

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

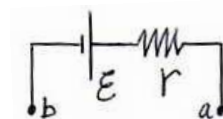
1. (2) For a resistor carrying a current, the point in it at the highest electric potential is the point
 - a. where the current enters.
 - b. where the current leaves.
 - c. in the center of the resistor.

2. (2) Three resistors R_A , R_B , and R_C are wired in series in some circuit. What can you say about an electron that goes through R_A ?
 - a. It has to go through R_B and R_C too.
 - b. It cannot go through either of the other resistors.
 - c. It might go through one of the other resistors.

3. (2) Three resistors R_A , R_B , and R_C are wired in parallel in some circuit. What can you say about an electron that goes through R_A ?
 - a. It has to go through R_B and R_C too.
 - b. It cannot go through either of the other resistors.
 - c. It might go through one of the other resistors.

4. (2) **T F** The sum of the voltage changes around any loop of a circuit is zero.
5. (2) **T F** A 100 W, 120 V-rms lightbulb has less resistance than a 60 W, 120 V-rms lightbulb.
6. (2) **T F** A real battery's terminal voltage is always less than its emf \mathcal{E} .

7. (10) The terminal voltage of a battery is 6.10 V with no load connected to it. When connected to a lightbulb that draws a current of 0.200 A, its terminal voltage drops to 6.00 V.

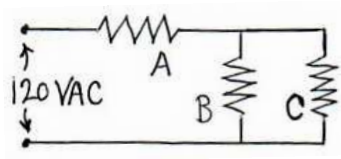


a) (4) What is the resistance of the lightbulb?

b) (6) What is the internal resistance of the battery?

8. (18) The resistors here are three incandescent 100-watt lightbulbs connected as shown. (They are rated at 100-watts when operating on 120 V rms AC.)

a) (4) How large is the resistance of an individual lightbulb?



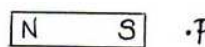
b) (6) How large is the equivalent resistance connected to the 120 VAC power?

c) (6) How much power is lightbulb A actually using?

d) (2) Which lightbulb glows the brightest in this setup?

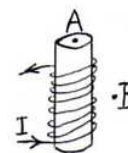
- a. A. b. B. c. C. d. B & C tie for brightest. e. all glow equally bright.

1. (2) A bar magnet is set as shown. Which is closest to the direction of its magnetic field at point P?



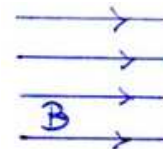
- a. \uparrow b. \downarrow c. \leftarrow d. \rightarrow e. \otimes f. \odot

2. (4) A solenoid carries a current as shown.



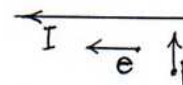
- a) (2) The direction of its magnetic field at point A is closest to
 a. \uparrow b. \downarrow c. \leftarrow d. \rightarrow e. \otimes f. \odot
- b) (2) The direction of its magnetic field at point B is closest to
 a. \uparrow b. \downarrow c. \leftarrow d. \rightarrow e. \otimes f. \odot

3. (6) A region has a uniform magnetic field pointing horizontally to the right as shown.



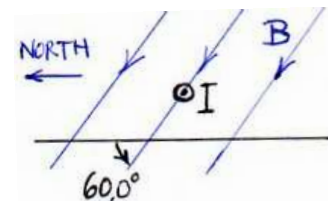
- a) (2) The north pole of a compass needle placed in this magnetic field points:
 a. \uparrow b. \downarrow c. \leftarrow d. \rightarrow e. \otimes f. \odot
- b) (2) The magnetic force on a proton instantaneously moving out of the page points:
 a. \uparrow b. \downarrow c. \leftarrow d. \rightarrow e. \otimes f. \odot
- c) (2) The magnetic force on a wire carrying a current upwards on the page points:
 a. \uparrow b. \downarrow c. \leftarrow d. \rightarrow e. \otimes f. \odot

4. (4) A wire carries a current horizontally to the left.



