1. The electric field in the region of space shown is given by $\mathbf{E} = (6\mathbf{i} + 2\mathbf{k}) \text{ N/C}$ where $y$ is in m. What is the magnitude of the electric flux through the top face of the cube shown?

(a) 96 N·m²/C
(b) 6.0 N·m²/C
(c) 11.4 N·m²/C
(d) 12 N·m²/C
(e) 126 N·m²/C

\[ \phi = \int_{e} E \cdot dA = \int_{e} 2y \, dy \, dz \]

\[ = \int_{e} 2 \left( 3 - \frac{1}{2} z^2 \right) dy \, dz = 54 \text{ N·m}^2/C \]

2. In an RC circuit, how many time-constants must elapse if an initially uncharged capacitor $C$ to reach 80% of its final potential difference?

(a) 2.2
(b) 1.9
(c) 1.6
(d) 3.0
(e) 5.0

\[ Q = C \epsilon \frac{V}{R} \left( 1 - e^{-t/T} \right) \]

\[ \epsilon V = C \epsilon \left( 1 - e^{-t/T} \right) \]

\[ \frac{Q}{Q_0} = 1 - e^{-t/R} \]

\[ e^{-t/R} = 0.2 \]

\[ \frac{t}{R} = \ln 0.2 = 1.2 \]
3. A particle (charge = +50 \mu C) is placed on the y-axis at the point \( y = +40 \text{ cm} \), and a second particle (charge = -30 \mu C) is placed at the origin \((x = y = 0)\). What is the direction of the total electrostatic force on a third particle with respect to the +x axis (charge = -5.0 \mu C) placed on the z-axis at the point \( z = +30 \text{ cm} \)?

(a) 33° (b) 57° (c) -83° (d) 121° (e) 63°

\[ F_x = F_z \cos \theta \]
\[ F_z = k \frac{q_1 q_2}{r^2} \cos \theta \]
\[ z = 5.11 \times 10^{-10} \text{ m} \]
\[ F_x = F_z \cos \theta = \frac{1}{2}(10^{-1} \text{ N}) \]
\[ \theta = \cos^{-1} \left( \frac{F_x}{F_z} \right) = 57.4° \]

4. A 2.0 \mu C point charge is placed at the center of a hollow (inner radius = 2.0 cm, outer radius = 4.0 cm) conducting sphere. The net charge of the conductor is 6.0 \mu C. Determine the surface charge density on the outer surface of the sphere.

(a) 0.50 \text{nC/m}^2  
(b) 0.45 \text{nC/m}^2  
(c) 0.40 \text{nC/m}^2  
(d) 0.55 \text{nC/m}^2  
(e) 1.50 \text{nC/m}^2

\[ \sigma = \frac{q}{(2 \pi r)^2} \]
\[ r = 2 \text{ cm} \]
\[ q = 2 \mu \text{ C} \]
\[ \sigma = \frac{6 \times 10^{-6} \mu \text{ C}}{(2 \pi (2 \text{ cm}))^2} = 0.6 \mu \text{ C/m}^2 \]
5. What is the potential difference across the 50 \( \mu F \) capacitor shown?

\[ \frac{1}{C_{eq}} = \frac{1}{C_A} + \frac{1}{C_B} + \frac{1}{C_0} = \frac{1}{25 \mu F} + \frac{1}{25 \mu F} + \frac{1}{25 \mu F} = \frac{3}{25 \mu F} \]

\[ V_{eq} = \frac{Q}{C_{eq}} = \frac{Q}{\frac{3}{25 \mu F}} = \frac{50 \mu F \cdot 35 V}{3} = 7 V \]

6. A proton enters a region of uniform electric field \( E = 30 \, \text{kV/m} \) with an initial velocity of 20 km/s directed perpendicularly to the electric field. What is the speed of the proton 2.0 \( \mu s \) after entering this region?

\[ v_f = v_i + a \cdot t = \frac{qE}{m} \cdot t = \frac{1.6 \times 10^{-19} \, \text{C} \cdot 30 \, \text{kV/m}}{1.67 \times 10^{-27} \, \text{kg}} \cdot 20 \times 10^{-6} \, \text{s} = v_i + 1.53 \times 10^5 \, \text{m/s} \]

\[ v = \sqrt{v_i^2 + v_f^2} = 2.51 \times 10^6 \, \text{m/s} \]

7. Charge is uniformly distributed along the entire x-axis. If each 20 cm length of the x-axis carries 2.0 \( \mu C \) of charge, what is the magnitude of the electric field at the point, \( y = 2.0 \, m \), on the y-axis?

