Physics 2140: Exam 1

Multiple Choice (10 points)
Identify the letter of the choice that best completes the statement or answers the question.

1. How can a charged object attract an uncharged object made of non-conducting material?
   a. The uncharged object must somehow gain a like charge.
   b. The uncharged object must somehow gain an unlike charge.
   c. The charges in the uncharged object can become polarized.
   d. Attraction of an insulator is not possible.
   e. Attraction of an insulator is possible only by another insulator.
   C

Short Answer (10 points)
Please show your work in solving the following problems. No credit will be awarded for answers without evidence of work supporting the answer.

2. If a metallic wire of cross sectional area $3.0 \times 10^{-6} \text{ m}^2$ carries a current of 6.0 A and has a mobile charge density of $4.24 \times 10^{28}$ carriers/m$^3$, what is the average drift velocity of the mobile charge carriers? (charge value = $1.6 \times 10^{-19} \text{ C}$)

   \[
   I = n q v_d A
   \]

   \[
   v_d = \frac{I}{n q A}
   \]

   \[
   = 2.9 \times 10^{-4} \text{ m/s}
   \]

   \[
   A = 3.0 \times 10^{-6} \text{ m}^2
   \]

   \[
   I = 6.0 \text{ A}
   \]

   \[
   n = 4.24 \times 10^{28} \text{ carriers/m}^3
   \]

   \[
   q = e = 1.6 \times 10^{-19} \text{ C}
   \]

3. Number 10 copper wire (radius = 1.3 mm) is commonly used for electrical installations in homes. What is the voltage drop in 40 m of #10 copper wire if it carries a current of 10 A? (The resistivity of copper is $1.7 \times 10^{-8} \text{ \Omega \cdot m}$)

   First find
   \[
   R = \rho \frac{L}{A}
   \]

   So
   \[
   R = 0.1281 \Omega
   \]

   Then
   \[
   V = IR = 1.3 V
   \]

4. By what factor is the resistance of a copper wire changed when its temperature is increased from 20°C to 120°C? The temperature coefficient of resistivity for copper is $3.9 \times 10^{-3} (\degree \text{C})^{-1}$.

   Use
   \[
   R = R_o \left[ 1 + \alpha (T - T_o) \right]
   \]

   \[
   \frac{R - R_o}{R_o} = \frac{\Delta R}{R_o} = \Delta T = 100 \degree \text{C}
   \]

   Factor the resistance changes:
   \[
   F \times R_o = R
   \]

   So
   \[
   F = \frac{R}{R_o} = 1 + \alpha \Delta T \rightarrow 1.39 = F
5. A high-voltage transmission line carries 1 000 A at 700 000 V. What is the power carried by the line?

The transmission line supplies \( 7 \times 10^5 \text{V} \) to some "device" that ends at 0 V. \( \Delta V = 7.0 \times 10^5 \text{V} \) to the "device" while consuming 1000 A. \( P = I \Delta V = 7.0 \times 10^8 \text{W} = 700 \text{ MW} \)

6. What is the equivalent capacitance of the combination shown?

7. A 0.25-\( \mu \text{F} \) capacitor is connected to a 400-V battery. What potential energy is stored in the capacitor?

\[ U = \frac{1}{2} CV^2 = 0.020 \text{ J} \]

8. If an electron is accelerated from rest through a potential difference of 1 200 V, find its approximate velocity at the end of this process. \( (e = 1.6 \times 10^{-19} \text{ C}; m_e = 9.1 \times 10^{-31} \text{ kg}) \)

\[ U = e \Delta V = \frac{1}{2} m_e v^2 \]

Solve for \( v \):

\[ v = \sqrt{\frac{2 e \Delta V}{m_e}} = 2.1 \times 10^7 \text{ m/s} \]
9. Two protons, each of charge $1.60 \times 10^{-19}$ C, are $2.00 \times 10^{-5}$ m apart. What is the change in potential energy if they are brought $1.00 \times 10^{-3}$ m closer together? ($k_e = 8.99 \times 10^9$ N\(\cdot\)m\(^2\)/C\(^2\))

\[ U_1 = k_e \frac{e^2}{r_i} \quad \quad U_2 = k_e \frac{e^2}{r_2} \]

\[ \Delta U = U_2 - U_1 = k_e e^2 \left( \frac{1}{r_2} - \frac{1}{r_i} \right) = 1.15 \times 10^{-23} \text{ J} \]

10. A parallel-plate capacitor has a capacitance of $20 \mu$F. What potential difference across the plates is required to store $7.2 \times 10^{-4}$ C on this capacitor?

\[ Q = CV \quad \Rightarrow \quad V = \frac{Q}{C} = 36 \text{ V} \]

11. In a thundercloud there may be an electric charge of $+40$ C near the top of the cloud and $-40$ C near the bottom of the cloud. These charges are separated by about 2.0 km. What is the electric force between these two sets of charges? ($k_e = 8.99 \times 10^9$ N\(\cdot\)m\(^2\)/C\(^2\))

\[ F = k_e \frac{Q_1 Q_2}{r^2} = 3.6 \times 10^6 \text{ N} \]

12. A ping-pong ball covered with a conducting graphite coating has a mass of $5.0 \times 10^{-3}$ kg and a charge of $4.0 \mu$C. What electric field directed upward will exactly balance the weight of the ball? ($g = 9.8$ m/s\(^2\))

\[ F_e = qE = mg \quad \Rightarrow \quad E = \frac{mg}{q} \]

\[ E = 1.2 \times 10^{4} \text{ N/C} \quad (\text{or} \quad V_m) \]
13. A spherical volume of space has an electric field of intensity 100 N/C directed radially outward from its surface of radius 0.600 m. What is the net charge enclosed within this surface?

Use Gauss' Law

\[ \Phi_E = \frac{Q_{enc}}{\varepsilon_0} \]

\[ \Phi_E = E \cdot \text{Area} \quad \text{since } E \text{ is a constant at the surface of the spherical volume.} \]

\[ \text{Area (of sphere)} = 4\pi r^2, \quad r = 0.600 \text{ m} \]

Then

\[ Q_{enc} = \varepsilon_0 \left( E \cdot \text{Area} \right) \]

\[ \varepsilon_0 = \frac{1}{4\pi k_e} \]

\[ Q_{enc} = \frac{E \cdot r^2}{k_e} = 4.00 \times 10^{-9} \text{ C} = 4 \text{nC} \]