Workbook Chapter 4 Homework Answers

1. See sheets.

2. See sheets.

3. If a positive test charge (for example) is placed at rest near q_1 ***or*** q_2 and then allowed to move freely, the test charge will accelerate due to the electrical force. Therefore, its KE will increase and its PE will decrease ($\Delta TE = 0$). If a positive charge goes toward ***lower*** PE, then it is also going toward lower V (potential), since $V = PE/q$. In this case, we can see that the test charges will be moving ***away*** from both q_1 and q_2 (i.e., moving toward lower V), so there must be a repulsive force, and therefore q_1 and q_2 are both ***positive.***

4. For a test charge q_{test}, we know that its potential energy near q_1 is given by $PE = kq_1 q_{test} / r$, so we can see that the ***potential*** V that it experiences near q_1 is given by

$$V_{q_1} = \frac{PE(q_{test})}{q_{test}} = \frac{kq_1}{r} \quad [potential\ near\ q_1]$$

For q_2 we will have

$$V_{q_2} = \frac{kq_2}{r} \quad [potential\ near\ q_2]$$

If we compare point D (3 meters away from q_1) and point F (6 meters away from q_2), we see that the potential is 1.0 volt at ***both*** of these points. This means that

$$1.0\ volt = \frac{kq_2}{6} = \frac{kq_1}{3}$$

And from this we can figure out that $q_2 = 2\ q_1$.

5. As shown in #4, $q_1 / q_2 = 0.5$

6. We can read off from the diagram the following values:

    $V_A > 2.0$ V
    $V_B = 1.0$ V
    $V_C = 2.0$ V
    $V_D = 1.0$ V
    $V_E \approx 0.6$ V [approximately]
    $V_F = 1.0$ V
    $V_G \approx 0.75$ V [approximately, but certainly larger than V_E)

From this list, we can rank them as follows: A > C > B = D = F > G > E

[A, C, B = D = F, G, E]

7. The magnitude of the electric field in the vicinity of an isolated point charge Q (such as q_1 and q_2) is given by the equation $E = kQ/r^2$. Using this formula, and our result from #5 that $q_2 = 2\,q_1$, we can determine the value of E at all of the given points, in terms of k and q_1, as follows:

   $E_A = k\,q_2\,/(2.5\text{ m})^2 = k\,q_2\,/(6.25\text{ m}^2) = k\,(2q_1)/\,(6.25\text{ m}^2) = k\,q_1/\,(3.125\text{ m}^2)$

   $E_B = k\,q_2\,/(6\text{ m})^2 = k\,q_2\,/(36\text{ m}^2) = k\,(2q_1)/\,(36\text{ m}^2) = k\,q_1/\,(18\text{ m}^2)$

   $E_C = k\,q_2\,/(3\text{ m})^2 = k\,q_2\,/(9\text{ m}^2) = k\,(2q_1)/\,(9\text{ m}^2) = k\,q_1/\,(4.5\text{ m}^2)$

   $E_D = k\,q_1\,/(3\text{ m})^2 = k\,q_1\,/(9\text{ m}^2)$

   $E_E \approx k\,q_1\,/(5.5\text{m})^2 = k\,q_1\,/(30.25\text{m}^2)$ [approximately]

   $E_F = k\,q_2\,/(6\text{ m})^2 = k\,q_2\,/(36\text{ m}^2) = k\,(2q_1)/\,(36\text{ m}^2) = k\,q_1/\,(18\text{ m}^2)$

   $E_G \approx k\,q_1\,/(4.6\text{m})^2 = k\,q_1\,/(21.16\text{m}^2)$ [approximately]

   This now gives the following ranking: $E_A > E_C > E_D > E_B = E_F > E_G > E_E$

   [A, C, D, B = F, G, E]

8. From the list in #6, we can determine the following:

   A > (2.0 V – 1.0 V) > 1.0 V
   B = (1.0 V – 1.0 V) = 0 V
   C = |1.0 V – 2.0 V| = 1.0 V
   D = (1.0 V – 0.6 V) ≈ 0.4 V
   E = (1.0 V – 1.0 V) = 0 V

   This gives the following ranking: A > C > D > B = E
   [A, C, D, B = E]

9. Since only the electrical force is acting in this case, the total energy TE is constant, so $\Delta TE = 0$, which means that $\Delta KE + \Delta PE = 0$. The protons are all the same mass, so whichever acquires the most kinetic energy will be the one with the fastest speed (since $KE = ½\,mv^2$). Since $\Delta KE = -\,\Delta PE$, the proton that loses the largest amount of potential energy will acquire the largest amount of kinetic energy. Now, since $\Delta PE = \Delta V/q$, and these are all positive charges of the same magnitude, the largest loss of potential energy will be associated with the largest loss of ***potential***. Then all we have to do is find out which proton experiences the largest decrease in potential.

   Proton A goes from point A to point B, and so experiences a change in potential from ≈ 2.5 V to 1.0 V; therefore its decrease in potential is approximately 1.5 V.

   Proton B goes from point D to point E; its potential goes from 1.0 V to approximately 0.6 V, so its decrease in potential is approximately 0.4 V.

   Proton C goes from point D out to a point 100 km from the origin. That far away from the origin, the potential will be very close to 0 V, so this proton experiences a decrease in potential of nearly 1.0 V.

   From this, we can rank the final speeds of the protons as follows: A > C > B.

10. In this situation, the kinetic energy of the protons does not change. However, external work is being done by a nonconservative force (you, pushing). Since $W_{nonconservative} = \Delta TE$, in this case the amount of work you have to do is equal to the ***increase*** in potential energy, ΔPE (because here, $\Delta KE = 0$). For the same reasons as discussed in #9, the largest increase in potential energy will be associated with the largest increase in ***potential.*** Therefore, the ***most*** work will have to be done on the proton that experiences the largest increase in ***potential***, which is proton A. Again, the correct ranking will be A > C > B.