1. (2) A tiny styrofoam ball is suspended on a thread. Some tests show it gets attracted to a positively charged rod, and repelled by a negatively charged rod. What can you conclude about the tiny styrofoam ball?
   a. It has a negative net charge  
   b. It has zero net charge.  
   c. It has positive net charge.  
   d. Its net charge changes when the rods are placed near it.

2. (6) An excess charge of $-88 \, \text{pC}$ is placed on a tiny metal sphere. How many electrons must have been transferred [to / from] (← select one) the sphere to produce this charge?

3. (4) A balloon acquires a positive charge when rubbed on a sweater.
   a) (2) As a result, the charge acquired by the sweater is a. negative  
   b. zero  
   c. positive.
   b) (2) T F  
   Electrons were lost by the sweater in the balloon charging process.

4. (12) Two charges, $Q_1 = +25.0 \, \mu\text{C}$ and $Q_2 = -50.0 \, \mu\text{C}$ are separated by $12.0 \, \text{cm}$ on the $x$-axis as shown. The charges produce an electric field in the surrounding region. Consider only the electric field along the $x$-axis.
   a) (2) T F  
   At any point between the charges, their net electric field points to the right.
   b) (2) T F  
   To the right of $Q_2$, there is a point at finite $x$ where the electric field is zero.
   c) (8) Determine the magnitude of the net electric field at the point midway between the charges.
5. (8) One day, there is a vertically downward electric field of 1800 N/C outside.
   a) (4) A particle in the air has an electric charge \( q = -22 \text{ pC} \). Determine the magnitude and direction of the electric force acting on it.

   b) (4) There is another dust particle with a mass of 7.0 \( \mu \text{g} \). What electric charge would it need so that its weight is exactly balanced by the electric force?

6. (6) Copper has a molar mass of 63.5 grams/mol. One electron from each atom is a “free” electron. Calculate the amount of free charge (in coulombs) in 63.5 grams of copper.

Questions about charges.
7. (2) T F  Good conductors are materials that have a lot of free charges.
8. (2) T F  Insulators are materials that lack free charges.
9. (2) T F  The electric force on an electrically neutral object is always zero.
10. (2) T F  The smallest magnitude of charge an object can acquire is \( 2e \).

Questions about electric fields.
11. (2) T F  Electric field lines point towards positive charges and away from negative charges.
12. (2) T F  The electric field inside a current-carrying conductor is non-zero.
13. (2) T F  The electric potential is higher where electric field lines are closer together.
14. (2) T F  A region of uniform electric field has parallel electric field lines.
15. (10) At a distance of 10.0 cm from an unknown point charge, the electric field is 45 kN/C and points towards the charge.
   a) (6) What is the charge (with sign)?

   b) (4) 10.0 cm from the charge, how large is the electric potential it produces?

Questions about electric potential.

16. (2) T F All points of a conductor with static charges are at the same electric potential.

17. (2) T F Electric field lines point towards regions of higher electric potential.

18. (2) T F An electron-volt is the same as $1.602 \times 10^{-19}$ volts.

19. (10) A proton ($q = +e$, mass=$1.67 \times 10^{-27}$ kg) is released from rest at point A and accelerates to point B by moving through the equipotentials shown, that are caused by other charges.
   a) (2) The electric field associated with the equipotentials points?
      a. ←  b. →  c. ↑  d. ↓
   b) (4) How much work (in J) did the electric field do on the proton?
   c) (4) What change in kinetic energy did the proton experience, in electron-volts?

   

20. (2) The electric field inside a parallel plate capacitor points
   a. from the positively charged plate towards the negatively charged plate.
   b. from the negatively charged plate towards the positively charged plate.
   c. parallel to the surfaces of the plates.
21. (12) A 58.0 µF capacitor is charged by connecting it to a 12.0 volt battery. The separation of the plates is 0.200 mm. The space between them is filled with air.
   a) (4) How much charge flowed through the battery while charging the capacitor?

b) (4) How much electric potential energy is now stored in the capacitor?

c) (4) How large is the electric field between the plates of the capacitor?

22. (8) A 6.0-volt battery is connected to a circuit that draws a direct current of 5.0 × 10⁻⁷ amperes.
   a) (4) During one minute of operation, how much charge flows through the battery?

b) (4) What is the resistance (in ohms) of the circuit?

23. (6) Four resistors, 2.00 Ω, 4.00 Ω, 6.00 Ω and 12.0 Ω are connected to a battery in the circuit shown. Calculate the equivalent resistance for the circuit.
24. (2) When Ohm’s Law, \( V = IR \), is applied to a resistor \( R \), the “\( V \)” refers to the potential ...
   a. where the current enters the resistor.    b. where the current exits the resistor.
   c. in the middle of the resistor.    d. difference between the ends of the resistor.

25. (10) Three lightbulbs that each normally operate on 120 V (60 W, 75 W, and 100 W) are connected in series to a power supply of 120 V as shown.

   a) (2) Which bulb has the lowest resistance?
      a. 60 W.    b. 75 W.    c. 100 W.    d. All have the same resistance.
   b) (2) Which bulb has the smallest current?
      a. 60 W.    b. 75 W.    c. 100 W.    d. All have the same current.
   c) (2) Which bulb has the smallest voltage drop across it?
      a. 60 W.    b. 75 W.    c. 100 W.    d. All have the same voltage drop.
   d) (2) Which bulb is using the least electric power?
      a. 60 W.    b. 75 W.    c. 100 W.    d. All use the same power.
   e) (2) Which bulb has the least brightness?
      a. 60 W.    b. 75 W.    c. 100 W.    d. They all look equally bright.

