1. (2) For a resistor carrying a current, the point in it at the highest 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 $R_A, R_B, \text{ and } R_C$ 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 $R_A, R_B, \text{ and } R_C$ 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 The sum of the currents entering any node of a circuit is zero.

6. (2) T F A real battery’s terminal voltage is always less than its emf $\varepsilon$.

7. (18) The resistors here are three standard 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?
8. (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 0.20 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?

9. (10) 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) (4) In what direction is the force $\vec{F}$ on the wire? Draw and label $\vec{F}$ on the diagram, or use $\bigcirc$ 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.

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

a. ↑  b. ↓  c. ←  d. →  e. ⊗  f. ⊙

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

a) (2) The direction of its magnetic field at point A is closest to

a. ↑  b. ↓  c. ←  d. →  e. ⊗  f. ⊙

b) (2) The direction of its magnetic field at point B is closest to

a. ↑  b. ↓  c. ←  d. →  e. ⊗  f. ⊙

12. (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. ↑  b. ↓  c. ←  d. →  e. ⊗  f. ⊙

b) (2) The magnetic force on a proton instantaneously moving out of the page points:

a. ↑  b. ↓  c. ←  d. →  e. ⊗  f. ⊙

c) (2) The magnetic force on a wire carrying a current upwards on the page points:

a. ↑  b. ↓  c. ←  d. →  e. ⊗  f. ⊙
13. (12) 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) (8) 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.

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

a) (2) T F Its cyclotron motion is counterclockwise.

b) (4) Calculate the radius of its cyclotron orbit.

c) (6) Calculate the period of its cyclotron motion.
15. (6) A wire carries a current horizontally to the left.
   a) (3) 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) (3) 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. \(\odot\)

16. (3) Imagine you take the north pole of a bar magnet and move it towards a square loop of wire facing you. The induced current in the wire loop is
   a. zero   b. clockwise   c. counterclockwise.

17. (3) A wire loop is near a current as shown. The induced current in the wire loop is
   a. zero   b. clockwise   c. counterclockwise.

18. (10) Initially, a 1.80-tesla magnetic field points parallel to the face of a 5.0 cm \(\times\) 5.0 cm square wire loop, of resistance 0.025 \(\Omega\).
   a) (2) T F While the loop is stationary and the magnetic field is maintained, there is an emf in the loop.
   b) (8) Now the loop is rotated 90.0\(^\circ\) in 0.20 seconds, making its face perpendicular to the magnetic field. Calculate the magnitude of the average induced current while the loop is being rotated.

19. (6) When a motor using 120 V (DC) is first turned on, the initial current is 6.0 A. When its gets to its top speed, the current drops to 2.0 A. How large is the back emf of the motor?
20. (3) The output voltage from an AC generator is given by $E = NBA\omega \sin \omega t$. Which change would double the peak voltage from a generator?
   a. double its angular speed.  
   b. double the magnetic field.  
   c. double the number of turns.  
   d. any of the above.

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

22. (10) An ideal transformer has $2.00 \times 10^2$ turns on the primary side and $1.00 \times 10^3$ 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?

Score = _________/133.
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

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

\[ \epsilon_0 = 1/4\pi k = 8.854 \text{ pF/m (permittivity of space)} \]
\[ \mu_0 = 4\pi \times 10^{-7} \text{ T.m/A (permeability of space)} \]

Units

\[ N_A = 6.02 \times 10^{23}/\text{mole (Avagodro’s #)} \]
\[ 1.0 \text{ eV} = 1.602 \times 10^{-19} \text{ J (electron-volt)} \]
\[ 1 \text{ F} = 1 \text{ C/V} = 1 \text{ farad = 1 C}^2/\text{J} \]
\[ 1 \text{ A} = 1 \text{ C/s} = 1 \text{ ampere = 1 coulomb/second} \]
\[ 1 \text{ T} = 1 \text{ N/A} \cdot \text{m} = 1 \text{ tesla = 1 newton/ampere} \cdot \text{meter} \]
\[ 1 \text{ G} = 10^{-4} \text{ T} = 1 \text{ gauss = 10}^{-4} \text{ tesla} \]

Chapter 16 Equations

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

Electric Force:
\[ F = k \frac{Q_1 Q_2}{r^2}, \quad k = 8.988 \times 10^9 \text{ N.m}^2/\text{C}^2, \]
\[ \vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots \text{ superposition of forces.} \]

