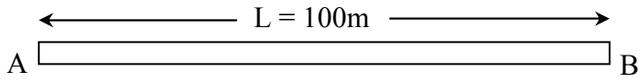
Physics 102 Midterm (2) – Solutions
Summer 2206/2007
Part I: Solve the following Problems

1. A copper wire of length L = 100 m connects two points A & B. The electric potential at point B is 25 V less than that at point A. If the resistivity of copper is 1.7×10^{-8} Ωm find the magnitude & direction of the current density in the wire.

2 Marks



$$E = \frac{\Delta V}{L} = \frac{25}{100} = 0.25\ \text{Vm}^{-1}$$

$$J = \frac{E}{\rho} = \frac{0.25}{1.7\times10^{-8}} = 1.48\times10^{7}\ \text{Am}^{-2}$$ from A to B.

2. A light bulb of 18 W power has a potential difference of 9 V across it. How much charge goes through the bulb in 4 hours?

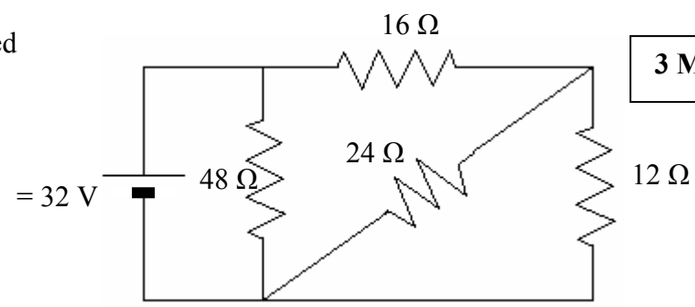
2 Marks

$$P = Vi \Rightarrow i = \frac{18}{9} = 2\text{A}$$

$$q = it = 2 \times 4 \times 3600 = 28.8 \times 10^{3}\ \text{C}$$

3. In the circuit shown find the power dissipated in the 24 Ω resistor.

3 Marks



$$\frac{1}{R_1} = \frac{1}{12} + \frac{1}{24} = \frac{3}{24} \Rightarrow R_1 = 8\ \Omega$$

$$R_2 = R_1 + 16 = 24\ \Omega$$

current through R_2 resistor $i_2 = \frac{32}{24} = \frac{4}{3}\text{A}$

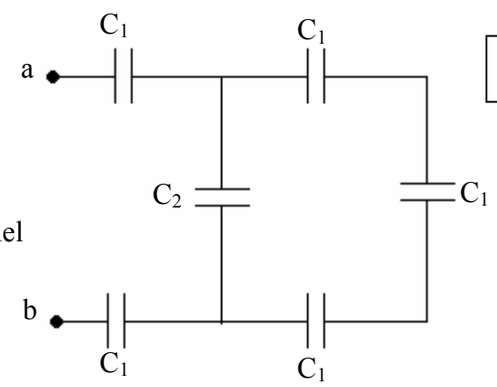
P.D across $R_1 = V_{R_1} = \frac{4}{3}R_1 = \frac{32}{3}\text{V}$

$\therefore$ P.D across 24 Ω resistor $= V_{R_1} = \frac{32}{3}\ \text{V}$

$$\Rightarrow P = \frac{V_{R_1}^2}{24} = \frac{1}{24}\left(\frac{32}{3}\right)^2 = 4.74\ \text{W}$$

4. In the figure each capacitance C_1 is 13.8 μF & the capacitance C_2 is 9.2 μF. Calculate the equivalent capacitance of the network between points a & b.

3 Marks



For the 3 capacitors on the right

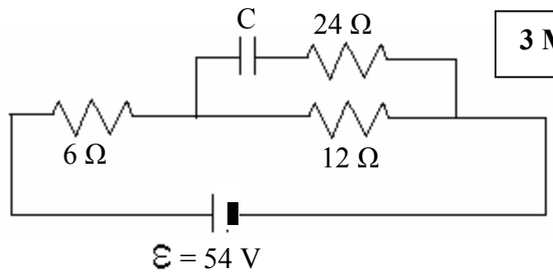
$C'_{eq} = \frac{1}{3}C_1 = 4.6\,\mu\text{F}$ C_2 & C_{eq} are in parallel

$$C''_{eq} = C_2 + C'_{eq} = 13.8\,\mu\text{F}$$

Finally C_1, C''_{eq}, C_1 are in series & as they are all equal $\Rightarrow$

$$C_{eq} = \frac{1}{3}C_1 = 4.6\,\mu\text{F}$$

5. The circuit shown in figure is used to fully charge the capacitor of capacitance C = 23 μF. Determine the final charge on the capacitor.



