Gen. Phys. II **Exam 2 - Chs. 21,22,23 - Circuits, Magnetism, EM Induction** **Mar. 5, 2018**

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.

OpenStax Ch. 21 - Electric Circuits

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

   a. R_A has the largest current, R_C has the smallest current.
   b. R_C has the largest current, R_A has the smallest current. c. they have the same currents.

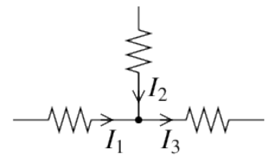
2. (2) **T F** A standard 100-watt lightbulb use 100 watts of power for any applied voltage.

3. (2) **T F** A standard 100-watt lightbulb has less resistance than a standard 60-watt lightbulb.

4. (2) **T F** An ohm is the same as a J·s/C^2.

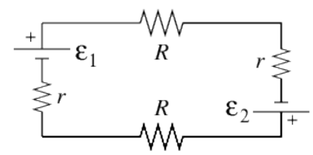
5. (2) **T F** The terminal voltage of a real battery is always less than or equal to its emf $\mathcal{E}$.

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



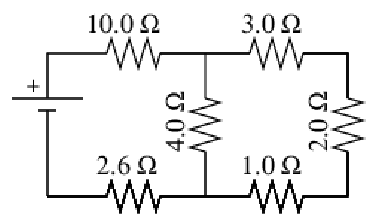
   a. $I_1 = I_2 + I_3$. b. $I_2 = I_1 + I_3$. c. $I_3 = I_1 + I_2$. d. $I_1 = I_2 = I_3$.

7. (4) For this circuit with $\mathcal{E}_1 > \mathcal{E}_2$, indicate whether each battery is charging or discharging by circling your choices below.



   Battery $\mathcal{E}_1$: charging / discharging. Battery $\mathcal{E}_2$: charging / discharging.

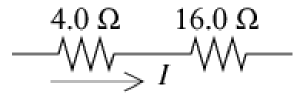
8. (12) An ideal 30.0 volt battery is connected to a resistor network as shown.



   a) (8) Determine the equivalent resistance connected to the battery.

   b) (4) How large is the current through the 10.0 Ω resistor?

9. (6) Two resistors are connected in series in some circuit. The voltage drop across the 4.0 Ω resistor is 8.0 V. Determine the voltage drop across the 16.0 Ω resistor.



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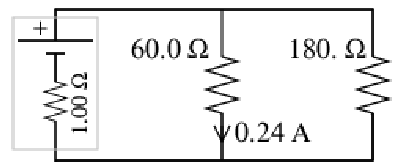
10. (14) A battery with 1.00 Ω of internal resistance is connected to two lightbulbs of resistances $R_1 = 60.0\ \Omega$ and $R_2 = 180.0\ \Omega$, wired in parallel. The current through R_1 is $I_1 = 0.24$ A.



a) (6) Determine the current I_2 through R_2.

b) (4) How large is the current through the battery?

c) (4) How large is the terminal voltage of the battery?

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

1. (2) **T F** Magnetic field lines point away from north magnetic poles and towards south magnetic poles.

2. (2) **T F** In Manhattan, KS Earth's magnetic field points within a few degrees of horizontal.

3. (2) **T F** The magnetic force on a moving electric charge is never zero.

4. (2) **T F** Ultimately, all magnetic fields are produced by electric currents.

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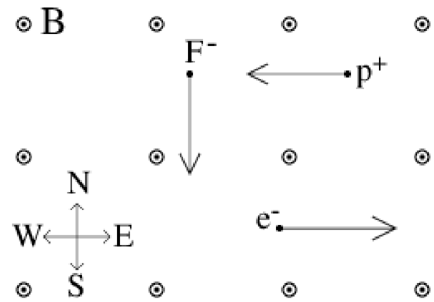
5. (6) A uniform magnetic field **B** points vertically upward (skyward or out of the page in a map view). The sketch shows the instantaneous velocities of an electron e^-, proton p^+, and a fluorine ion F^-.



a) (2) The direction of the magnetic force on the proton is

a. N b. E c. S d. W e. downward f. skyward

a) (2) The direction of the magnetic force on the electron is

a. N b. E c. S d. W e. downward f. skyward

a) (2) The direction of the magnetic force on the fluorine ion F^- is

a. N b. E c. S d. W e. downward f. skyward

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6. (3) A long straight wire carries a current as shown. The direction of its magnetic field at point A is

a. $\uparrow$ b. $\downarrow$ c. $\leftarrow$ d. $\rightarrow$ e. $\otimes$ f. $\odot$ g. none, $B = 0$.

