \cdot d\bar{A} = BA$$
$$= BLx$$

The induced Emf is

$$\text{Induced Emf} = -\frac{d\phi_B}{dt} = -\frac{d}{dt}(BLx)$$
$$= -BL\frac{dx}{dt}$$
$$= -BLV$$

plug in numbers. Forget about the (-) for now

$$\text{Induced Emf} = BLv = (0.350)(0.25)(0.55\,m/s)$$
$$= 0.0481 \text{ Volts}$$

b) This is a simple circuit with a resistor

$$\text{Ind Emf} = IR$$
$$I = \frac{0.0481}{18} = 0.00267 \text{ Amp} = 2.67 \text{ mA}$$

c) Power lost in resistor

$$\text{Power} = IV = I^2R = (0.00267)^2\, 18$$
$$= 0.000128 \text{ Watts} = 0.128 \text{ milliWatts}$$

•3 SSM WWW In Fig. 30-32, a 120-turn coil of radius 1.8 cm and resistance 5.3 Ω is coaxial with a solenoid of 220 turns/cm and diameter 3.2 cm. The solenoid current drops from 1.5 A to zero in time interval $\Delta t = 25$ ms. What current is induced in the coil during Δt?

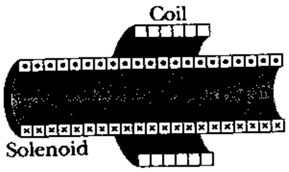


Fig. 30-32 Problem 3.

$220 \frac{\text{turns}}{\text{cm}} = 22000 \frac{\text{turns}}{\text{m}}$

diameter 3.2 cm → radius 1.6 cm

The central solenoid generates a B-field

$$B = \mu_0 \frac{N_{sol}}{L} I$$

The B-field threads the outer coil. $\vec{B} \parallel \hat{n}$

$$\phi_B = \int \bar{B} \cdot d\bar{A} = N_{coil} B A = N_{coil} B \pi r^2$$

← be careful. This should only be $r = 1.6$ cm.

$$\phi_B = N_{coil} \mu_0 \frac{N_{solenoid}}{L} I \pi r^2$$

The induced Emf is caused by the changing current

$$\text{Ind Emf} = -\frac{d\phi_B}{dt} = -N_{coil} \mu_0 \left(\frac{N_{solenoid}}{L}\right)\left(\frac{dI}{dt}\right) \pi r^2$$

$$= -120 \left(4\pi \times 10^{-7}\right) \left[22000 \frac{\text{turns}}{\text{m}}\right] \left[\frac{-1.5}{0.025}\right] \pi (0.016)^2$$

$$= 0.160 \text{ Volts}$$

This is a simple resistor circuit

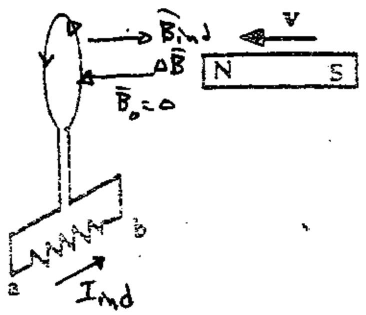
$$\text{Emf} = IR$$

$$I = \frac{0.160}{5.3} = 0.030 \text{ Amp}$$

Polarity of Induced Voltage—1

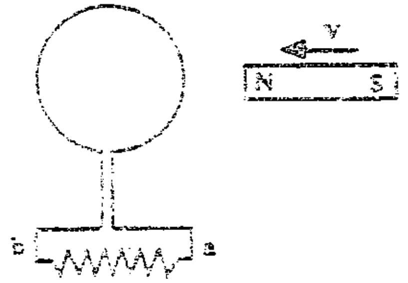
For each situation described below, indicate whether a voltage is induced across the resistor. If so, indicate the side of the resistor at the higher voltage and the direction of the induced current.

A magnet in the plane of the paper moves toward the fixed loop that is perpendicular to the paper.



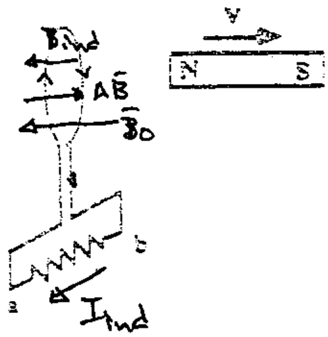
A magnet in the plane of the paper moves toward a fixed loop that is also in the plane of the paper.

No $\vec{B}$ field lines thread the loop & this doesn't change

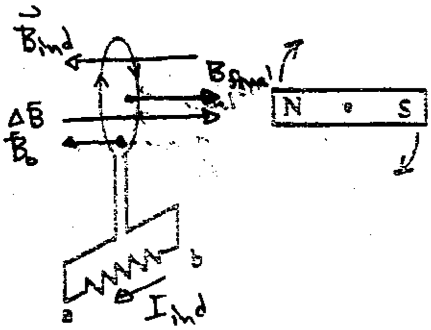


$I_{ind} = 0$

A magnet in the plane of the paper moves away from a fixed loop that is perpendicular to the plane of the paper.



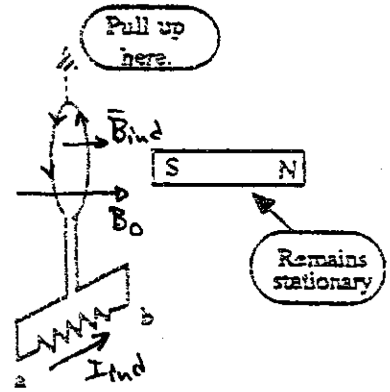
(d) A magnet in the plane of the paper is rotated about its center so that the North pole and South pole exchange positions relative to a fixed loop that is perpendicular to the plane of the paper.



(e) A magnet in the plane of the paper is held fixed as a loop perpendicular to the plane and originally open is stretched vertically so its opposite sides come together.

$\phi_m = \int \vec{B} \cdot d\vec{A}$

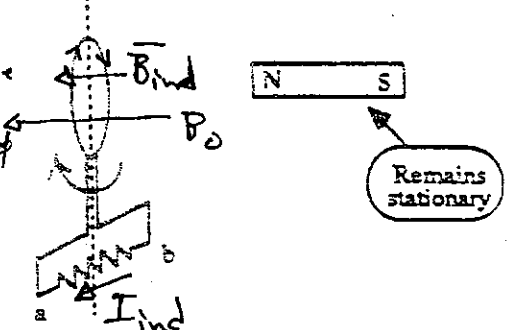
the area goes to zero so we Need more B to keep the value of ϕ_{mag} up



(f) A magnet in the plane of the paper is held fixed as a loop originally perpendicular to the plane of the paper, is rotated clockwise into the plane of the paper.

$\phi = \int \vec{B} \cdot d\vec{A}$

the angle changes making ϕ smaller. ∴ Need more B to compensate



A FIPSE Project