1. A charged particle with \( q = -1 \, \mu \text{C} \) and mass \( m = 20 \, \text{g} \) is confined to move along the z-axis without friction. It is initially at the origin with a velocity \( v_0 = 10 \, \text{m/s} \) in the positive z direction. Four positive point charges of same magnitude \( Q = 10 \, \mu \text{C} \) are symmetrically placed on x-axis and y-axis at (1) \( x = 10 \, \text{cm} \); (2) \( x = -10 \, \text{cm} \); (3) \( y = 10 \, \text{cm} \); and (4) \( y = -10 \, \text{cm} \).

(a) (15 points) Find the potential energy of the charged particle when it is at the origin (referenced to infinity).

(b) (15 points) Let the charged particle travel up along the z-axis. Find the z coordinate at which the particle stops moving and just begins to return back toward the origin.

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2. A long and straight coaxial cable consists of a conducting cylindrical shell (with inner radius \( b = 3 \, \text{mm} \) and outer radius \( c = 4 \, \text{mm} \)) and a concentric conducting rod of radius \( a = 1 \, \text{mm} \) inside the shell. The rod carries a charge of \(+2 \, \mu \text{C}\) per meter, while the shell carries a net charge of \(-4 \, \mu \text{C}\) per meter.

(a) (15 points) Find the potential difference between the rod and the shell.

(b) (15 points) If an electron with the charge of \(-1.6 \times 10^{-19} \, \text{C}\) moves from just outside of the outer surface of the shell outward to a location 1 m from the cylindrical axis, what is the work done to the electron by the electrostatic force?
3. In the following circuit,
   (a) (20 points) Find the currents through all resistors.
   (b) (10 points) Find the power dissipated in the 20Ω resistor.

![Circuit Diagram]

4. In the following circuit, the switch is initially open.
   (a) (10 points) Find the equivalent capacitance between a and g.
   (b) (10 points) Find the charge on the 2 µF capacitor.
   (c) (15 points) After switch S is closed for a long time, again what is the charge on the 2 µF capacitor?

![Circuit Diagram]

5. A rod-like permanent magnet has a diameter of 1 cm with the magnetic poles at the two ends of the rod. In a uniform magnetic field of 0.4 T, the maximum torque it experiences is 0.25 N·m.
   (a) (10 points) Find the magnetic dipole moment (magnitude) of the magnet.
   (b) (10 points) For a single circular current loop with same diameter of 1 cm, how much current do you need to pass through the loop in order to produce the same magnetic dipole moment?
6. A long conducting wire along x-axis carries a current of 2A in the positive x direction. Another long conducting wire along y-axis carries a current of 2A in the negative y direction.

(a) (10 points) Find the direction and magnitude of the magnetic field in the x-y plane at x = 0.1 m and y = −0.2 m

(b) (10 points) Find the direction and the magnitude of the magnetic field on the z-axis at z = 0.2 m.

7. A conducting rod \(ab\) can slide without friction on two parallel conducting rails. A resistor \(R = 2\Omega\) connects the two rails at one end (as shown). The resistances of the rails and the sliding rod can be neglected. This apparatus is placed in a constant magnetic field of \(B = 0.5T\) that points into the paper.

(a) (10 points) If an external force of \(F_{\text{ext}} = 20\text{N}\) to the right is applied to the conducting rod, the rod will gain in velocity to the right. Find the direction and the magnitude (in terms of the rod velocity) of the induced \(emf\) in the loop of \(acdb\).

(b) (10 points) When the induced \(emf\) produces a current in the \(acdb\) loop, find the direction and magnitude (in terms of the rod velocity) of the magnetic force on the conducting rod.

(c) (15 points) The rod will reach a constant velocity (the terminal velocity). Explain why so, and find the terminal velocity.