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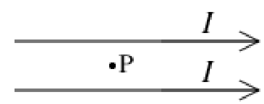
7. (3) Two parallel long straight wires carry equal currents as shown. The direction of its magnetic field at point P halfway between them is



a. $\uparrow$ b. $\downarrow$ c. $\leftarrow$ d. $\rightarrow$ e. $\otimes$ f. $\odot$ g. none, $B = 0$.

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

a. $\uparrow$ b. $\downarrow$ c. $\leftarrow$ d. $\rightarrow$ e. $\otimes$ f. $\odot$ g. none, $B = 0$.

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

a. $\uparrow$ b. $\downarrow$ c. $\leftarrow$ d. $\rightarrow$ e. $\otimes$ f. $\odot$ g. none, $F = 0$.

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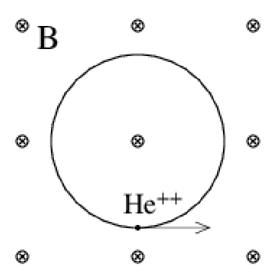
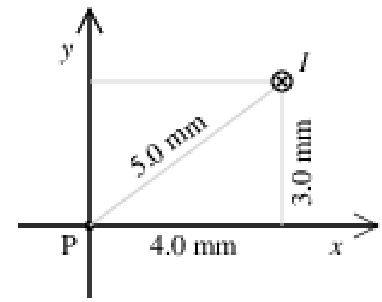
10. (6) A helium nucleus He^{++} (also known as an α-particle, mass = 4u) moving at 68 km/s enters a region with a uniform 98 mT magnetic field, perpendicular to the field lines. At what frequency in Hz does its circular motion take place?



11. (6) A long straight wire carries a 25 A current into the page, see diagram. Calculate the magnitude of the magnetic field it produces at point P ($x = 0$, $y = 0$) and then draw an arrow on the diagram to show its direction there.



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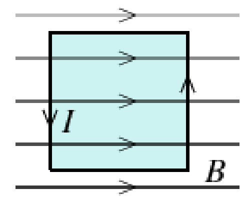
12. (12) A 12.0 cm × 12.0 cm square coil has 250 turns and carries a current of 4.00 A. A uniform magnetic field of strength 230 mT exists in the plane of the coil as shown.



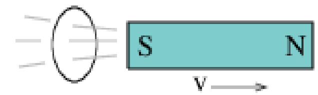
a) (6) Calculate the magnitude and direction of the net magnetic force on the right side segment of the coil (where the current is upward).

b) (4) Calculate the magnitude of the net torque on the coil, in N·m.

c) (2) The torque causes the coil to rotate around a **vertical / horizontal** axis (⟵ select one).

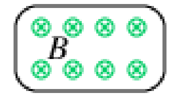
OpenStax Ch. 23 - Electromagnetic Induction **Name**____________________________________

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



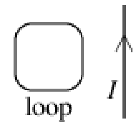
a. zero. b. clockwise. c. counterclockwise.

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



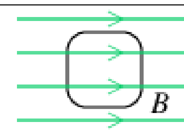
a. zero. b. clockwise. c. counterclockwise.

3. (3) A wire loop is moving towards a straight wire with a constant current directed as shown. The induced emf in the loop is



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

4. (3) A magnetic field in the plane of a wire loop reverses direction in a short time. The induced emf in the loop is



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

5. (2) **T** **F** The inductive reactance of an inductor increases with frequency.

6. (2) **T** **F** The rms voltages on capacitor and inductor are equal in an RLC circuit at resonance.

7. (2) **T** **F** One henry is the same as one ohm·second.

8. (2) **T** **F** The rms output voltage of a generator will quadruple if angular speed is doubled.

9. (10) The 5.00 cm × 10.0 cm coil of a generator has 680 turns and rotates at a frequency of 3600 rpm around the long axis, in a 125 mT magnetic field.

a) (4) What is the frequency of its AC output voltage, in hertz?

b) (6) Determine the rms output voltage of this generator.

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

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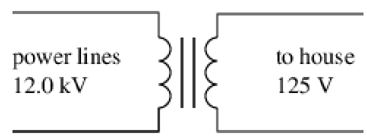
11. (12) The transformer outside Joe's house, considered ideal, changes the 12.0 kV (rms) voltage on the neighborhood power lines to 125 V (rms) that enters his house. There are 2880 turns on the (high voltage) primary side.



a) (6) How many turns are there on the (low voltage) secondary side of the transformer?

b) (6) If the average power being consumed by the house is 2.4 kW, how large is the rms current through the primary side of the transformer?

 Ch. 21 = ___________/50 Ch. 22 = ___________/50 Ch. 23 = ___________/50

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.

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

$P =$ 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.

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

$I_{\text{rms}} = \sqrt{\overline{I^2}} = I_0/\sqrt{2} =$ 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.

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

OpenStax Chapter 21 Equations

Resistor Combinations

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

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

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

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

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