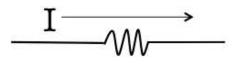
General Phys. II Exam 2 - Chs. 21,22,23 - Circuits, Magnetism, EM Induction - Mar. 8, 2021

Rec. Time Name

For full credit, make your work clear. Show formulas used, essential steps, and results with correct units and significant figures. Points shown in parenthesis. For TF and MC, choose the *best* answer or answers.

OpenStax Ch. 21 - Electric Circuits

1. (4) The sketch shows one resistor carrying a current in a Galaxy cell phone. Which point is at the highest electric potential?



a. The left end of the resistor.
b. The right end of the resistor.
c. The middle of the resistor.
d. No point is highest because all points in the resistor have the same potential.

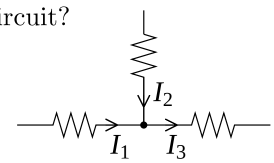
2. (4) When Jayden connects a 5 Ω and a 20 Ω resistor in series to an 18-volt lantern battery, which of these statements are true? Check all that apply.

a. Both resistors have the same current.
b. The 5 Ω has the larger current.
c. Both resistors produce heat at the same rate.
d. The 20 Ω produces heat faster.

3. (4) When Maria Elena connects a 25 Ω and a 200 Ω resistor in parallel to an 18-volt utility battery, which of these statements are true? Check all that apply.

a. Both resistors have the same current.
b The 25 Ω has the larger current.
c. Both resistors have the same voltage drop.
d. The 200 Ω has the larger voltage drop.

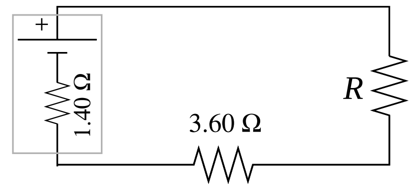
4. (4) Which equation applies to the currents at this node in the Galaxy cell phone circuit?



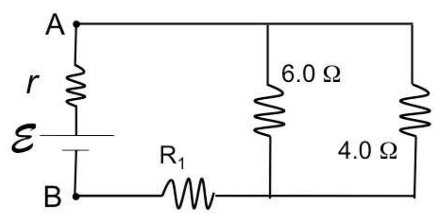
a. $I_1 + I_2 = I_3$
b. $I_1 = I_2 + I_3$
c. $I_2 = I_1 + I_3$
d. $I_1 + I_2 + I_3 = 0$
e. $I_1 = I_2 = I_3$

5. (6) The lightbulb in Jingyu's flashlight uses 3.29 watts of electrical power when connected to two ideal 1.50-volt batteries in series. How large is the resistance of the lightbulb, in ohms?

6. (8) In this circuit, the battery has emf = 72.0 volts and internal resistance of 1.40 Ω. The 3.60 Ω resistance represents the cables going out to power the ΦΓΗ island party house, and R=13.6 Ω represents all the lights and the stereo there. Calculate the total power used by the island party house, in watts.



7. (10) This is the problem for which you need to show and upload your work. Qualcomm engineers are trying to design a voltage and current dividing circuit, like that in the diagram. The battery emf and internal resistance are unknown. When the adjustable resistor is $R_1 = 15.0\ \Omega$, the current through it is $I_1 = 521$ mA. What do they measure for the battery's terminal voltage V_{AB}, in volts?



OpenStax Ch. 22 - Magnetism **Name**____

1. (4) A bar magnet is placed as shown. The direction of the magnetic field it produces at point P is closest to

a. ↑ b. ↓ c. ← d. → e. ⊗ f. ⊙

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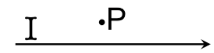
2. (4) A long straight wire carries a current as shown. The direction of the magnetic field it produces at point P is closest to



a. ↑ b. ↓ c. ← d. → e. ⊗ f. ⊙

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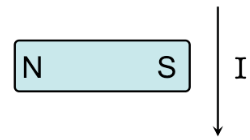
3. (4) Harold has placed a bar magnet near a current-carrying wire as shown. The direction of the magnetic force produced on the wire is closest to



a. ↑ b. ↓ c. ← d. → e. ⊗ f. ⊙

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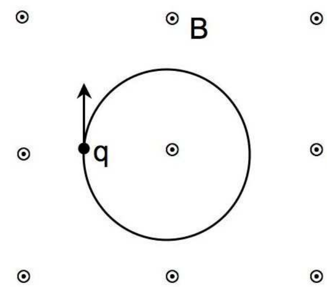
4. (5) In Prof. Thomson's physics lab the students have launched a charged particle into a uniform magnetic field, and it moves in a clockwise circle, see sketch. What can they conclude about the charge of the particle?



a. It has a positive charge.
b. It has zero charge.
c. It has a negative charge.
d. Nothing. They can't determine the charge from this experiment.