\[ \lambda = \frac{2.0 \times 10^{-6} \, \text{C}}{0.2} \]

\[ E = \frac{\lambda}{2 \pi \epsilon_0} = \frac{2(1.6 \times 10^{-19} \, \text{C} \cdot \text{m}^2) \cdot 2}{2 \pi \epsilon_0} = 10 \, \text{N/C} \]

(a) 45 N/C
(b) 90 N/C
(c) 18 N/C
(d) 36 N/C
(e) 180 N/C
3. A charge of 10 nC is distributed uniformly along the x axis from x = -2 m to x = +3 m. Which of the following integrals is correct for the electric potential (relative to zero at infinity) at the point x = +5 m on the x axis?

(a) \[ \int_{-2}^{3} \frac{90 \, dx}{x} \]

(b) \[ \int_{-2}^{5} \frac{90 \, dx}{5 - x} \]

(c) \[ \int_{-2}^{18} \frac{18 \, dx}{x} \]

(d) \[ \int_{-2}^{18} \frac{18 \, dx}{5 - x} \]

(e) \[ \int_{-2}^{90} \frac{18 \, dx}{5 + x} \]

9. A 40 \mu C charge is positioned on the x axis at x = 4.0 cm. To produce a net electric field of zero at the origin where should a -60 \mu C charge be placed on the x axis?

(c) - 5.3 cm

(b) 5.7 cm

(d) + 6.0 cm

(e) + 6.0 cm

10. If \( I = 0.40 \, A \) in the circuit segment shown, what is the potential difference \( V_a - V_b \)?

(a) 31 V

(b) 28 V

(c) 25 V

(d) 34 V

(e) 10 V

\[ V_a = \frac{(10 \, V)(12 \, \Omega)}{10 \, \Omega} = 12 \, V \]

\[ i_1 = \frac{V_a - V_b}{B} = \frac{12 - 0}{B} = \frac{12}{B} \]

\[ i_2 = i_1 \times \frac{R}{B} = \frac{12}{B} \times \frac{10}{B} = \frac{120}{B^2} \]

\[ V_c = (0)(10 \, \Omega) + 0 = 0 \, V \]

\[ V_b = \frac{(3)(4.8 \, V)}{2 + 3} = 2.16 \, V \]
11. The total electric flux through a closed cylindrical (length = 1.2 m, diameter = 0.20 m) surface is equal to \(-5.8 \text{ Nm}^2/\text{C}\). Determine the net charge within the cylinder.

(a) \(-62 \text{ pC}\)
(b) \(-53 \text{ pC}\)
(c) \(+44 \text{ pC}\)
(d) \(-71 \text{ pC}\)
(e) \(-16 \text{ pC}\)

12. A 15 nC point charge is placed at the origin, and a charge of \(-55 \text{nC}\) is placed on the y axis at \(y = 4.0 \text{ m}\). Point A is on the x axis at \(x = 3.0 \text{ m}\), and point B is on the y axis at \(y = -1.0 \text{ m}\). Determine the potential difference \(V_A - V_B\).

(a) \(-56 \text{ V}\)
(b) \(-78 \text{ V}\)
(c) \(-90 \text{ V}\)
(d) \(-84 \text{ V}\)
(e) \(0 \text{ V}\)
13. An electric device, which heats water by immersing a resistance wire in the water, generates 50 cal of heat per second when an electric potential difference of 12 V is placed across its leads. What is the resistance of the heater wire?
(Note: 1 cal = 4.185 J)

(a) 0.04 Ω
(b) 0.81 Ω
(c) 0.58 Ω
(d) 0.99 Ω
(e) 1.2 Ω

\[ P = \frac{50 \text{ cal}}{1 \text{ sec}} = \frac{50 \times 4.185 \text{ J}}{1 \text{ sec}} = 209.3 \text{ W} \]
\[ R = \frac{V^2}{P} = \frac{12^2}{209.3} = 0.688 \Omega \]

14. A 15 μF capacitor is charged to 40 V and then connected across an initially uncharged 25 μF capacitor. What is the final potential difference across the 25 μF capacitor?

(a) 12 V
(b) 18 V
(c) 21 V
(d) 24 V
(e) 26 V

\[ V = \frac{15 \mu F}{60 \mu F} \times 40 \text{ V} = \frac{15}{60} \times 40 \text{ V} = 10 \text{ V} \]