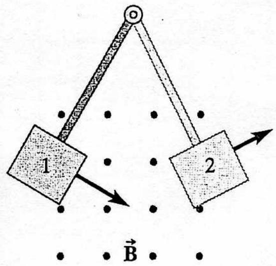
CQ 20.5, 20, PR 20.11, 21a, 23, 27, 33, 70, 79, 88, 22.12, 19, 24

5. A metal plate is attached to the end of a rod and positioned so that it can swing into and out of a perpendicular magnetic field pointing out of the plane of the paper as shown. In position 1, the plate is just swinging into the field; in position 2, the plate is swinging out of the field. Does an induced eddy current circulate clockwise or counterclockwise in the metal plate when it is in (a) position 1 and (b) position 2? (c) Will the induced eddy currents act as a braking force to stop the pendulum motion? Explain.



a) POSITION 1
- OUTWARD $\vec{B}$ INCREASING
⇒ I CREATES INWARD $\vec{B}$
⇒ CLOCKWISE I
⇒ SAME MAGNETIC POLE
⇒ PLATE REPELLED
⇒ FORCE AGAINST MOTION

b) POSITION 2
- OUTWARD $\vec{B}$ DECREASING
⇒ I CREATES OUTWARD $\vec{B}$
⇒ COUNTERCLOCKWISE CURRENT
⇒ OPPOSITE MAGNETIC POLE
⇒ PLATE ATTRACTED SO IT'S PULLED BACK TOWARD VERTICAL!

⇒ c) INDUCED I'S & B'S ACT AS A BRAKE!

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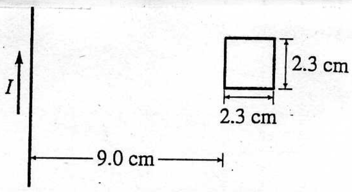
20. High-voltage power lines run along the edge of a farmer's field. Describe how the farmer might be able to steal electric power without making any electrical connection to the power line. (Yes, it works. Yes, it has been done. Yes, it is illegal.)

SINCE US POWER IS AC, THE MAGNETIC FIELD IS CONSTANTLY CHANGING IN BOTH MAGNITUDE AND DIRECTION.

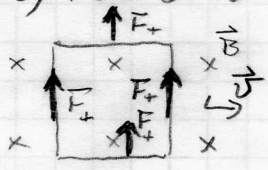
⇒ A LOOP OF WIRE UNDER THE WIRES WOULD EXPERIENCE A CHANGING MAGNETIC FLUX AND A CURRENT WOULD BE INDUCED, EFFECTIVELY STEALING ELECTRICITY!

✦11. A square loop of wire of side 2.3 cm and electrical resistance 79 Ω is near a long straight wire that carries a current of 6.8 A in the direction indicated. The long wire and loop both lie in the plane of the page. The left side of the loop is 9.0 cm from the wire. (a) If the loop is at rest, what is the induced emf in the loop? What are the magnitude and direction of the induced current in the loop? What are the magnitude and direction of the magnetic force on the loop? (b) Repeat if the loop is moving to the right at a constant speed of 45 cm/s. (c) In (b), find the electric power dissipated in the loop and show that it is equal to the rate at which an external force, pulling the loop to keep its speed constant, does work.



a) FOR NO MOTION $\mathcal{E} = 0$
- FLUX IS NOT CHANGING

b) FOR $\vec{v}$ TO THE RIGHT



FORCES ON + CHARGES IS UP

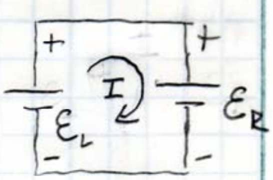
⇒ NO I IN TOP & BOTTOM (INDUCE emf ACROSS WIRE)

⇒ I IN LEFT AND RIGHT

20.11 CONTINUED

b) emf's ON LEFT AND RIGHT IN SAME DIRECTION BUT UNEQUAL BECAUSE $\vec{B}$ IS STRONGER CLOSER TO THE WIRE

$$B = \frac{\mu_0 I}{2\pi r} \Rightarrow B_L = \frac{\mu_0 I}{2\pi r_L} \quad \text{AND} \quad B_R = \frac{\mu_0 I}{2\pi r_R}$$



THE INDUCED emf's ARE

$$\mathcal{E}_L = vLB_L \;\&\; \mathcal{E}_R = vLB_R \rightarrow \mathcal{E}_{TOTAL} = \mathcal{E}_L - \mathcal{E}_R$$

$$\mathcal{E}_{TOT} = vL(B_L - B_R) = \frac{vL\mu_0 I}{2\pi}\left(\frac{1}{r_L} - \frac{1}{r_R}\right)$$

$$\mathcal{E}_{TOT} = \frac{(0.45)(0.023)(4\pi \times 10^{-7})(6.8)}{2\pi}\left(\frac{1}{0.09} - \frac{1}{0.113}\right)$$