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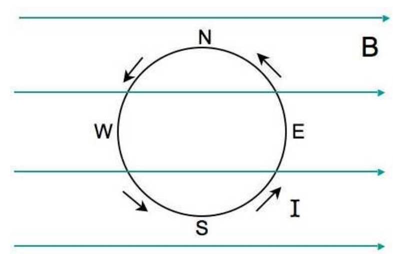
5. (5) In yet another experiment, Prof. Thomson's physics students have set up a horizontal coil with a counterclockwise current in a uniform magnetic field pointing due east. Which edge would move out of the page as the torque rotates the coil?



a. N (north) b. S (south) c. E (east) d. W (west)
e. No edge. The torque is zero.

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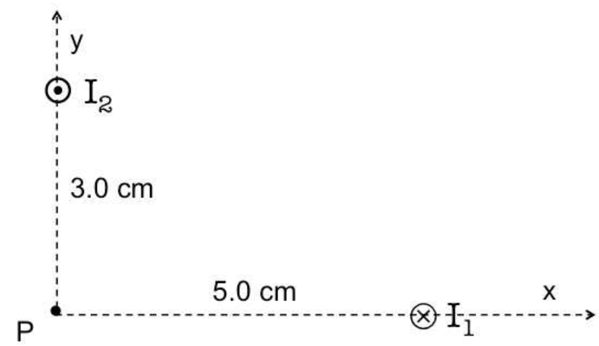
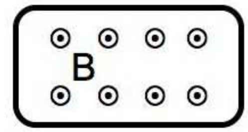
6. (8) Deltron Electronics is experimenting with using Mg^{2+} ions (mass=4.04×10^{-26} kg) revolving in a uniform magnetic field as a way to make an oscillator. In their apparatus the Mg^{2+} ions perform cyclotron motion at a frequency of 1,556 kHz and a radius of 3.65 mm. What is the strength of the magnetic field they are using, in tesla?

7. (10) This is the problem for which you need to show and upload your work. Two long straight wires have currents I_1=48.3 A and I_2=48.6 A as shown in an xy plane. At point P, what angle does the magnetic field make with respect to the positive x-axis, in degrees? Hint, find the contributions from each wire first, then do vector addition.



OpenStax Ch. 23 - Electromagnetic Induction **Name**____________________________________

1. (6) Sherry does an experiment where a magnetic field points through a wire loop as shown. Which actions will induce a counterclockwise current in the wire loop? Check all that apply.



a. Decrease the strength of the magnetic field.
b. Increase the strength of the magnetic field.
c. Suddenly rotate the loop through 30 degrees around a vertical axis.
d. Pull the loop out of the region with magnetic field.

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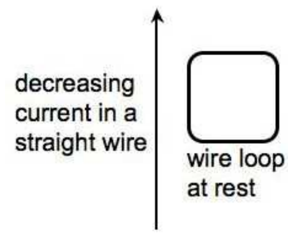
2. (4) At Amanda Arnold school the kids are playing with a wire loop next to a decreasing current in a straight wire as in the sketch. The induced current in the loop is



a. zero. b. clockwise. c. counterclockwise.
d. impossible to determine from the given information.

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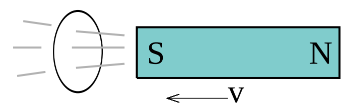
3. (4) A bar magnet is approaching a small loop of wire. Viewed from the right, the induced current in the loop is



a. zero. b. clockwise. c. counterclockwise.
d. impossible to determine from the given information.

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4. (4) When the rotational speed of an AC generator is tripled, the rms voltage produced by it is

a. increased by a factor of 3. b. decreased by a factor of 1/3.
c. increased by a factor of 9. d. decreased by a factor of 1/9.

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5. (4) In the physics and engineering lab a certain inductor has an inductive reactance of 44 Ω at a frequency of 60.0 Hz. Now the students change the circuit frequency to 120.0 Hz. The new inductive reactance is

a. 22 Ω b. 66 Ω c. 88 Ω d. 176 Ω e. 2640 Ω

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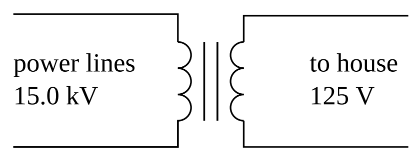
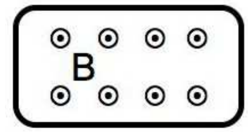
6. (8) The 60.0 Hz AC power coming into Sydney's house is transmitted at 15.0 kV (rms) in the neighborhood. It goes through an ideal transformer to step it down to 125 volts (rms) at Sydney's house. If the rms current through the secondary side is 94.4 A, how large is the rms current through the primary side, in amperes?



