Phys 2B Summer 2022

Quiz 2 Solutions

Question 1:

The drift velocity is:

$$v_d = uE$$

The field can be calculated from the voltage drop and block's length using:

$$E = \Delta V / L$$

(We only care about the magnitude of the field and, relatedly, drift velocity, so drop the minus sign.) Substitute that in to obtain:

$$v_d = \frac{u\Delta V}{L}$$

Now plug in numbers.

$$v_d = \frac{(4.5 \times 10^{-3}\,\frac{\mathrm{m/s}}{\mathrm{V/m}})(1.6 \times 10^{-3}\,\mathrm{V})}{0.12\,\mathrm{m}} \approx \boxed{60\,\mu\mathrm{m/s}}$$

This is choice (b).

Question 2:

The electric potential energy of a pair of point charges is:

$$U = \frac{kq_1q_2}{r}$$

This system has three pairs of charges:

$$U_{\mathrm{tot}} = U_{OO} + U_{OC} + U_{CO} = U_{OO} + 2U_{CO}$$

Plug in the given values of the charges, and let $d = 116.3\,\mathrm{pm}$.

$$U_{\mathrm{tot}} = \frac{k(-2e)(-2e)}{2d} + 2\frac{k(+4e)(-2e)}{d} = \frac{ke^2}{d}\left(\frac{4}{2} - 16\right)$$

$$U_{\mathrm{tot}} = -14\frac{ke^2}{d}$$

Now plug in numbers.

$$U_{\text{tot}} \approx -14\frac{(8.988\times10^{9}\,\mathrm{Nm^2/C^2})(1.602\times10^{-19})^2}{116.3\times10^{-12}\,\mathrm{m}} \approx \boxed{-2.770\times10^{-17}\,\mathrm{J}}$$

This is choice (c)

The actual binding energy of CO_2 is closer to 10^{-18} J.

Question 3:

We are told that, at the origin:

$$V_1 + V_2 = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} = 0$$

Since the point of interest is the origin, $r_1 = x_1$ and $r_2 = x_2$.

$$\frac{q_1}{x_1} + \frac{q_2}{x_2} = 0$$

We want to solve for q_2.

$$q_2 = -q_1\frac{x_2}{x_1}$$

Now plug in numbers.

$$q_2 = -(-2.8\,\mathrm{C})\frac{2.0\,\mathrm{m}}{0.80\,\mathrm{m}} \approx \boxed{+7.0\,\mathrm{C}}$$

This is choice (d).

Question 4:

The field between two parallel plates is constant, so:

$$|E| = \frac{|\Delta V|}{\Delta x}$$

We can get $|E|$ from $|F| = |q||E| = e|E|$.

$$\frac{|F|}{e} = \frac{|\Delta V|}{\Delta x}$$

Now solve for the potential difference.

$$|\Delta V| = \frac{|F|}{e}(\Delta x)$$

Now plug in numbers.

$$|\Delta V| = \frac{2.2\times10^{-16}\,\mathrm{N}}{1.6\times10^{-19}\,\mathrm{C}}(1.9\times10^{-3}\,\mathrm{m}) \approx \boxed{2.6\,\mathrm{V}}$$

Thus, the correct choice is (a).

Question 5:

The parallel-plate capacitance formula is:

$$C = \kappa\epsilon_0 \frac{A}{d}$$

Solve for the dielectric constant κ.

$$\kappa = \frac{Cd}{A\epsilon_0}$$

Now plug in numbers.

$$\kappa = \frac{(190 \times 10^{-12}\,\mathrm{F})(0.95 \times 10^{-3}\,\mathrm{m})}{(55 \times 10^{-4}\,\mathrm{m}^2)(8.85 \times 10^{-12}\,\mathrm{F/m})} \approx \boxed{3.7}$$

This is choice (a).

Question 6:

The defining equation of capacitance is:

$$Q = CV$$

The field strength inside a parallel-capacitor is constant, so $V = Ed$, where d is the plate separation.

$$Q = CEd$$

We want to solve for E.

$$E = \frac{Q}{Cd}$$

Plug in the charge at breakdown, and this expression returns the corresponding field strength.

$$E = \frac{(22 \times 10^{-6}\,\mathrm{C})}{(1.4 \times 10^{-9}\,\mathrm{F})(0.87 \times 10^{-3}\,\mathrm{m})} \approx \boxed{1.8 \times 10^7\,\mathrm{V/m}}$$

This is choice (e).

Based on this value, there's a good chance that the unknown dielectric is rubber. Choice (a) is air, (b) is quartz, (c) is paraffin, (d) is nylon, and (e) is rubber.

Question 7:

I is true. This is in a sense a definition of what it means to be in series.

II is false. Capacitors in *parallel* have the same voltage difference, but not series.

III is false. $U = \frac{Q^2}{2C}$. Capacitors in series have the same Q, but not necessarily the same C.

This is choice (a).

Question 8:

As discussed in class, a general solution to this type of problem is:

$$Q_A = \frac{Q_i}{1 + \frac{C_B}{C_A}}$$

Plug in numbers.

$$Q_A = \frac{24\,\mathrm{nC}}{1 + \frac{75}{150}} = \frac{24\,\mathrm{nC}}{1 + 0.5} = \boxed{16\,\mathrm{nC}}$$

This is choice (d).

Question 9:

We want to apply the equation:

$$U = \frac{1}{2}CV^2$$

First, we need to calculate the equivalent capacitance of the entire network. First, the 6.0 pF and 5.0 nF capacitors are in parallel, so:

$$C_{56} = 11\,\mathrm{pF}$$

Then, this capacitor is in series with the original 11 pF capacitor.

$$C_{\mathrm{eq}} = \frac{(11\,\mathrm{pF})(11\,\mathrm{pF})}{11\,\mathrm{pF} + 11\,\mathrm{pF}} = 5.5\,\mathrm{pF}$$

Now, plug in numbers to the energy formula:

$$U = \frac{1}{2}(5.5\,\mathrm{pF})(6.0\,\mathrm{V})^2 = \boxed{99\,\mathrm{pJ}}$$

This is choice (e).

Question 10:

The power consumed by a circuit is:

$$P = IV$$

So for this particular circuit:

$$P = (0.12\,\mathrm{A})(110\,\mathrm{V}) = 13.2\,\mathrm{W}$$

Running for one second, then, consumes 13.2 J.

The cost is:

$$\text{COST} \approx (13.2\,\text{J})(1.8 \times 10^{-7}\,\$/\text{J}) \approx \boxed{\$2.4 \times 10^{-6}}$$

This is choice (a).

If you leave such a circuit on for an entire day, it costs a few cents (some of those hours will be at the off-peak rates). An entire month costs a few dollars. All of the circuits in a home combined produce the typical ∼\$100s monthly electric bills.