3 Marks

Let I be current out of the battery after capacitor is fully charged:

$$54 - (6 + 12)\,I = 0 \Rightarrow I = \frac{54}{18} = 3A$$

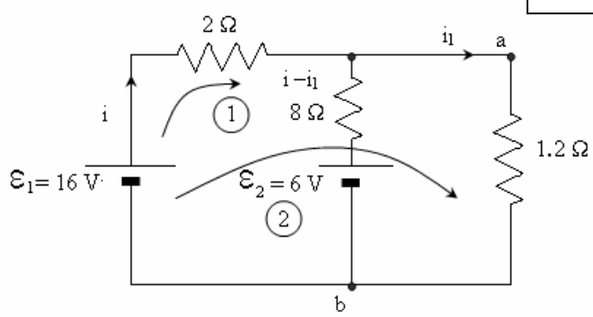
P.D across 12 Ω resistor = P.D across capacitor

$$\therefore V_c = 12 \times 3 = 36\ V$$

$$\Rightarrow Q = CV_c = 36 \times 23 = 828\,\mu C$$

6. In the circuit shown find the potential difference between points 'a' & 'b'.

4 Marks



Loop 1 : $16 - 2i - 8(i - i_1) - 6 = 0$

$$\Rightarrow 5 - 5i + 4i_1 = 0 \ldots\ldots\ldots (1)$$

Loop 2 : $16 - 2i - 1.2i_1 = 0 \ldots\ldots\ldots (2)$

X Eq (1) by 2 & Eq (2) by (5) $\Rightarrow$

$$10 - 10i + 8i_1 = 0$$
$$80 - 10i - 6i_1 = 0$$

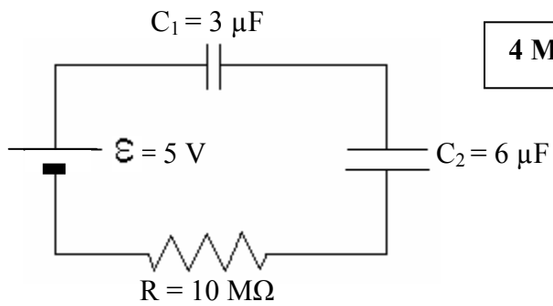
Substitute:

$$-70 + 14i_1 = 0 \quad \Rightarrow i_1 = 5\ A$$

$$V_a - 1.2i_1 = V_b \Rightarrow V_a - V_b = 6V$$

7. In the circuit shown determine the potential difference across the capacitor with capacitance $C_1 = 3\ \mu F$ at t = 20s.

4 Marks



$$q = C_{eq}\ \mathcal{E}\left(1 - e^{-t/RC_{eq}}\right)$$

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{3(6)}{3+6} = 2\,\mu F$$

RC = 20s; at t = 20s, $q = C_{eq}\ \mathcal{E}\left(1 - e^{-1}\right) = 0.63(5)(2) = 6.3\,\mu C$

$$V_1 = \frac{6.3}{C_1} = \frac{6.3}{3} = 2.1V$$

8. A spherical conductor of 5 cm radius & carrying a charge of 25 μC is immersed in an infinite dielectric medium of dielectric constant K = 2. Calculate the electrical energy stored in the system.

3 Marks

Method 1: $C = 4\pi K \in_o R$

$$C = 8\pi\left(8.85\times10^{-12}\right)\left(5\times10^{-12}\right) = 1.11\times10^{-11}\ \text{F}$$

$$U = \frac{Q^2}{2C} = \frac{(25)^2\times10^{-12}}{2.22\times10^{-11}} = 28\,\text{J}$$

Method 2:

$$dU = 4\pi r^2\, u\, dr = 4\pi r^2 \bullet \frac{1}{2} K\varepsilon_o E^2 dr = 2\pi K \in_o r^2 E^2 dr$$

$$E = \frac{Q^2}{4\pi\pi K \in_o r^2} \Rightarrow dU = \frac{Q^2}{8\pi\pi K \in_o} \frac{dr}{r^2}$$

i.e $$U = \frac{Q^2}{8\pi\pi\ K\varepsilon_o} \int_R^\infty \frac{dr}{r^2} = \frac{Q^2}{8\pi K \in_o R}$$