Electric Field:
\[ \vec{E} = \frac{q \vec{F}}{q}, \quad q = \text{ test charge.} \quad \text{Or: } \vec{F} = q \vec{E}. \]
\[ |\vec{E}| = E = k \frac{Q}{r^2}, \quad \text{due to point charge. Negative } Q \text{ makes inward } \vec{E}, \text{ positive } Q \text{ makes outward } \vec{E}. \]
\[ \vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots \text{ superposition of many electric fields.} \]
\[ E = k \frac{Q}{r^2} \text{ = electric field around a point charge or } \text{outside a spherical charge distribution.} \]

Chapter 17 Equations

Potential Energy and Work:
\[ W_{ba} = F_E d \cos \theta = \text{ work done by electric force } F_E \text{ on test charge, in displacement } d \text{ from } a \text{ to } b. \]
\[ W_{ba} = -q \Delta V = -q(V_b - V_a) = \text{ work done by electric force on a test charge, moved from } a \text{ to } b. \]
\[ \Delta \text{PE} = q \Delta V = q(V_b - V_a) = \text{ change in electric potential energy of the system. Also: } \Delta \text{PE} = -W_{ba}. \]

Potential:
\[ \Delta V = \Delta \text{PE} = \text{ definition of change in electric potential.} \]
\[ \Delta V = Ed = \text{ potential change in a uniform electric field.} \]
\[ V = k \frac{Q}{r} = \text{ potential produced by a point charge or } \text{outside a spherical charge distribution.} \]
\[ \text{PE} = qV = \text{ potential energy for a test charge at a point in a field.} \]
\[ \text{PE} = k \frac{Q_1 Q_2}{r_{12}} = \text{ potential energy of a pair of charges.} \]

Capacitance:
\[ Q = CV, \quad C = K \epsilon_0 \frac{A}{d} = \text{ capacitor equations.} \]
\[ U = \frac{1}{2} Q V = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C} = \text{ stored energy.} \]
\[ E = \frac{Q}{\epsilon_0} = \text{ electric field strength very near a charged conductor.} \]
Chapter 18 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.
\[ P = IV, \quad P = I^2 R, \quad P = V^2 / R. \] \[ P = \text{instantaneous work/time.} \]

Alternating current:
\[ V = V_0 \sin 2\pi f t = \text{time-dependent AC voltage.} \]
\[ V_{\text{rms}} = \sqrt{\overline{V^2}} = V_0 / \sqrt{2} = \text{root-mean-square voltage.} \]
\[ \overline{F} = \frac{1}{2} I_0^2 R = \frac{1}{2} V_0^2 / R = \frac{1}{2} I_0 V_0 = \text{average power.} \]

AC power in resistors:
\[ \overline{P} = \overline{I}^2 R = \overline{V}_{\text{rms}}^2 / R = I_{\text{rms}} V_{\text{rms}} = \text{average power.} \]

Chapter 19 Equations

Resistor Combinations
\[ R_{\text{eq}} = R_1 + R_2 + R_3 + \ldots \] (series) \[ \frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \] (parallel)

Real batteries
\[ V_{\text{ab}} = \mathcal{E} - Ir \] (terminal voltage) \[ V_{\text{ab}} = IR \] (connected to load \( R \))

Kirchhoff’s Rules
\[ \sum \Delta V = 0 \] (loop rule, energy conservation) \[ \sum I = 0 \] (node rule, charge conservation)

Chapter 20 Equations

Magnetic forces, torque
\[ F = II B \sin \theta \] (on a current) \[ F = qvB \sin \theta \] (on a moving charge)
\[ F/l = \frac{\mu_0 I^2 L^2}{2 \pi} \] (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
\[ B = \frac{\mu_0 I}{2\pi r} \] (due to long straight wire) \[ B = \mu_0 IN / l \] (inside a solenoid)

Right Hand Rules

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

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

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

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

Chapter 21 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) \[ \mathcal{E} = NBA \omega \sin \omega t \] (AC generator)
\[ V - \mathcal{E} = IR \] (motor’s counter-emf) \[ \mathcal{E}_1 = -M \frac{\Delta I}{\Delta t} \] (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)
\[ Z = \sqrt{R^2 + (XL - XC)^2} \] (series RLC impedance) \[ V_{\text{gen}} = \sqrt{V_R^2 + (V_L - V_C)^2} \] (series RLC)
\[ \omega_0 = 1/\sqrt{LC}, \quad \omega_0 = \frac{B_0}{2r} \] (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) \[ \overline{P} = I_{\text{rms}}^2 R \] (series RLC)