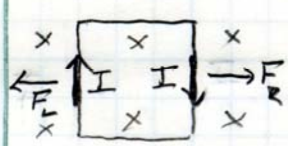
$$\mathcal{E}_{TOT} = (1.41 \times 10^{-8})(7.26) = 3.18 \times 10^{-8}\,V = \boxed{31.8\,nV = \mathcal{E}_{TOT}}$$

FIND CURRENT FROM OHM'S LAW $V = IR$

$$I = \frac{\mathcal{E}_{TOT}}{R} = \frac{3.18 \times 10^{-8}}{79} = 4.03 \times 10^{-10}\,A = \boxed{40.3\,pA = I}$$

- I IS CLOCKWISE SINCE $\mathcal{E}_L > \mathcal{E}_R$

MAGNETIC FORCE ON LEFT & RIGHT OPPOSITE & UNEQUAL



$$F_L = ILB_L = IL\left(\frac{\mu_0 I_{WIRE}}{2\pi r_L}\right), \quad F_R = IL\left(\frac{\mu_0 I_{WIRE}}{2\pi r_R}\right)$$

$$F_{TOTAL} = F_L - F_R = \frac{IL\mu_0 I_{WIRE}}{2\pi}\left(\frac{1}{r_L} - \frac{1}{r_R}\right)$$

$$F_{TOTAL} = (4.03 \times 10^{-10})(0.023)(2 \times 10^{-7})(6.8)\left(\frac{1}{0.09} - \frac{1}{0.113}\right)$$

$$\boxed{\vec{F}_{TOTAL} = 2.85 \times 10^{-17}\,N \text{ TO THE LEFT (TOWARD THE WIRE)}}$$

c) DISSIPATED POWER: $P = I^2 R = (4.03 \times 10^{-10})^2(79)$

$$\boxed{P = 1.28 \times 10^{-17}\,W}$$

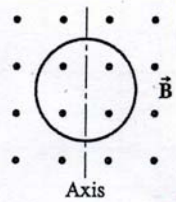
RATE OF WORK: $P_W = \frac{W}{\Delta t} = \frac{F\Delta x}{\Delta t} = Fv$

$$P_W = (2.85 \times 10^{-17})(0.45)$$

$$\boxed{P_W = 1.28 \times 10^{-17}\,W}$$

EQUAL

21. A circular conducting coil with radius 3.40 cm is placed in a uniform magnetic field of 0.880 T with the plane of the coil perpendicular to the magnetic field. The coil is rotated 180° about the axis in 0.222 s. (a) What is the average induced emf in the coil during this rotation? (b) If the coil is made of copper with a diameter of 0.900 mm, what is the average current that flows through the coil during the rotation?



a) FLUX FLIPS DIRECTION

$$\mathcal{E} = -\frac{\Delta\Phi}{\Delta t} = -\frac{BA-(-BA)}{\Delta t}$$

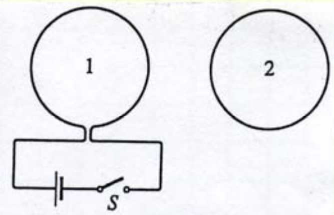
$$\mathcal{E} = \frac{2BA}{\Delta t} = \frac{2(0.880)(0.034)^2\pi}{0.222}$$

$$\mathcal{E} = 0.0288\,V = 28.8\,mV$$

Problem 23 is on the next page

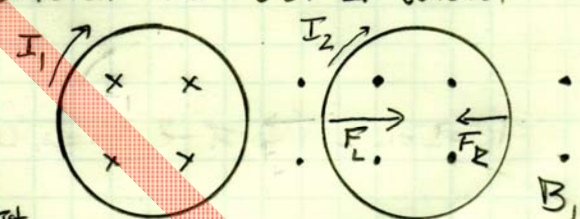
Not Assigned

27. Two loops of wire are next to one another in the same plane. (a) If the switch S is closed, does current flow in loop 2? If so, in what direction? (b) Does the current in loop 2 flow for only a brief moment, or does it continue? (c) Is there a magnetic force on loop 2? If so, in what direction? (d) Is there a magnetic force on loop 1? If so, in what direction?