- a) (2) The magnetic force on a proton (p) moving up towards the wire as shown points
 a. \uparrow b. \downarrow c. \leftarrow d. \rightarrow e. \otimes f. \odot
- b) (2) The magnetic force on an electron (e) moving parallel to the current as shown points
 a. \uparrow b. \downarrow c. \leftarrow d. \rightarrow e. \otimes f. \odot

5. (8) A 20.0-meter long straight wire carries a 25 A current towards the west. The Earth's 0.60-gauss magnetic field there points north but 60.0° below horizontal.

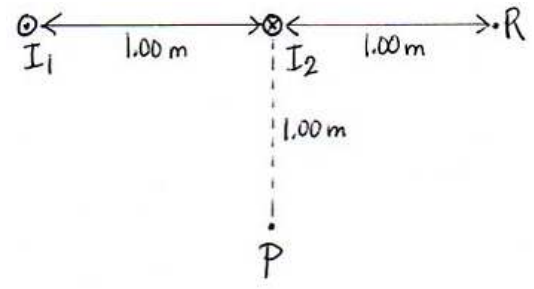


- a) (2) In what direction is the force \vec{F} on the wire? Draw and label \vec{F} on the diagram, or use \odot to show that \vec{F} is out-of-the-page or \otimes to show that \vec{F} is into-the-page.
- b) (6) Calculate the magnitude of the magnetic force on the wire.

6. (10) Two long straight wires separated by 1.00 m carry 75 A currents. I_1 is out of the page and I_2 is into the page.

b) (4) On the diagram at point P, draw and label the magnetic fields vectors \vec{B}_1 and \vec{B}_2 caused by each current, respectively. You do not need to calculate them, just show their directions correctly at point P.

a) (6) Ralph (R) is 1.00 m to the right of I_2 . Calculate the net magnetic field strength that the currents produce at his location.



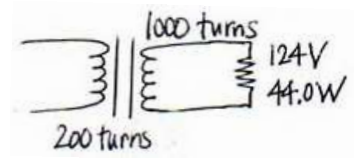
7. (8) A proton ($m = 1.67 \times 10^{-27} \text{ kg}$) is performing cyclotron motion in the plane of the page at a speed of $2.2 \times 10^7 \text{ m/s}$ in a uniform magnetic field of 2.5 T out of the page.

a) (4) Briefly explain why the proton moves at constant speed.

b) (4) Calculate the radius of the proton's circular orbit.

6. (6) An AC generator has a square $12.0\text{ cm} \times 12.0\text{ cm}$ armature coil with 480 turns rotating at 720 rpm in a 0.50-tesla magnetic field. How large is its peak voltage?

7. (10) An ideal transformer has 2.00×10^2 turns on the primary side and 1.00×10^3 turns on the secondary side. The secondary side is connected to a stereo using 44.0 watts at 124 volts rms, 60.0 Hz.



a) (5) How large is the rms voltage across the primary side of the transformer?

b) (5) How large is the rms current through the primary side of the transformer?

Prefixes

a=10⁻¹⁸, f=10⁻¹⁵, p=10⁻¹², n=10⁻⁹, μ = 10⁻⁶, m=10⁻³, c=10⁻², k=10³, M=10⁶, G=10⁹, T=10¹², P=10¹⁵

Physical Constants

$k = 1/4\pi\epsilon_0 = 8.988 \text{ GNm}^2/\text{C}^2$ (Coulomb's Law)
 $e = 1.602 \times 10^{-19} \text{ C}$ (proton charge)
 $m_e = 9.11 \times 10^{-31} \text{ kg}$ (electron mass)

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

Units

$N_A = 6.02 \times 10^{23}/\text{mole}$ (Avogadro's #)
1.0 eV = 1.602 × 10⁻¹⁹ J (electron-volt)
1 F = 1 C/V = 1 farad = 1 C²/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/A²
1 Ω = 1 V/A = 1 ohm = 1 J·s/C²
1 G = 10⁻⁴ T = 1 gauss = 10⁻⁴ tesla

OpenStax Chapter 18 Equations

Charges:

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

Electric Force:

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

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

Electric Field:

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

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

$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \dots$ 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:

