Rec. Time **Name**

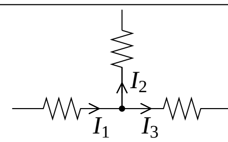
For full credit, make your work clear. Show formulas used, essential steps, and results with correct units and significant figures. Points shown in parenthesis. For TF and MC, choose the *best* answer. Bonus points possible by correctly using prefixes like 2.0 mV, 7.8 MW, 1.6 kΩ, 3.4 μT, etc., in lieu of scientific notation like 2.0×10^{-3} V.

OpenStax Ch. 21 - Electric Circuits

1. (3) When three resistors, $R_A > R_B > R_C$, are wired in series and connected to a real battery,

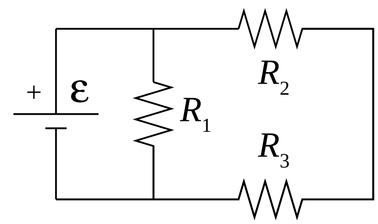
a. R_A has the largest voltage drop across it. b. R_B has the largest voltage drop across it.
c. R_C has the largest voltage drop across it. d. they all have equal voltage drops.

2. (3) For this node in some circuit, which statement is true about the currents?



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

3. (12) In the circuit shown, the ideal battery's emf is $\mathcal{E} = 2.40$ V, and the resistances are $R_1 = 48.0\ \Omega$ and $R_2 = 24.0\ \Omega$, and $R_3 = 72.0\ \Omega$.



a) (6) Determine the equivalent resistance R_{eq} connected to the ideal battery.

b) (6) How large and in which direction is the current through the battery, in mA (milliamperes)?

4. (2) **T F** 1 volt × 1 ampere = 1 ohm.

5. (2) **T F** The greater the power used by a 120 VAC lightbulb, the less its resistance must be.

6. (2) **T F** When conventional current flows into the (-) terminal of a real battery, it is supplying power.

7. (2) **T F** When a real battery is supplying power, its terminal voltage is lower than its electromotive force.

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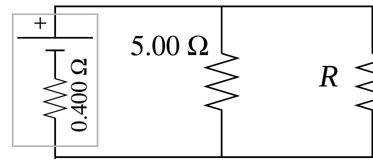
8. (16) A battery with emf $\mathcal{E} = 9.00$ V and internal resistance $r = 0.400\ \Omega$ is connected to two lightbulbs as shown. with resistances of 5.00 Ω and an unknown value R. A measurement shows that the terminal voltage of the battery is 8.00 V.



a) (6) How large is the current through the battery?

b) (6) How large is the current through the unknown resistance R?

c) (4) What is the value of R in ohms?

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

1. (2) **T** **F** The north (N) pole on a compass needle points the same direction as the magnetic field affecting it.

2. (2) **T** **F** When a proton is moving parallel to a magnetic field, the magnetic force is the greatest.

3. (2) **T** **F** The tesla = 1 N/(A· m) is the SI unit of magnetic field.

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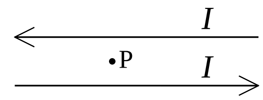
4. (2) Two long straight wires carry equal but opposite currents as shown. The direction of its magnetic field at point P halfway between them is



a. ↑ b. ↓ c. ← d. → e. ⊗ f. ⊙ g. none, $B = 0$.

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5. (2) A bar magnet is placed as shown. The direction of the magnetic field at point P is

a. ↑ b. ↓ c. ← d. → e. ⊗ f. ⊙ g. none, $B = 0$.

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6. (2) A bar magnet is placed near a wire carrying a current as shown. The direction of the magnetic force on the wire is

a. ↑ b. ↓ c. ← d. → e. ⊗ f. ⊙ g. none, $F = 0$.

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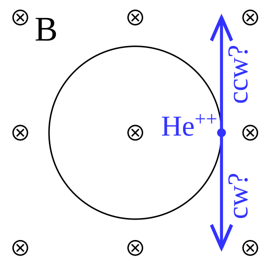
7. (14) A helium nucleus He^{++} with mass = 4u = 6.64×10^{-27} kg is performing uniform circular motion with a period of 0.455 μs in a region with a uniform magnetic field **B**, as shown.



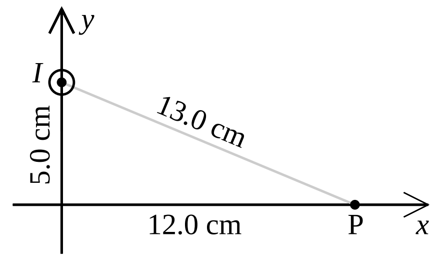
a) (2) The direction of the motion is: a. clockwise (cw) b. counterclockwise (ccw).

b) (4) Determine the frequency (f) of the motion, in (Hz or kHz or MHz, for example).

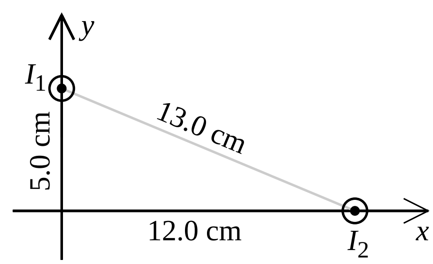
b) (8) Determine the strength of the magnetic field **B**.

8. (14) A long straight wire carries a current $I_1 = 125$ A out of the page, see diagram.

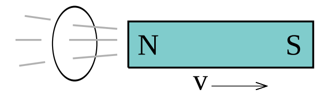
a) (7) Calculate the magnitude (5 pts.) of the magnetic field it produces at point P ($x = 12$ cm, $y = 0$) and then draw an arrow labeled B_1 on the diagram (2 pts.) to show its direction there.



b) (7) Now a 10.0 m long straight wire with a current $I_2 = 250.$ A out of the page is placed at P. Calculate the magnitude (5 pts.) of the magnetic force on that wire, and draw an arrow on the diagram (2 pts.) labeled F_2 to show its direction.



