HW #2 Solutions

Ch 16

Q14) A negative charge can be used to determine the electric field. The magnitude of $\vec{E}$ is still $\frac{F}{q}$, but the direction of $\vec{E}$ is opposite to the direction of the force on the negative charge.

Q18) The electric field at any point in space has a unique magnitude and direction. If the lines crossed, then at the crossing point the field would have two directions, which doesn't make sense.

Q20) Suppose Q is to the left of 2Q. In both cases there is a point along the line that passes through them where E = 0. If the charges have the same polarity, then between the two charges, but closer to Q, the electric field due to Q and the electric field due to 2Q will be in opposite directions and have the same magnitude, and thus cancel. If the charges have the opposite polarity, then to the left of Q there is a point where the fields will have the same magnitude and opposite directions.

Ch 17

Q2) A negative charge released from rest will move toward a region of higher potential. A positive charge will move toward a region of lower potential. In both cases the potential energy decreases.

Ch 16

P23) $F = qE = (1.6 \times 10^{-19} C)(2360 \frac{N}{C}) = 3.8 \times 10^{-16} N$. Direction is west since it is a negative charge.

P26) $E = \frac{kQ}{r^2} = \frac{(9.0 \times 10^9 \frac{N \cdot m^2}{C^2})(33.0 \times 10^{-6} C)}{(0.20m)^2} = 7.4 \times 10^6 \frac{N}{C}$. Direction is up (away from the + charge).

P29) Roughly the same as Fig. 16-31c in textbook except that lines are reversed and three times as many lines entering -3Q as leaving +Q.

P36) Electric field at P due to Q1 is $E = \frac{kQ_1}{x^2}$, to the right. Electric field at P due to Q2 is $E = \frac{kQ_2}{(12 + x)^2}$, to the left. Setting these two equal, plugging in the charge values and dividing both sides by $25k$ gives $\frac{1}{x^2} = \frac{2}{(12+x)^2}$. There are two ways to solve this. One is to cross multiply and expand $(12+x)^2$. This gives $144 + 24x + x^2 = 2x^2$, or $x^2 - 24x - 144 = 0$. Using the quadratic formula gives $x = \frac{24 \pm \sqrt{596 - 4(1)(-144)}}{2} = \frac{24 \pm \sqrt{1172}}{2} = \frac{24 \pm 34.2}{2}$ = 29 cm or -5.1. The negative answer does not make sense but 29 cm does.

The easier way to solve $\frac{1}{x^2} = \frac{2}{(12+x)^2}$ is to just take the square root of both sides. Then cross multiplying gives $12 + x = \sqrt{2}x$. From this we get $\sqrt{2}x - x = 12$ or $x = \frac{12}{\sqrt{2} - 1} = 29$ cm.

Two things to note: 1) We do not have to convert to m or C to do this problem, as long as we use the same units for both values of E. 2) The point P is 29 cm from Q1 and 41 cm from Q2. $\frac{41}{29} = \sqrt{2}$. Because E is inversely proportional to r^2 and proportional to Q, a factor of 2 in charge is balanced by a factor of $\sqrt{2}$ in distance.

P40) Point P is a distance $\sqrt{x^2 + a^2}$ from each charge. Therefore, the magnitude of the electric field due to each charge is $E = \frac{kQ}{r^2} = \frac{kQ}{x^2 + a^2}$. The field due to +Q is away from the + charge and the field due to –Q is toward the – charge. If we imagine a coordinate system where +x is to the right and +y is up, then the x-components of the two fields cancel and the y-components are both in the –y-direction and add. Thus the electric field at P = $2E_y$, and is in the negative y-direction. If we define θ as the angle that E makes with the x-axis, then one can show that $E_y = E\sin\theta$, and $\sin\theta = \frac{a}{\sqrt{x^2 + a^2}}$. This then yields

$$\vec{E} = 2E_y = 2(-E\sin\theta) = 2\left(\frac{kQ}{x^2 + a^2}\right)\left(\frac{a}{\sqrt{x^2 + a^2}}\right) = \frac{2kQa}{(x^2 + a^2)^{\frac{3}{2}}}$$

. This is the magnitude of $\vec{E}$. The direction is in the – y direction, or down for the arrangement shown in the textbook.

P59) $\vec{F} = m\vec{a}$. For uniform circular motion, the magnitude of the acceleration is given by $a = \frac{v^2}{r}$. For an electron in orbit around a proton, the magnitude of the force is $F = \frac{kQ_eQ_p}{r^2}$. Thus, $\frac{kQ_eQ_p}{r^2} = m_e\frac{v^2}{r}$. Solving for r gives $r = \frac{kQ_eQ_p}{m_ev^2} = 2.1 \times 10^{-10}$m.

Ch 17

P4) By conservation of energy, the increase in KE must be offset by a decrease in PE. Thus ΔPE = -7.45×10^{-16} J. The minus sign indicates that the final PE is less than the initial.

$$\text{Potential Difference } = V_B - V_A = \frac{PE_B}{q} - \frac{PE_A}{q} = \frac{\Delta PE}{q} = \frac{-7.45\times10^{-16} J}{-1.6\times10^{-19} C} = 4600 \text{ V}.$$

Notice the – sign on q. The potential difference is positive, indicating that the final potential is greater than the initial potential, thus plate B is at the higher. Alternatively you could not worry about the signs and then just argue that negative charges will feel a force toward a higher potential, and since the electron is accelerating toward B, B must be at the higher potential.

AP1

a) F=qE=$(1.6\times10^{-19}$C)(1200N/C)= 1.92×10^{-16}N
b) North
c) a=F/m = 1.92×10^{-16}N/9.11×10^{-31}kg=2.1×10^{14}m/s^2. Wow! That is a huge acceleration compared to what we are used to seeing from last semester.
d) $v=v_0+at$, $v_0 = 0$ so t=v/a=5.7×10^{-8}s. Wow, that is a really short time to reach such a high speed (1.2×10^7m/s). That speed is about 13,000 miles/sec, or halfway around the earth in 1 second.

AP2

a) We need to find Fe. Then knowing k and r we can find Q. From lab we know $F_e=F_t\sin\theta$, and $mg=F_t\cos\theta$. We also know that $\sin\theta=x/L=8/40=0.2$, so $\theta=11.5°$. Using $mg=F_t\cos\theta$, we find

$$F_t = \frac{mg}{\cos\theta} = \frac{0.0001kg(9.8\frac{m}{s^2})}{\cos(11.5°)} = .0010N.$$ Then we get

$F_e = F_t\sin\theta = (0.0010N)\sin(11.5°) = 0.00020N$. Setting this equal to $F_e = \frac{kQQ}{r^2}$, putting in r = 0.05m, and solving for Q gives

Q = 7.5×10^{-9} C.

b) # protons = 7.5×10^{-9} C/1.6×10^{-19} C/proton=4.7×10^{10} protons.

AP3

a) To counter gravity, the force on the oil drop must be up. Since the field is down, the charge on the oil drop must be negative.
b) The net force on the oil drop is 0. The only two forces acting are the gravitational force and the force from the electric field. Thus, mg=qE and q = mg/E = $(7.86\times10^{-15}$ kg $\times$ 9.8 m/s^2)/1.605$\times10^5$ N/C = 4.8$\times10^{-19}$ C.
c) This is 3 fundamental charges, i.e. the charge of three electrons.