ALGEBRA-BASED PHYSICS-2: ELECTRICITY, MAGNETISM, AND MODERN PHYSICS (PHYS135B-01): HOMEWORK 1 SOLUTIONS

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February 19, 2018

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CHAPTER 18

Exercise 7: Let the number of protons be N_p and the number of electrons be N_e, and $q = 1.6 \times 10^{-19}$ C. For an un-charged object, the net charge must be

$$Q_{Net,i} = qN_p - qN_{e,i} = 0 \tag{1}$$

If there is a net charge $Q_{Net,f}$, then electrons have been removed and $N_{e,f} < N_{e,i}$. Thus for a charged object,

$$N_{e,f} = N_p - \frac{Q_{Net,f}}{q} \tag{2}$$

Dividing both sides by the original number of electrons yields the fraction of remaining electrons, r:

$$r = \frac{N_{e,f}}{N_{e,i}} = \frac{N_p}{N_{e,i}} - \frac{Q_{Net,f}}{qN_{e,i}} \tag{3}$$

$$r = \frac{N_{e,f}}{N_{e,i}} = \frac{N_p}{N_{e,i}} - \frac{Q_{Net,f}}{qN_{e,i}} \tag{4}$$

Recall that $N_{e,i} = N_p$. Substituting, we have

$$r = 1 - \frac{Q_{Net,f}}{qN_p} \tag{5}$$

The exercise is asking for the fraction *removed*, which is $1 - r$:

$$1 - r = \frac{Q_{Net,f}}{qN_p} \tag{6}$$

Using 50.0 g divided by 63.5 g/mol, and multiplying by 29 gives the total number of protons, $N_p \approx 1.5 \times 10^{25}$. Thus,

$$1 - r = \frac{2 \times 10^{-6}\ C}{1.6 \times 10^{-19}\ C\, 1.5 \times 10^{25}} \approx 10^{-12} \tag{7}$$

One electron in a trillion is removed.

Exercise 12: This is a scaling problem. If the force is 5.00 N, and goes as $1/r^2$, then the force must decrease to $1/(3)^2 = 1/9$ of the original value, or 5/9 N.

Exercise 15: Apply the Coulomb force:

$$F = \frac{1}{4\pi\epsilon_0}\frac{q^2}{r^2} = 9 \times 10^9 \times 1^2/10^6 \approx 10^4\ N \tag{8}$$

This is ten times the weight of a grown man, so the electrostatic force is a very strong one, if we are dealing with Coulombs of charge.

Exercise 30: a) Use the definition of the electric field E for a point charge Q at a distance r:

$$E = \frac{kQ}{r^2} \tag{9}$$

$$Q = \frac{r^2 E}{k} \approx 0.07\mu C \tag{10}$$

b) This is a scaling problem. The distance is increasing by a factor of 40, so the field drops by a factor of 1600, to 6.25 N/C.

Exercise 31: Set Newton's second law equal to the electric force on a test charge:

$$F_C = F_{Net} = m_p a = qE \tag{11}$$

$$a = \frac{qE}{m_p} = \frac{1.6 \times 10^{-19} \times 5 \times 10^{6}}{1.67 \times 10^{-27}}\ m/s^2 \tag{12}$$

$$a \approx 5 \times 10^{27+6-19} = 5 \times 10^{14}\ m/s^2 \tag{13}$$

With this acceleration the proton would reach light speed in about 600 nanoseconds.

CHAPTER 19

Exercise 13: The units of V/m and N/C are equivalent, because energy is charge times voltage:

$$U = qV \tag{14}$$

This means a Volt is 1 Joule per Coulomb, and a Joule is a Newton-meter. Thus, a Volt is a (Newton-meter) per Coulomb. Dividing both sides by a meter, we see that a Volt per meter is a (Newton-meter) per (Coulomb-meter), or a Newton per Coulomb.

Exercise 15: a) $V = Ed$, so multiply the two numbers to find 3 kV. b) Given that the potential rises from 0 to 3 kV in 4 cm, we can think of this as our charged plates in the PHeT simulation. The voltage increases linearly from 0 V, and so the slope is the electric field. Thus, $V = 7.5 \times 10^4 \times 10^{-2}$ V = 750 V.

Exercise 22: If the energy gained is 32 keV, this would mean the voltage is 32 kV for an electron. However, the ion has a net charge of two times an electron charge (positive or negative). Thus, the voltage must be 16 kV. The plates are separated by $V = Ed$, so $E = V/d$ and the result is 8 kV/cm, or $V = 8 \times 10^5$ V/m.

Exercise 37: Full points for any diagram with the following properties: 1) symmetry about a horizontal line drawn through both points where the charges are located, 2) equipotential lines are orthogonal to electric field lines, and 3) the fact that $V \propto r^{-1}$, meaning that all points on an equipotential line must have an equal amount of $1/r_1 + 1/r_2$, where r_1 and r_2 are the distances to the two charges.

Exercise 47: Definition of capacitance: $Q = CV = 8 \times 5.5 \times 10^{-12}$ C, so 44 pC.

Exercise 60: The two capacitors on the left side add together like $1/C = 1/C_1 + 1/C_2$, so $C = (C_1)(C_2)/(C_1 + C_2)$. This new capacitance, C, adds with the capacitor on the right, C_3 like $C + C_3$. Thus, the total is $C_{tot} = (C_1)(C_2)/(C_1 + C_2) + C_3 \approx 5.4 \mu F$.