Short Answer
(12 Points Each)

1. A glass rod receives a positive charge by rubbing it with a silk cloth. In the rubbing process, have protons been added to the object? Why is it positively charged?

   **No!** THE ROD BECOMES POSITIVELY CHARGED BECAUSE ELECTRONS LEAVE IT AND MOVE TO THE CLOTH.

2. An electron (charge is $q = -1.60 \times 10^{-19}$ C) moves directly down the negative x-axis (towards the left side of this page) with a speed of 10.0 m/s. Imagine that it does so in a uniform magnetic field pointing straight out of this page towards you. The strength of the magnetic field is $B = 3.50$ T. What are the magnitude and direction of the magnetic force on the electron?

   \[
   F = |\frac{e}{m}| v \times B \sin(\theta)
   \]

   \[
   = |-1.60 \times 10^{-19} C| \times (10.0 \times 10^3 \text{ m/s}) \times (3.50 \text{ T}) \times \sin(\pi/2)
   \]

   \[
   = 5.60 \times 10^{-18} \text{ N}
   \]

   **Downwards!**

3. Draw the electric field around a pair of oppositely charged particles. Be sure to include arrows indicating the direction of the field lines.

![Electric Field Diagram](image-url)
4. Three electrons and one proton are contained inside a closed spherical surface. What is the electric flux through this surface?

\[
\Phi_E = \frac{Q_{\text{inside}}}{\varepsilon_0} = \frac{-2 \left( 1.60 \times 10^{-19} \right)}{8.85 \times 10^{-12} \text{C}^2/\text{N}\cdot\text{m}^2}
\]

\[
\Rightarrow \Phi_E = -3.62 \times 10^{-8} \frac{\text{N} \cdot \text{m}^2}{\text{C}}
\]

5. A particle with charge \( q = 3.0 \times 10^{-19} \text{ C} \) is fired into a uniform magnetic field with a speed of 16 m/s. If the particle begins spiraling in a circular loop with radius \( R = 5.0 \text{ cm} \) and the strength of the magnetic field is \( B = 4.5 \text{ T} \), what is the mass of the particle?

\[
F = q \cdot v \cdot B \quad \& \quad F = m \frac{v^2}{R}
\]

\[
\Rightarrow M = \frac{qBR}{v}
\]

\[
M = \frac{(3.0 \times 10^{-19})(4.5)(0.050)}{(16 \text{ m/s})} = 4.2 \times 10^{-21} \text{ kg}
\]
Problems
(20 Points Each)

1. The following questions refer to the circuit diagram below. 1) Find the total effective resistance of the circuit. 2) Determine the current flowing through resistors $a$, $b$, $c$, and $d$. Express your answers to three significant figures.

$$\frac{1}{R_A} = \frac{1}{\frac{3}{2} + \frac{3}{2}} + \frac{1}{\frac{3}{2}} = \Rightarrow R_A = 2 \Omega$$

$$\frac{1}{R_B} = \frac{1}{\frac{3}{2} + \frac{3}{2}} + \frac{1}{\frac{3}{2}} = \Rightarrow R_B = 1 \Omega$$

$$\therefore R_{\text{total}} = 15.0 \Omega$$

Now, $I_{\text{total}} = \frac{10 \text{V}}{15 \Omega} = \frac{2}{3} A = \Rightarrow I_a = I_b = 0.667 A$

$$\Delta V_A = \left(\frac{2}{3} A\right) \left(\frac{3}{2} \Omega\right) = \frac{2}{3} V$$

$$\Delta V_B = \left(\frac{2}{3} A\right) \left(\frac{1}{2} \Omega\right) = \frac{2}{3} V$$

$$I_c = \frac{\Delta V_B}{\frac{3}{2} \Omega} = \frac{1}{3} A \Rightarrow I_c = 0.333 A$$

$$I_d = \frac{\Delta V_A}{6 \Omega} = \frac{2}{9} A \Rightarrow I_d = 0.222 A$$
2. A constant magnetic field with strength $B = 1.30$ T points straight down the positive x-axis. A single loop of wire with area $A = 0.200$ m$^2$ begins aligned with the y-axis so that the magnetic field points directly through it. The loop is quickly rotated counterclockwise by 45.0° during a time period of 0.200 s. If the total resistance of the wire loop is 0.120 Ω, what is the average current induced in the loop during this time?

\[
\Delta V = -N \frac{\Delta \Phi_B}{\Delta t} \quad \Phi_B = BA \cos(\theta) \quad I = \frac{\Delta V}{R}
\]

\[
\Phi_f = (1.30 T)(0.200 m^2) \cos(45.0^\circ) = 0.1838 T \cdot m^2
\]

\[
\Phi_i = (1.30 T)(0.200 m^2) \cos(0^\circ) = 0.2600 T \cdot m^2
\]

\[
\Rightarrow \Delta \Phi_B = -0.0762 T \cdot m^2 \quad N = 1 \quad \Delta t = 0.200 s
\]

So...

\[
\Delta V = -1 \times \left( \frac{-0.0762 T \cdot m^2}{0.200 s} \right) = 0.381 V
\]

\[\text{Hence}\]

\[I = \frac{0.381 V}{0.120 \Omega} = 3.17 A\]

\[\Rightarrow I = 3.17 A\]
2. Three charges given by \( q_1 = 4.0 \times 10^{-6} \text{ C}, \ q_2 = 2.0 \times 10^{-6} \text{ C}, \) and \( q_3 = 6.0 \times 10^{-6} \text{ C} \) are held in place as shown in the figure below. Determine the magnitude of the net force on charge \( q_3. \)

\[
F_1 = \left( 9 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2} \right) \frac{|(4.0 \times 10^6 \text{ C})(6.0 \times 10^6 \text{ C})|}{2q_1 \mu^2} = 7.45 \times 10^{-3} \text{ N}
\]

\[
F_2 = \left( 9 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2} \right) \frac{|(2.0 \times 10^6 \text{ C})(6.0 \times 10^6 \text{ C})|}{2q_2 \mu^2} = 3.72 \times 10^{-3} \text{ N}
\]

\[
F_{\text{NET}}^{(x)} = F_1 \cos(\theta) + F_2 \cos(\theta) = 1.037 \times 10^{-2} \text{ N}
\]

\[
F_{\text{NET}}^{(y)} = F_2 \sin(\theta) - F_1 \sin(\theta) = -1.38 \times 10^{-3} \text{ N}
\]

\[
\theta = \tan^{-1}\left(\frac{2/5}{1}\right) = 21.8^\circ
\]

\[
F_{\text{NET}} = \sqrt{(F_{\text{NET}}^{(x)})^2 + (F_{\text{NET}}^{(y)})^2} = 1.05 \times 10^{-2} \text{ N}
\]