26. (12) An 1800-watt hair dryer operates on 125 volts-rms AC at 60.0 Hz.

   a) (2) How many times per second does the current through the hair dryer reverse its direction?

   b) (2) The 1800 watts in the question refers to the
      a. average power.    b. instantaneous power.    c. root-mean-square power.    d. peak power.
   c) (4) Calculate the rms current through the hair dryer.

   d) (4) Calculate the peak current through the hair dryer.

Score = __________/132.
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

\[ k = \frac{1}{4\pi\varepsilon_0} = 8.988 \text{ GN}\cdot\text{m}^2/\text{C}^2 \quad (\text{Coulomb’s Law}) \]
\[ \varepsilon_0 = \frac{1}{4\pi} = 8.854 \text{ pF/m} \quad (\text{permittivity of space}) \]
\[ e = 1.602 \times 10^{-19} \text{ C} \quad (\text{proton charge}) \]
\[ m_e = 9.11 \times 10^{-31} \text{ kg} \quad (\text{electron mass}) \]
\[ m_p = 1.67 \times 10^{-27} \text{ kg} \quad (\text{proton mass}) \]

Units

\[ N_A = 6.02 \times 10^{23}/\text{mole} \quad (\text{Avagodro’s #}) \]
\[ 1 \text{ u} = 1 \text{ g}/N_A = 1.6605 \times 10^{-27} \text{ kg} \quad (\text{mass unit}) \]
\[ 1.0 \text{ eV} = 1.602 \times 10^{-19} \text{ J} \quad (\text{electron-volt}) \]
\[ 1 \text{ V} = 1 \text{ J}/\text{C} = 1 \text{ volt} = 1 \text{ joule/coulomb} \]

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:
\[ F = k\Delta Q_1 Q_2, \quad k = 8.988 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2, \quad F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}, \quad \varepsilon_0 = \frac{1}{4\pi k} = 8.854 \text{ pF/m}. \]
\[ \vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots \quad \text{superposition of many forces}. \]

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

Chapter 17 Equations

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

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

Capacitance:
\[ Q = CV, \quad C = K\varepsilon_0 \frac{1}{d} \quad \text{capacitor equations}. \]
\[ U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2} \frac{Q^2}{C} \quad \text{stored energy}. \]
\[ E = \frac{Q}{\varepsilon_0 A} \quad \text{electric field strength very near a charged conductor}. \]
Chapter 18 Equations

Electric current:
$$I = \frac{\Delta Q}{\Delta t},$$ or $$\Delta Q = I \Delta t,$$ definition of current.
$$V = IR,$$ or $$I = V/R,$$ Ohm’s law.
$$R = \rho \frac{L}{A} =$$ calculation of resistance.
$$\rho_T = \rho_0 [1 + \alpha (T - T_0)] =$$ temperature-dependent resistivity.

Electric power:
$$P = IV, \quad P = I^2R, \quad P = V^2/R, \quad P =$$ instantaneous energy/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.
$$V_{rms} = \sqrt{\langle V^2 \rangle} = V_0/\sqrt{2} =$$ root-mean-square voltage.  
$$I_{rms} = \sqrt{\langle I^2 \rangle} = I_0/\sqrt{2} =$$ root-mean-square current.

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

Chapter 19 Equations

Resistor Combinations
$$R_{eq} = R_1 + R_2 + R_3 + \ldots$$ (series)  
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$ (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)

Other Information

Vectors

Written $$\vec{V}$$ or $$\mathbf{V},$$ described by magnitude=$$V,$$ direction=$$\theta$$ or by components ($$V_x, V_y$$).

$$V_x = V \cos \theta, \quad V_y = V \sin \theta,$$
$$V = \sqrt{V_x^2 + V_y^2}, \quad \tan \theta = \frac{V_y}{V_x}. \quad \theta$$ is the angle from $$\vec{V}$$ to $$+x$$-axis.

Addition: $$\mathbf{A} + \mathbf{B},$$ head to tail.  
Subtraction: $$\mathbf{A} - \mathbf{B}$$ is $$\mathbf{A} + (-\mathbf{B}),$$ $$-\mathbf{B}$$ is $$\mathbf{B}$$ reversed.

Trig summary

$$\sin \theta = \frac{\text{(opp)}}{\text{(hyp)}}, \quad \cos \theta = \frac{\text{(adj)}}{\text{(hyp)}}, \quad \tan \theta = \frac{\text{(opp)}}{\text{(adj)}}, \quad \text{(opp)}^2 + \text{(adj)}^2 = \text{(hyp)}^2.$$

$$\sin \theta = \sin(180^\circ - \theta), \quad \cos \theta = \cos(-\theta), \quad \tan \theta = \tan(180^\circ + \theta), \quad \sin^2 \theta + \cos^2 \theta = 1.$$