PHYSICS 1B(b) Quiz #2 Solutions

Problem 1

Voltage $= 10\ kV = 10^4\ V$

$r = 1\ mm = 10^{-3}\ m$

$\rho = 10^3\ kg/m^3$

$$\rho = \frac{\text{mass}}{\text{Volume}} = \frac{m}{\frac{4}{3}\pi(10^{-3}\,m)^3}$$

$$\Rightarrow m = \frac{4}{3}\pi(10^{-3}m)^3 \cdot 10^3\ \frac{kg}{\cancel{m^3}}$$

$$= 4.18\times10^{-6}\ kg.$$

By conservation of energy,

$$\Delta PE = KE$$

$$\Rightarrow qV = \tfrac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2qV}{m}}$$

$$q = (10^{16}\ \cancel{\text{electrons}})\left(\frac{1.6\times10^{-19}\,C}{\cancel{\text{electrons}}}\right)$$

$$= 1.6\times10^{-3}\,C$$

$$\Rightarrow v = \sqrt{\frac{2(1.6\times10^{-3}C)(10^4V)}{4.12\times10^{-5}\,kg}}$$

$$\approx 2.78\times10^3\ m/s$$

Problem 2

$$V_y^2 = V_{0,y}^2 + 2a_y \Delta y$$

$$a_y = -g = -9.8 \text{ m/s}^2$$

Want position at top of path, so $V_y = 0$.

$$V_{0,y} = 2.78 \times 10^3 \text{ m/s}$$

$$2a_y \Delta y = -(V_{0,y})^2$$

$$\Rightarrow \Delta y = \frac{-(V_{0,y})^2}{2a_y}$$

$$= -\frac{(2.78 \times 10^3 \text{ m/s})^2}{2(-9.8 \text{ m/s}^2)}$$

$$\approx 3.94 \times 10^5 \text{ m} = 394 \text{ km}.$$

Problem 3

$$V = \frac{k|q|}{r} = \frac{(8.99\times10^{9}\ \frac{N m^2}{C^2})(1.0\times10^{-6} C)}{2\times10^{-3}\ m}$$

$$\simeq 4.5\times10^{6}\ V$$

Problem 4

$$C = \frac{\varepsilon_0 A}{d} = \frac{(8.85\times10^{-12}\ F/m)(4\times10^{-4}\ m^2)}{10^{-6}\ m}$$

$$= 3.54\times10^{-9}\ F = 3.54\ nF$$

Problem 5

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

$$C_1 = K_1 C \ , \ C_2 = K_2 C$$

$$\Rightarrow C_{eq} = \frac{(K_1 C)(K_2 C)}{(K_1 + K_2)(C)} = \frac{(K_1)(K_2)}{K_1 + K_2} C$$

$$= \frac{(15)(10)}{(15+10)} C = 6C = 2.12\times10^{-8} F$$

Problem 6

$$E = \tfrac{1}{2} C_{eq} V^2 = \tfrac{1}{2}(2.12\times10^{-8}\,F)(10\,V)^2$$
$$\approx 1.06\times10^{-6}\,J$$

Problem 7

Since the capacitors are in series, the charge on each is the same.

$$\Rightarrow Q_T = Q_1 = Q_2 = C_{eq} V = (2.12\times10^{-8}\,F)(10\,V)$$
$$= 2.12\times10^{-7}\,C$$

$$C_{\substack{\text{bottom}\\\text{capacitor}}} = (10)(3.54\times10^{-9}\,F) = 3.54\times10^{-8}\,F$$

$$\Rightarrow V_{\substack{\text{bottom}\\\text{capacitor}}} = \frac{Q}{C_{\substack{\text{bottom}\\\text{capacitor}}}} = \frac{2.12\times10^{-7}\,C}{3.54\times10^{-8}\,F} \approx 6.0\,V$$

Problem 8

$$C_{eq,\,left\ branch} = C_1 + C_2 = 5\ F$$

$$C_{eq,\,right\ branch} = \frac{C_3 C_4}{C_3 + C_4} = 2.67\ F$$

$$\Rightarrow C_{eq,\,upper} = 7.67\ F$$

$$C_{TOTAL} = \frac{(C_{eq,\,upper})(C_5)}{C_{eq,\,up} + C_5} = \frac{(7.67\ F)(3\ F)}{7.67\ F + 3\ F}$$

$$\Rightarrow C_{TOTAL} \approx 2.16\ F$$

Problem 9

$$P = \frac{I}{A}$$

$$\text{Power} = P = I\Delta V \Rightarrow I = \frac{P}{\Delta V} = \frac{100\ W}{110\ V} \approx 0.9\ A$$

$$\text{Cross-sectional area} = \pi r^2 = \pi \left(\frac{0.25 \times 10^{-3}\ m}{2}\right)^2 \approx 4.91 \times 10^{-8}\ m^2$$

$$\Rightarrow P = \frac{0.9\ A}{4.91 \times 10^{-8}\ m^2} \approx 1.83 \times 10^7\ A/m^2$$

Problem 10

$$V = IR \Rightarrow R = \frac{V}{I} = \frac{110\ V}{0.9\ A}$$

$$\Rightarrow R \approx 122\ \Omega$$