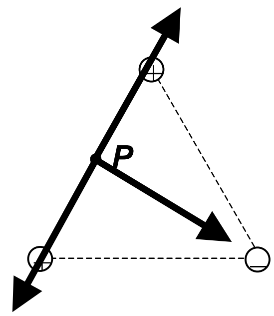
Physics 112 Fall 2000: Answers to Exam #1

1. ***Answer: I*** The diagram shows the three electric field vectors at point P, due to the three separate source charges. Two of the vectors cancel each other out, and so the net field points toward the negative charge.



2. ***Answer: I.***

$$\frac{F_{new}}{F_{old}} = \frac{\left[\dfrac{kq_1q_2}{r_{new}^2}\right]}{\left[\dfrac{kq_1q_2}{r_{old}^2}\right]} = \frac{r_{old}^2}{r_{new}^2} = \frac{(63\ m)^2}{(0.20\ m)^2} = \frac{3969\ m^2}{0.04\ m^2} = 99225$$

and so we have:

$$F_{new} = 99225\, F_{old} = (99225)(4\ N) = 396{,}900\ N$$

3. ***Answer: C.*** At the origin, the electric field due to the negative charge points in the same direction as the electric field due to the two positive charges. Therefore, to get the magnitude of the net field, we just have to *add* the magnitudes of the three individual fields. This gives $E_{net} = [k(2)/1] + [k(2)/4] + [k(2)/4] = 3k$ N/C $= 2.7 \times 10^{10}$ N/C.

4. ***Answer: A.*** **A** Initial distance between charges is 5 m, final distance is 4 m. The change in the kinetic energy is zero, $\Delta KE = 0$.

$W = \Delta TE = \Delta PE = PE(final) - PE(initial) = kQq/r_{final} - kQq/r_{initial} = kQq/4 - kQq/5 = (1/20)\, kQq = (1/4)\,(kQq/5) = (1/4)\,(40\ J) = 10J.$

5. ***Answer: C.*** $F = qE$, and the magnitude of the electric field E is determined solely by the source charges. Every test charge will experience the same electric field at that point. However, the *force* on the test charge will depend on the magnitude of the test charge, since $F_{qtest} = q_{test}E$. Therefore the force on a $3q$ test charge will be three times the magnitude of the force on a test charge q.

6. $\boldsymbol{F} = \dfrac{\boldsymbol{k q_1 q_2}}{\boldsymbol{r}^2} = \dfrac{\left(9\times10^{9}\ \boldsymbol{Nm}^2/\boldsymbol{C}^2\right)\left(1.6\times10^{-19}\ \boldsymbol{C}\right)\left(1.6\times10^{-19}\ \boldsymbol{C}\right)}{\left(5\times10^{-11}\ \boldsymbol{m}\right)^2} = 9.22\times10^{-8}\ \boldsymbol{N}$

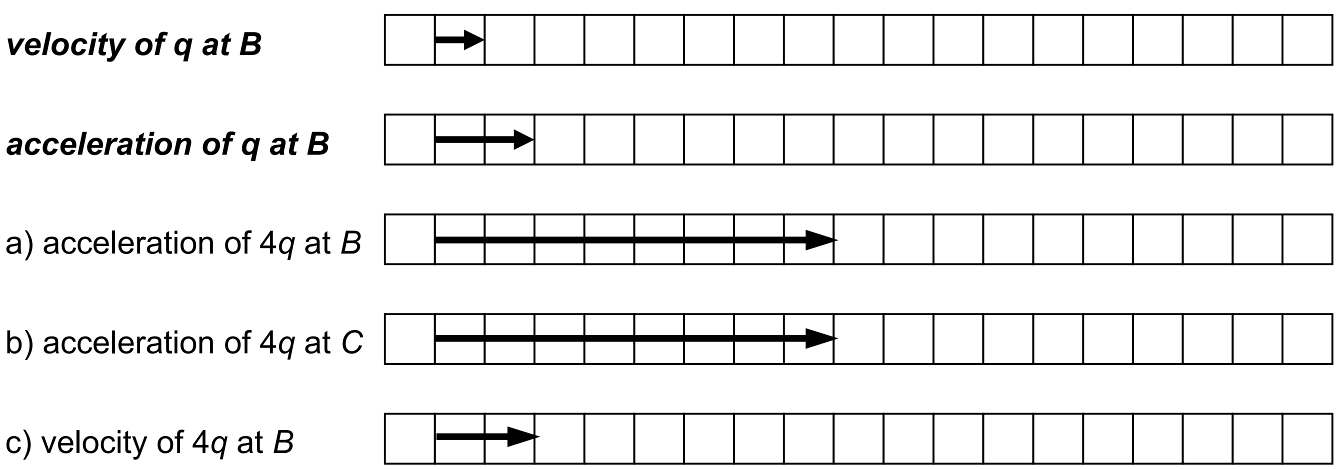
7.