a) WHEN SWITCH IS CLOSED
⇒ I BEGINS TO FLOW CLOCKWISE IN LOOP 1
⇒ $\vec{B}$ BUILDS UP
- INWARD INSIDE LOOP 1
- OUTWARD OUTSIDE LOOP 1
⇒ LOOP 2 SEES INCREASING $\vec{B}$ OUTWARD (INSIDE LOOP)
⇒ I IN LOOP 2 CREATES $\vec{B}$ INWARD
⇒ I FLOWS CLOCKWISE IN LOOP 2 WHILE $\vec{B}_1$ INCREASES

b) I FLOWS FOR A BRIEF MOMENT IN LOOP 2 (ONLY WHILE B_1 IS CHANGING



c) AS IN PROBLEM 11 THE FORCES ON THE L & R SIDES ARE OPPOSITE & UNEQUAL WITH $F_{LEFT} > F_{RIGHT}$ BECAUSE ITS IN A STRONGER FIELD

⇒ F_{TOTAL} IS TO THE RIGHT (AWAY FROM LOOP 1)

d) FORCES ARE EQUAL & OPPOSITE! SO LOOP 2'S CURRENT CREATES B_2 THAT EXERTS A FORCE ON LOOP 1 BUT IT IS DIRECTED TO THE LEFT!

33. A doorbell uses a transformer to deliver an amplitude of 8.5 V when it is connected to a 170-V amplitude line. If there are 50 turns on the secondary, (a) what is the turns ratio? (b) How many turns does the primary have?

a) $$\frac{N_2}{N_1} = \frac{\mathcal{E}_2}{\mathcal{E}_1} = \frac{8.5}{170} = 0.05$$

b) $$N_1 = \frac{N_2}{\mathcal{E}_2/\mathcal{E}_1} = \frac{50}{0.05}$$

$$N_1 = 1000 \text{ TURNS}$$

Chapter 20

23. The component of the extend magnetic field along the central axis of a 50 turn coil of radius 5.0 cm increases from 0 to 0.18T in 3.6 s.

a) if R = 2.8 Ω, what is the magnitude of the induced current in the coil?

b) What is the direction of the current if the axial component of the field points away from the viewer?

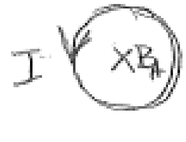
a) $Emf = -N\frac{\Delta \Phi_B}{\Delta t}$

$= -N\left(\frac{\Phi_f - \Phi_I}{\Delta t}\right)$

$= 50\frac{(0.18T-0)}{3.6s} = 2.5V$

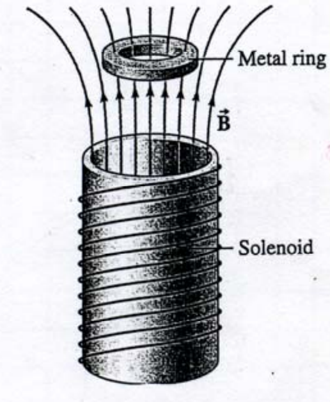
$I = V/R = 2.5V/2.8\Omega = 0.893A = I$

b)



Φ is increasing so B induced points opposite B applied. ∴ ⊙B induced is out of the page. Thumb along B, fingers curl along I in a counter clockwise direction

70. A circular metal ring is suspended above a solenoid. The magnetic field due to the solenoid is shown. The current in the solenoid is increasing. (a) What is the direction of the current in the ring? (b) The flux through the ring is proportional to the current in the solenoid. When the current in the solenoid is 12.0 A, the magnetic flux through the ring is 0.40 Wb. When the current increases at a rate of 240 A/s, what is the induced emf in the ring? (c) Is there a net magnetic force on the ring? If so, in what direction? (d) If the ring is cooled by immersing it in liquid nitrogen, what happens to its electrical resistance, the induced current, and the magnetic force? The change in size of the ring is negligible. (With a sufficiently strong magnetic field, the ring can be made to shoot up high into the air.)



a) FOR $\vec{B}$ SHOWN INCREASING, I IN THE RING WILL CREATE $\vec{B}$ DOWNWARD

$\Rightarrow$ I IS CLOCKWISE

b) THE FLUX THROUGH THE RING DUE TO THE COIL IS

$$\Phi = AB = A(\mu_0 N I)$$

$$\Rightarrow \mu_0 N A = \frac{\Phi}{I} = \frac{0.4}{12} = \frac{1}{30}$$

THE INDUCED $\mathcal{E}$ IS DUE TO CHANGING FLUX

$$|\mathcal{E}| = \frac{\Delta\Phi}{\Delta t} = \frac{\Delta(\mu_0 N A I)}{\Delta t}$$

$$|\mathcal{E}| = \mu_0 N A \frac{\Delta I}{\Delta t}$$

$$\Rightarrow |\mathcal{E}| = \left(\frac{1}{30}\right)(240) = \boxed{8.0\,V = \mathcal{E}}$$

c) SINCE THE RING CREATES A NORTH POLE BENEATH ITSELF THAT REPELS THE NORTH POLE OF THE COIL,

FORCE ON THE RING IS UPWARD

d) COOLING THE RING WILL REDUCE R & INCREASE I & F

$\Rightarrow$ IT'LL JUMP HIGHER!

