PS250 T1 Spring 2003. Put the letter of the best answer in the blank. Write the principle equation(s) beneath the problem.

__________ 1. Find the magnitude of the electric field at (0,4) due to a segment of charge with $\lambda = 1 \times 10^{-9}\ C/m$ stretching from y=0 to y=1 and a point charge of 2 nanocoulombs at (2,4). Answer in N/C. (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

Solution: Find the individual fields and add them. The point charge is easy. For the segment,

$$\vec{E}_1 = \int_0^1 \frac{k\lambda dy\hat{y}}{(4-y)^2} = \frac{9}{4-y}\hat{y}\bigg|_0^1 = \left(3 - \frac{9}{4}\right)\hat{y} = \frac{3}{4}\hat{y}$$

$$\vec{E}_2 = \frac{kq\hat{r}}{r^2} = \frac{18}{4}(-\hat{x})$$

Add together and find the magnitude.

__________ 2. Use Gauss's law to find the charge distribution on the outer spherical conductor. Answer in coulombs, inner surface, outer surface . (A) -7 , 4 (B) -3 , 0 (C) -5 , 2 (D) -9, 6 (E) none of these C

__________ 3. A ball of mass 5 kg is carrying a charge of 0.5 coulombs. If allowed to drop from a height of ten meters, at what speed does it hit the ground? Assume the Earth's electric field is -150 N/C, and that $g = 10m/s^2$. Answer in m/s. (A) -22 (B) -16 (C) -29 (D) -19 (E) none of these

Solution: Use elementary ballistics.

$$m\hat{a} = q\hat{E} - mg\hat{z} \rightarrow 5a = 0.5 \cdot (-150) - 5 \cdot 9.8$$

$$z = \frac{1}{2}at^2 + v_0 t + z_0 = \frac{1}{2} \cdot \frac{-124}{5}t^2 + 10$$

Set this last equation equal to zero to find the time of the drop, and then plug into the velocity equation:

$$v = at + v_0$$

__________ 4. In the absence of any other forces, how much work would be required to assemble two protons and one helium nucleus into an equilateral triangle one femtometer on a side? Answer in picojoules. (A) 3.5 (B) 2.2 (C) 1.2 (D) 5.7 (E) none of these

Solution: Use conservation of energy and the work-energy theorem.

$$W = \Delta K + \Delta U$$

Here, there is no kinetic energy at the start or at the end, so

$$W = \Delta U = U_f - U_i = \frac{kQ_pQ_{he}}{r} + \frac{kQ_pQ_{he}}{r} + \frac{kQ_pQ_p}{r}$$

__________ 5. Find the electric potential at (2,5) due to a 7 nanocoulomb charge at (2,-5) and a -4 nanocoulomb charge at (-2, 2). Answer in volts. (A) -0.5 (B) -0.9 (C) 0.3 (D) 1.2 (E) -0.7

Solution: This is no sweat. Just add up all the contributions from each charge, using

$$V = \frac{kq}{r}$$

Positive adds, negative subtracts, no vectors are needed, as long as you can find the distance between points.

__________ 6. A parallel plate capacitor with area 0.01 m^2 and plate separation of 2 mm is hooked up to a 8 V. battery. How much charge is contained, if a dielectric with constant 2.5 is put between the plates? Answer in coulombs, as a multiple of ϵ_o. (A) 24 (B) 45 (C) 67 (D) 100 (E) none of these

Solution: Just plug and chug around.

$$C = \frac{\epsilon A}{d} = \frac{K\epsilon_0 A}{d}$$

$$C = \frac{Q}{\Delta V}$$

__________ 7. Find the charge on the 2 F. capacitor in the picture. Answer in coulombs. (A) 1.55 (B) 1.94 (C) 2.86 (D) 3.21 (E) none of these

Solution: For these problems, just apply the following:

$$C = \frac{Q}{\Delta V}$$

$$C_{eq} = C_1 + C_2 \quad \text{parallel capacitors}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \quad \text{series capacitors}$$

First simplify the picture by applying the last two equations, then work your way back to the original diagram, remembering that all series capacitors have the same charge and parallel capacitors have the same voltage drop.

__________ 8. After a long time, what's the charge on the capacitor? Answer in coulombs. (A) 4.5 (B) 2.2 (C) 8.8 (D) 11.3 (E) none of these

Solution: In this problem, after a long time the capacitors are fully charged and no current flows in any circuit having a capacitor. Solve with elementary means–Kirchoff's laws and Ohm's law.

__________ 9. The drift velocity in a wire with resistance R is 5 mm/s. What's the drift velocity in a wire with same area but twice the length, if the voltage drop is the same? Answer in mm/s. (A) 1 mm/s (B) 2.5 mm/s (C) 3.3 m/s (D)

5 m/s (E) 10 mm/s

Solution: Use the following equations:

$$J = nqv_d$$

where J is the current density, n is the number density of electrons, q the charge per electron, v_d the drift velocity.

$$\Delta V = IR$$

$$R = \frac{\rho_e L}{A}$$

This is a little elaborate. The resistance is twice as great in the second wire, since it has twice the length. Since the voltage drop is the same, the second wire has half the current, hence half the current density of the first wire. This means the drift velocity will be half, also, by the first equation. __________ 10. Find the current in the 3 ohm resistor. Answer in Amperes. (A) 0.3 (B) 0.45 (C) 0.66 (D) 0.75 (E) 1.1

Solution: Use Kirchoff's laws and $\Delta V = IR$.