A. ***Answers: 2, 4, 5.*** The charge will experience a force with unchanging magnitude, and so its acceleration also will not change. However, its velocity (and so its speed) will continuously increase. Since the kinetic energy is given by $KE = ½\ mv^2$, the kinetic energy will also always increase. The work done on an object when acted upon by a constant force is given by $W = Fd \cos\theta$. Here, we will have $W = Fd = qEd$. The charge q and the electric field E don't change and so as the distance traveled increases, the total work done on the charge by the electrical force will continue to increase.

B. ***Answer: 6.*** The total energy of the charge will remain constant because it is only acted upon by the electrical force, which is a conservative force. As the kinetic energy increases, the potential energy must decrease.

C. ***Answers: 1, 3, 7.*** See explanations for A and B above.

8.



(Explanation on next page)

Explanation for #8: The force acting on the charge is given by $F = qE$. Since the acceleration of the charge is given by $a = F/m$, we have that $a = F/m = qE/m$. The electric field is uniform so the acceleration will not change as the charge moves. To compare the acceleration of the two charges, we find:

$\frac{a_{4q}}{a_q} = \frac{4qE/m}{qE/m} = 4$, so we see that $a_{4q} = 4a_q$. That means that the acceleration vector of the 4q charge should be four times as long as that of the q charge, and so we draw it 8 squares long.

Now, to find the velocity of the 4q charge at point B, we can compare the amount of kinetic energy gained by the two charges as they travel from A to B. That will allow us to compare the velocities. (Note that both charges start with $KE = 0$, and so the KE at point B is equal to the ΔKE in going from point A to point B.) We have:

$$\frac{KE_{4q}^{at\,B}}{KE_q^{at\,B}} = \frac{\Delta KE_{4q}^{A\to B}}{\Delta KE_q^{A\to B}} = \frac{W_{4q}}{W_q} = \frac{F_{4q}\,d}{F_q\,d} = \frac{4qEd}{qEd} = 4$$

Now we can compare the velocities at point B, since $\frac{\frac{1}{2}mv_{4q}^2}{\frac{1}{2}mv_q^2} = 4$. Then we have:

$v_{4q}^2 = 4v_q^2 \quad \Rightarrow \quad v_{4q} = \sqrt{4v_q^2} = 2v_q$ and so we see that the velocity of the 4q charge at point B is twice that of the q charge at point B. Therefore we draw the velocity vector of the 4q charge *two* boxes long, instead of one.

9.

A. ***DOWN.*** Since the force on the positive test charge is in the "down" direction, the direction of the electric field must be "down."

B. ***6 N/C.*** This follows from $E = F/q$ = 18 N/3 C = 6 N/C.

C. ***UP.*** Since the force on the positive test charge is "down," the force on the negative charge would be "up."

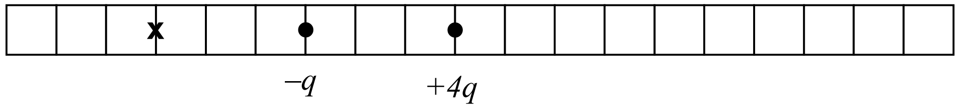
D. ***72 N.*** We know that the electric field has a magnitude of 6 N/C, so the force on the –12 C test charge would be given by $F = qE$ = (12 C) (6 N/C) = 72 N. (Here we only consider the magnitude of the charge, not its sign.)

E. ***DOWN.*** The direction of the electric field does not depend on the test charge. We have already determined – in question (A) – that the direction of the electric field is "down."

F. ***6 N/C.*** The magnitude of the electric field does not depend on the test charge. We have already determined – in question (B) – that the magnitude of this field is 6 N/C.