7. (10) This is the problem for which you need to show and upload your work. While working on a new power supply, Naya has to check the electromagnetic induction taking place in some metal parts. One part is a 20.4 cm $\times$ 8.1 cm conducting loop, in a 343 mT (millitesla) magnetic field that drops to zero in 98.7 ms (milliseconds). What emf in millivolts is induced in that part?



Prefixes

a=10^{-18}, f=10^{-15}, p=10^{-12}, n=10^{-9}, $\mu = 10^{-6}$, m=10^{-3}, c=10^{-2}, k=10^{3}, M=10^{6}, G=10^{9}, T=10^{12}, P=10^{15}

Physical Constants

$k = 1/4\pi\epsilon_0 = 8.988$ GNm^2/C^2 (Coulomb's Law)	$\epsilon_0 = 1/4\pi k = 8.854$ pF/m (permittivity of space)
$e = 1.602 \times 10^{-19}$ C (proton charge)	$\mu_0 = 4\pi \times 10^{-7}$ T·m/A (permeability of space)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass)	$m_p = 1.67 \times 10^{-27}$ kg (proton mass)

Units

$N_A = 6.02 \times 10^{23}$/mole (Avogadro's #)	1 u = 1 g/N_A = 1.6605×10^{-27} kg (mass unit)
1.0 eV = 1.602×10^{-19} J (electron-volt)	1 V = 1 J/C = 1 volt = 1 joule/coulomb
1 F = 1 C/V = 1 farad = 1 C^2/J	1 H = 1 V·s/A = 1 henry = 1 J/A^2
1 A = 1 C/s = 1 ampere = 1 coulomb/second	1 Ω = 1 V/A = 1 ohm = 1 J·s/C^2
1 T = 1 N/A·m = 1 tesla = 1 newton/ampere·meter	1 G = 10^{-4} T = 1 gauss = 10^{-4} tesla

OpenStax Chapter 18 Equations

Charges:

$Q = \pm Ne, \quad \Delta Q_1 + \Delta Q_2 = 0, \quad e = 1.602 \times 10^{-19}$ C.

Electric Force:

$F = k\frac{Q_1 Q_2}{r^2}, \quad k = 8.988 \times 10^9$ N·m^2/C^2, $\qquad F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}, \quad \epsilon_0 = \frac{1}{4\pi k} = 8.854$ pF/m.

$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots$ superposition of forces.

Electric Field:

$\vec{E} = \frac{\vec{F}}{q}, \quad q=$ test charge. Or: $\vec{F} = q\vec{E}$.

$|\vec{E}| = E = k\frac{Q}{r^2} = \frac{Q}{4\pi\epsilon_0 r^2}$, due to point charge. Negative Q makes inward $\vec{E}$, positive Q makes outward $\vec{E}$.

$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots$ superposition of many electric fields.

$E = k\frac{Q}{r^2}$ = electric field around a point charge or *outside* a spherical charge distribution.

OpenStax Chapter 19 Equations

Potential Energy and Work:

$W_{ba} = F_E d \cos\theta$ = work done by electric force F_E on test charge, in displacement d from a to b.

$W_{ba} = -q\Delta V = -q(V_b - V_a)$ = work done by electric force on a test charge, moved from a to b.

$\Delta\text{PE} = q\Delta V = q(V_b - V_a)$ = change in electric potential energy of the system. Also: $\Delta\text{PE} = -W_{ba}$.

Potential:

$\Delta V = \frac{\Delta\text{PE}}{q}$ = definition of change in electric potential.

$\Delta V = Ed$ = potential change in a uniform electric field.

$V = k\frac{Q}{r}$ = potential produced by a point charge or *outside* a spherical charge distribution.

$\text{PE} = qV$ = potential energy for a test charge at a point in a field.

$\text{PE} = k\frac{Q_1 Q_2}{r_{12}}$ = potential energy of a pair of charges.

Capacitance:

$Q = CV, \quad C = K\epsilon_0 \frac{A}{d}$ = capacitor equations.

$U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$ = stored energy.

$E = \frac{Q/A}{\epsilon_0}$ = electric field strength very near a charged conductor.

OpenStax Chapter 20 Equations

Electric current and power:

$I = \frac{\Delta Q}{\Delta t}, \quad \Delta Q = I\Delta t$ current definition. $V = IR, \quad I = V/R$ Ohm's law.