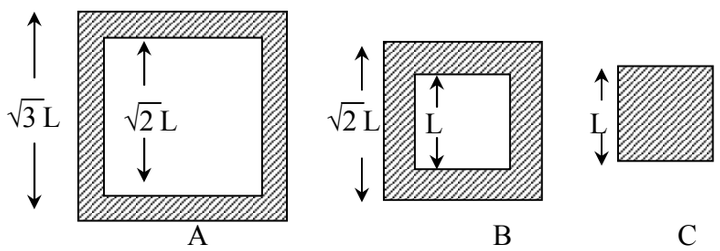
$= 28$ J

Part II: Conceptual Questions

In the following questions tick (✓) for the best answer

1. A parallel plate capacitor is charged using a battery, & the battery is then removed. The plates of the capacitor are then brought closer together. Which of the following statements is false?
   a. The electric field inside the capacitor remains the same.
   b. The capacitance of the capacitor increases.
   c. The charge on the capacitor remains the same.
   d. The potential difference between the plates of the capacitor decreases.
   ✓ **e. The energy stored in the capacitor increases.**

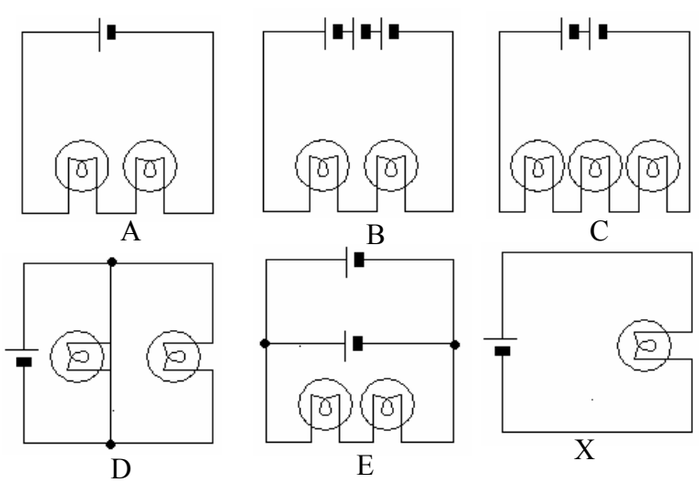
2. The figure below shows square cross sections through three long linear conductors of the same length & material. Assuming that Ohm's law is obeyed, which conductor has the greatest resistance when a potential difference is applied across its length?



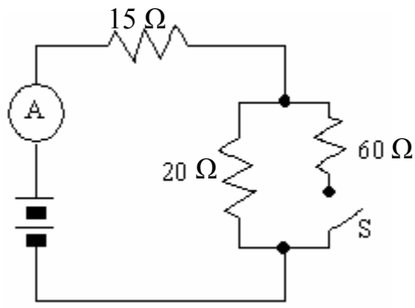
   a. Conductor A.
   b. Conductor B.
   c. Conductor C.
   ✓ **d. All three have the same resistance.**

3. Which of the following represents the emf of a battery?
   a. The chemical energy stored in the battery.
   ✓ **b. The terminal voltage of the battery when no current flows.**
   c. The maximum current that the battery can supply.
   d. The amount of charge the battery can deliver.
   e. The chemical energy of the battery divided by the net charge of the battery.

4. The bulbs in the diagram below are all identical and all emf sources are identical also. In which circuit will the total power dissipated by the bulbs equal that of circuit X?
   a. Circuit A.
   b. Circuit B.
   c. Circuit C.
   ✓ **d. Circuit D.**
   e. Circuit E.



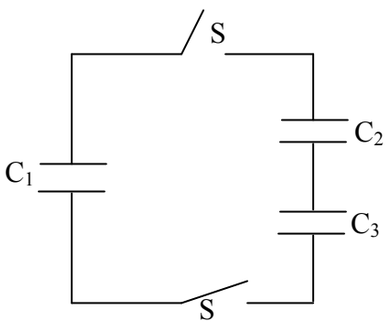
5. When switch S is open, the ammeter reads a current I. When S is closed the ammeter reading will



   a. remain the same.
   b. increase.
   c. decrease.
   d. all of the above, depending on the value of the emf.

6. The energy stored in an isolated charged spherical capacitor is U_o. If the radii of the spherical shells are doubled, the energy stored by the system becomes
   a. U_o .
   b. $2\ U_o$.
   c. $U_o/2$.
   d. $U_o/4$.

7. Before closing the switches S, capacitor C_1 carries a charge Q_o, while the other two capacitors are uncharged. Assuming $C_1 = C_2 = C_3$, the charge on the plates of C_1 after closing the switches becomes



   a. 2/3 Q_o.
   b. 3/2 Q_o.
   c. Q_o.
   d. $Q_o/2$.
   e. $Q_o/4$.

8. A dielectric is inserted between the plates of a fully charged capacitor that is connected to a battery. The dielectric completely fills the space between the plates. Compared to what it was before the dielectric was inserted, the electric field between the plates is
   a. larger in magnitude.
   b. the same.
   c. smaller in magnitude.
   d. the same in magnitude but opposite in direction.