$Q = CV$, $C = K \epsilon_0 \frac{A}{d}$ = 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:

$$I = \frac{\Delta Q}{\Delta t}, \quad \Delta Q = I\Delta t \quad \text{current definition.}$$

$$R = \rho L/A \quad \text{calculation of resistance.}$$

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

$$V = IR, \quad I = V/R \quad \text{Ohm's law.}$$

$$\rho = \rho_0[1 + \alpha(T - T_0)] \quad \text{resistivity changes.}$$

$$P = \text{instantaneous work/time.}$$

Alternating current:

$$V = V_0 \sin(2\pi ft) = \text{time-dependent AC voltage.}$$

$$I = I_0 \sin(2\pi ft) = \text{time-dependent AC current.}$$

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

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

AC power:

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

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

OpenStax Chapter 21 Equations

Resistor Combinations

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

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

Real batteries

$$V_{ab} = \mathcal{E} - Ir \quad (\text{terminal voltage})$$

$$V_{ab} = IR \quad (\text{connected to load } R)$$

Kirchhoff's Rules

$$\sum \Delta V = 0 \quad (\text{loop rule, energy conservation})$$

$$\sum I = 0 \quad (\text{node rule, charge conservation})$$

OpenStax Chapter 22 Equations

Magnetic forces, torque

$$F = IlB \sin \theta \quad (\text{on a current})$$

$$F = qvB \sin \theta \quad (\text{on a moving charge})$$

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

$$F = qvB = mv^2/r \quad (\text{during cyclotron motion})$$

$$\tau = NBAI \sin \theta \quad (\text{torque on a coil})$$

$$v = \omega r = 2\pi fr = 2\pi r/T \quad (\text{circular motion})$$

Magnetic Fields

$$B = \frac{\mu_0 I}{2\pi r} \quad (\text{due to long straight wire})$$

$$B = \mu_0 IN/l \quad (\text{inside a solenoid})$$

Right Hand Rules

$$\text{Force (thumb)} = [I \text{ (4 fingers)}] \times [\text{magnetic field (palm)}] \quad (\text{force on a current})$$

$$\text{Force (thumb)} = [qv \text{ (4 fingers)}] \times [\text{magnetic field (palm)}] \quad (\text{force on a moving charge})$$

$$\text{Current (thumb)} \iff [\text{magnetic field (4 fingers)}] \quad (\text{magnetic field around a wire})$$

$$\text{Current (4 fingers)} \iff [\text{magnetic field (thumb)}] \quad (\text{magnetic field inside a current loop})$$

OpenStax Chapter 23 Equations

Faraday's Induced EMF

$$\Phi_B = BA \cos \theta \quad (\text{magnetic flux})$$

$$\mathcal{E} = -N \frac{\Delta \Phi_B}{\Delta t} \quad (\text{induced emf})$$

$$\mathcal{E} = Blv \quad (\text{moving conductor})$$

$$\mathcal{E} = NBA\omega \sin(\omega t), \quad \omega = 2\pi f \quad (\text{AC generator})$$

$$V - \mathcal{E} = IR \quad (\text{motor's back-emf})$$

$$\mathcal{E}_1 = -M \frac{\Delta I_2}{\Delta t} \quad (\text{mutual inductance emf})$$

$$V_S/V_P = N_S/N_P \quad (\text{transformer equation})$$

$$I_P V_P = I_S V_S \quad (\text{power in} = \text{power out})$$

AC Circuits, Inductors, Capacitors, Reactance

$$\mathcal{E} = -L \frac{\Delta I}{\Delta t} \quad (\text{self-inductance emf})$$

$$U = \frac{1}{2}LI^2 \quad (\text{stored magnetic energy})$$

$$X_L = 2\pi fL = \omega L \quad (\text{inductive reactance})$$

$$V_L = IX_L \quad (\text{inductor voltage})$$

$$X_C = 1/(2\pi fC) = 1/(\omega C) \quad (\text{capacitive reactance})$$

$$V_C = IX_C \quad (\text{capacitor voltage})$$

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

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

$$\omega_0 = 1/\sqrt{LC}, \quad f_0 = \frac{\omega_0}{2\pi} \quad (\text{LC resonance})$$

$$\tan \phi = (X_L - X_C)/R \quad (\text{series RLC phase})$$

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

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