1. (2) A bar magnet is pulled away from a loop of wire. Viewed from the right, the induced current in the wire loop is



a. zero. b. clockwise. c. counterclockwise.

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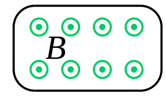
2. (2) A magnetic field B passes through a wire loop as shown. When B is increasing, the induced emf in the loop is



a. zero. b. clockwise. c. counterclockwise.

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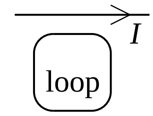
3. (2) The current I in the straight wire is increasing. The induced emf in the loop is



a. zero. b. clockwise. c. counterclockwise.

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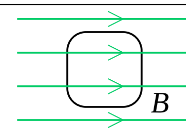
4. (2) A magnetic field in the plane of a wire loop is switched off in a short time. The induced emf in the loop is



a. zero. b. clockwise. c. counterclockwise.

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5. (2) **T F** In an electric motor, the back emf is caused by electromagnetic induction in the armature.

6. (2) **T F** Capacitive reactance increases with frequency.

7. (2) **T F** At resonance in a series RLC circuit, the rms current is a maximum.

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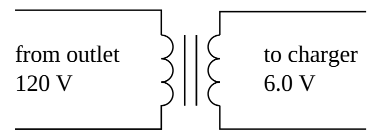
8. (8) Trying to measure magnetic storms, Alex lays out a circular coil with 250 turns of radius $r = 75$ m in a corn field. Normally, the vertical component of Earth's magnetic field is $B = 40\ \mu$T (downward). If a magnetic storm causes the field to change by $\Delta B = 250$ nT (downward) in 1.0 ms, how large is the emf developed in the coil?

9. (8) The usual AC power in our houses is 120 volts rms at 60 Hz. What value of inductance connected directly to an outlet would result in an rms current of 1.00 A?

10. (12) An ideal transformer in a cell phone charger changes the 120 V rms voltage from the outlets into 6.0 V rms. There are 80 turns on the secondary side coil in the transformer.



a) (6) How many turns are there on the primary side coil of the transformer?

b) (6) If the secondary side rms current is 1.80 A, how large is the rms current through the primary side?

 Ch. 21 = __________/42 Ch. 22 = __________/40 Ch. 23 = __________/42

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)
$e = 1.602 \times 10^{-19}$ C (proton charge)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass)

$\epsilon_0 = 1/4\pi k = 8.854$ pF/m (permittivity of space)
$\mu_0 = 4\pi \times 10^{-7}$ T·m/A (permeability of space)
$m_p = 1.67 \times 10^{-27}$ kg (proton mass)

Units

$N_A = 6.02 \times 10^{23}$/mole (Avogadro's #)
1.0 eV = 1.602×10^{-19} J (electron-volt)
1 F = 1 C/V = 1 farad = 1 C^2/J
1 A = 1 C/s = 1 ampere = 1 coulomb/second
1 T = 1 N/A·m = 1 tesla = 1 newton/ampere·meter

1 u = 1 g/N_A = 1.6605×10^{-27} kg (mass unit)
1 V = 1 J/C = 1 volt = 1 joule/coulomb
1 H = 1 V·s/A = 1 henry = 1 J/A^2
1 Ω = 1 V/A = 1 ohm = 1 J·s/C^2
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, $\quad F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}, \quad \epsilon_0 = \frac{1}{4\pi k} = 8.854$ pF/m.

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

Electric Field:

$\vec{E} = \frac{\vec{F}}{q}$, 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 $\vec{E}$.

$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + ...$ 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.

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

$P =$ instantaneous work/time.

Alternating current:

$V = V_0 \sin(2\pi f t) =$ time-dependent AC voltage.

$I = I_0 \sin(2\pi f t) =$ time-dependent AC current.

$V_{\rm rms} = \sqrt{\overline{V^2}} = V_0/\sqrt{2} =$ root-mean-square voltage.

$I_{\rm rms} = \sqrt{\overline{I^2}} = I_0/\sqrt{2} =$ root-mean-square current.

AC power:

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

$\overline{P} = I_{\rm rms}V_{\rm rms} = I_{\rm rms}^2 R = V_{\rm rms}^2/R =$ average power.

OpenStax Chapter 21 Equations

Resistor Combinations

$R_{\rm eq} = R_1 + R_2 + R_3 + ...$ (series)

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

$F/l = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d}$ (between currents)

$F = qvB = mv^2/r$ (during cyclotron motion)

$\tau = NBAI\sin\theta$ (torque on a coil)

$v = \omega r = 2\pi f r = 2\pi r/T$ (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)

$I_P V_P = I_S V_S$ (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)

$X_L = 2\pi f L = \omega L$ (inductive reactance)

$V_L = IX_L$ (inductor voltage)

$X_C = 1/(2\pi f C) = 1/(\omega C)$ (capacitive reactance)

$V_C = IX_C$ (capacitor voltage)

$Z = \sqrt{R^2 + (X_L - X_C)^2}$ (series RLC impedance)

$V_{\rm gen} = IZ = \sqrt{V_R^2 + (V_L - V_C)^2}$ (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)

$\overline{P} = I_{\rm rms}V_{\rm rms}\cos\phi$ (AC average power)

$\overline{P} = I_{\rm rms}V_{\rm rms}\cos\phi = I_{\rm rms}^2 R$ (series RLC)