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79. A TV tube requires a 20.0-kV-amplitude power supply. (a) What is the turns ratio of the transformer that raises the 170-V-amplitude household voltage to 20.0 kV? (b) If the tube draws 82 W of power, find the currents in the primary and secondary windings. Assume an ideal transformer.

a)
$$\frac{N_2}{N_1} = \frac{\mathcal{E}_2}{\mathcal{E}_1} = \frac{20\times10^3}{170}$$

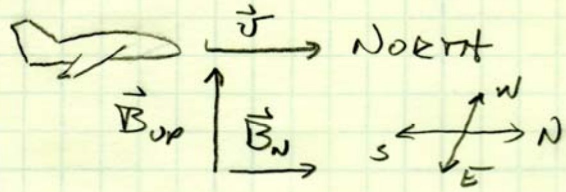
$$\boxed{\frac{N_2}{N_1} = 118}$$

b) $P = \mathcal{E}_1 I_1 = \mathcal{E}_2 I_2$

$$I_1 = \frac{P}{\mathcal{E}_1} = \frac{82}{170} = \boxed{0.482\,A = I_1}$$

$$I_2 = \frac{P}{\mathcal{E}_2} = \frac{82}{20\times10^3} = 0.0041\,A = \boxed{4.1\,mA = I_2}$$

88. An airplane is flying due north at 180 m/s. Earth's magnetic field has a northward component of 0.30 mT and an upward component of 0.38 mT. (a) If the wingspan (distance between the wingtips) is 46 m, what is the motional emf between the wingtips? (b) Which wingtip is positively charged?



a) $\mathcal{E}$ IS DUE TO B ⊥ TO $\vec{v} = \vec{B}_{UP}$: $\mathcal{E} = vLB_{UP}$

$$\mathcal{E} = (180)(46)(0.38\times10^{-3}) = \boxed{3.15\ V = \mathcal{E}}$$

b) THE FORCE ON A + CHARGE IS OUTWARD IN THE DIAGRAM

⇒ EAST WING HAS A + CHARGE

CH 22

12. What is the wavelength of the radio waves broadcast by an FM radio station with a frequency of 90.9 MHz?

$c = f\lambda \Rightarrow \lambda = \frac{c}{f}$

SO $\lambda_{FM} = \frac{3\times10^8}{90.9\times10^6} = \boxed{3.30\,m = \lambda_{FM}}$

19. Light of wavelength 692 nm in air passes into window glass with an index of refraction of 1.52. (a) What is the wavelength of the light inside the glass? (b) What is the frequency of the light inside the glass?

a) $\lambda_{GLASS} = \frac{\lambda_0}{n_{GLASS}}$

$\lambda_{GLASS} = \frac{692}{1.52} = \boxed{455\,nm = \lambda_G}$

b) THE FREQUENCY IS THE SAME IN & OUT OF GLASS

$$f = \frac{c}{\lambda} = \frac{3\times10^8}{692\times10^{-9}} = 4.34\times10^{14}\ Hz$$

24. You and a friend are sitting in the outfield bleachers of a major league baseball park, 140 m from home plate on a day when the temperature is 20°C. Your friend is listening to the radio commentary with headphones while watching. The broadcast network has a microphone located 17 m from home plate to pick up the sound as the bat hits the ball. This sound is transferred as an EM wave a distance of 75,000 km by satellite from the ball park to the radio. (a) When the batter hits a hard line drive, who will hear the "crack" of the bat first, you or your friend, and what is the shortest time interval between the bat hitting the ball and one of you hearing the sound? (b) How much later does the other person hear the sound?

a) FIND TRAVEL TIME FOR SOUND

$t_{SOUND} = \frac{x_{SOUND}}{v_{SOUND}} = \frac{140}{343}$ ← p424

$t_{SOUND} = 0.408\,s$

FIND TRAVEL TIME TO RADIO

$t_{RADIO} = \frac{x_{MIC}}{v_{SOUND}} + \frac{x_{EM}}{c}$

$= \frac{17}{343} + \frac{75\times10^6}{3\times10^8}$

$t_{RADIO} = 0.300\,s$

22.24 CONTINUED

SINCE $t_{SOUND} > t_{RADIO}$ ⇒ RADIO LISTENER HEARS SOUND FIRST!

SHORTEST TIME IS $\boxed{t_{RADIO} = 0.300\,S \text{ AFTER HIT}}$

b) "LIVE" SOUND ARRIVES 0.408 S AFTER THE HIT

$$\Rightarrow \Delta t = t_{SOUND} - t_{RADIO}$$

$$\boxed{\Delta t = 0.408 - 0.300 = 0.108\,S \text{ AFTER RADIO}}$$