10. A**. *Answer: 1***

C.



B. At any point *between* the two charges, the electric field vector from each of the charges points to the left. Therefore, there is no point between the charges where the fields could cancel each other out to leave a zero net field.

At all locations to the *right* of the +4q charge, the electric field due to that charge points to the right and the field due to the negative charge points to the left. However, at all points in this region the field due to the 4q charge will be stronger than that due to the –q charge. This is because $E = kq/r^2$ and every point in this region is closer to the +4q charge (so "r" is smaller), and the 4q charge has larger magnitude than the –q charge. Therefore the field from the –q charge can never be large enough to cancel the field from the +4q charge.

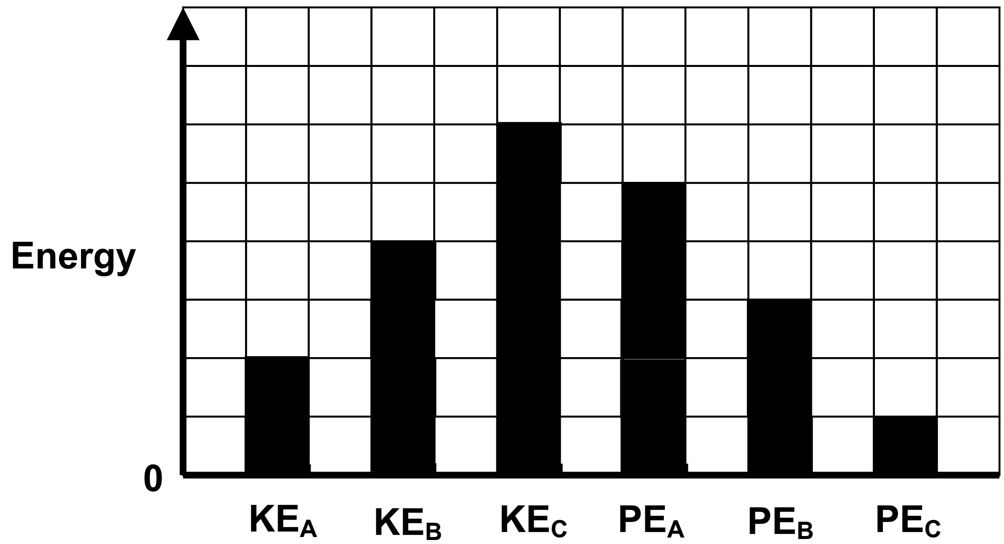
In the region to the left of the –q charge, the electric field produced by that charge points to the right and the field produced by the +4q charge points to the left. Since they have opposite directions, they will cancel each other out if their magnitudes are equal. Then we need: $\frac{\boldsymbol{kq}}{\boldsymbol{r}^2} = \frac{\boldsymbol{k}(4\boldsymbol{q})}{(\boldsymbol{r}+3)^2}$ Here, r represents the distance from the –q charge to the point where we are finding the net field. This point will be 3 squares farther away from the +4q charge than it is from the –q charge, and so we represent that distance by (r + 3).

Then we get:

$$\frac{1}{\boldsymbol{r}^2} = \frac{4}{(\boldsymbol{r}+3)^2} \quad \Rightarrow \quad 4\boldsymbol{r}^2 = \boldsymbol{r}^2 + 6\boldsymbol{r} + 9 \quad \Rightarrow \quad 3\boldsymbol{r}^2 - 6\boldsymbol{r} - 9 = 0$$

We can factor this as $[(3\boldsymbol{r}+3)(\boldsymbol{r}-3)] = 0$ and so we find solutions of $r = 3$ and $r = –1$. The solution that relates to the region to the left of the –q charge is $r = 3$ (which is a point that is a distance *six* boxes from the +4q charge). (The solution $r = –1$ corresponds to a point between the charges. Although the magnitudes of the two electric fields are equal at that point, their directions are the same and so they will not cancel at that point.)

11. The charge loses four units of kinetic energy between points C and A. Since the distance traveled from C to B is the same as that between B and A, and $\Delta KE = W = Fd = qEd$, the charge must lose two units of kinetic energy going from C to B, and the other two going from B to A. The amount of potential energy *gained* will equal the amount of kinetic energy *lost* along each step of the way.



12.