$R = \rho L/A$ calculation of resistance. $\rho = \rho_0[1 + \alpha(T - T_0)]$ resistivity changes.

$P = IV, \quad P = I^2R, \quad P = V^2/R.$ $P =$ instantaneous work/time.

Alternating current:

$V = V_0 \sin(2\pi ft) =$ time-dependent AC voltage. $I = I_0 \sin(2\pi ft) =$ time-dependent AC current.

$V_{\mathrm{rms}} = \sqrt{\overline{V^2}} = V_0/\sqrt{2} =$ root-mean-square voltage. $I_{\mathrm{rms}} = \sqrt{\overline{I^2}} = I_0/\sqrt{2} =$ root-mean-square current.

AC power:

$\overline{P} = \frac{1}{2}I_0V_0 = \frac{1}{2}I_0^2R = \frac{1}{2}V_0^2/R =$ average power. $\overline{P} = I_{\mathrm{rms}}V_{\mathrm{rms}} = I_{\mathrm{rms}}^2R = V_{\mathrm{rms}}^2/R =$ average power.

OpenStax Chapter 21 Equations

Resistor Combinations

$R_{\mathrm{eq}} = R_1 + R_2 + R_3 + ...$ (series) $\frac{1}{R_{\mathrm{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$ (parallel)

Real batteries

$V_{ab} = \mathcal{E} - Ir$ (terminal voltage) $V_{ab} = IR$ (connected to load R)

Kirchhoff's Rules

$\sum \Delta V = 0$ (loop rule, energy conservation) $\sum I = 0$ (node rule, charge conservation)

OpenStax Chapter 22 Equations

Magnetic forces, torque

$F = IlB\sin\theta$ (on a current) $F = qvB\sin\theta$ (on a moving charge)

$F/l = \frac{\mu_0}{2\pi}\frac{I_1I_2}{d}$ (between currents) $F = qvB = mv^2/r$ (during cyclotron motion)

$\tau = NBAI\sin\theta$ (torque on a coil) $v = \omega r = 2\pi fr = 2\pi r/T$ (circular motion)

Magnetic Fields

$B = \frac{\mu_0}{2\pi}\frac{I}{r}$ (due to long straight wire) $B = \mu_0 IN/l$ (inside a solenoid)

Right Hand Rules

Force (thumb) = [I (4 fingers)] × [magnetic field (palm)] (force on a current)

Force (thumb) = [qv (4 fingers)] × [magnetic field (palm)] (force on a moving charge)

Current (thumb) $\Longleftrightarrow$ [magnetic field (4 fingers)] (magnetic field around a wire)

Current (4 fingers) $\Longleftrightarrow$ [magnetic field (thumb)] (magnetic field inside a current loop)

OpenStax Chapter 23 Equations

Faraday's Induced EMF

$\Phi_B = BA\cos\theta$ (magnetic flux) $\mathcal{E} = -N\frac{\Delta\Phi_B}{\Delta t}$ (induced emf)

$\mathcal{E} = Blv$ (moving conductor) $\mathcal{E} = NBA\omega\sin(\omega t), \ \omega = 2\pi f$ (AC generator)

$V - \mathcal{E} = IR$ (motor's back-emf) $\mathcal{E}_1 = -M\frac{\Delta I_2}{\Delta t}$ (mutual inductance emf)

$V_S/V_P = N_S/N_P$ (transformer equation) $I_PV_P = I_SV_S$ (power in = power out)

AC Circuits, Inductors, Capacitors, Reactance

$\mathcal{E} = -L\frac{\Delta I}{\Delta t}$ (self-inductance emf) $U = \frac{1}{2}LI^2$ (stored magnetic energy)

$X_L = 2\pi fL = \omega L$ (inductive reactance) $V_L = IX_L$ (inductor voltage)

$X_C = 1/(2\pi fC) = 1/(\omega C)$ (capacitive reactance) $V_C = IX_C$ (capacitor voltage)

$Z = \sqrt{R^2 + (X_L - X_C)^2}$ (series RLC impedance) $V_{\mathrm{gen}} = IZ = \sqrt{V_R^2 + (V_L - V_C)^2}$ (series RLC)

$\omega_0 = 1/\sqrt{LC}, \quad f_0 = \frac{\omega_0}{2\pi}$ (LC resonance) $\tan\phi = (X_L - X_C)/R$ (series RLC phase)

$\overline{P} = I_{\mathrm{rms}}V_{\mathrm{rms}}\cos\phi$ (AC average power) $\overline{P} = I_{\mathrm{rms}}V_{\mathrm{rms}}\cos\phi = I_{\mathrm{rms}}^2R$ (series RLC)