Homework week 2

5. SSM ***REASONING*** The only force acting on the moving electron is the conservative electric force. Therefore, the total energy of the electron (the sum of the kinetic energy KE and the electric potential energy EPE) remains constant throughout the trajectory of the electron. Let the subscripts A and B refer to the initial and final positions, respectively, of the electron. Then,

$$\tfrac{1}{2}mv_A^2 + \text{EPE}_A = \tfrac{1}{2}mv_B^2 + \text{EPE}_B$$

Solving for v_B gives

$$v_B = \sqrt{v_A^2 - \frac{2}{m}(\text{EPE}_B - \text{EPE}_A)}$$

Since the electron starts from rest, $v_A = 0\,\text{m/s}$. The difference in potential energies is related to the difference in potentials by Equation 19.4, $\text{EPE}_B - \text{EPE}_A = q(V_B - V_A)$.

SOLUTION The speed v_B of the electron just before it reaches the screen is

$$v_B = \sqrt{-\frac{2q}{m}(V_B - V_A)} = \sqrt{-\frac{2(-1.6\times10^{-19}\ \text{C})}{9.11\times10^{-31}\ \text{kg}}(25\,000\ \text{V})} = \boxed{9.4\times10^7\ \text{m/s}}$$

7. ***REASONING*** The energy to accelerate the car comes from the energy stored in the battery pack. Work is done by the electric force as the charge moves from point *A* (the positive terminal), through the electric motor, to point *B* (the negative terminal). The work W_{AB} done by the electric force is given by Equation 19.4 as the product of the charge and the potential difference $V_A - V_B$, or $W_{AB} = q_0(V_A - V_B)$. The power supplied by the battery pack is the work divided by the time, as expressed by Equation 6.10a.

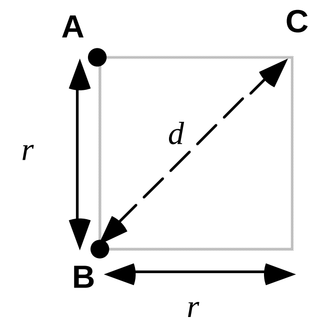
SOLUTION According to Equation 6.10a, the power *P* supplied by the battery pack is

$$P = \frac{W_{AB}}{t} = \frac{q_0(V_A - V_B)}{t} = \frac{(1200\ \text{C})(290\ \text{V})}{7.0\ \text{s}} = 5.0\times10^4\ \text{W}$$

Since 745.7 W = 1 hp (see the page facing the inside of the front cover of the text), the power rating, in horsepower, is

$$(5.0\times10^4\ \text{W})\left(\frac{1\ \text{hp}}{745.7\ \text{W}}\right) = \boxed{67\ \text{hp}}$$

15. SSM WWW ***REASONING*** Initially, suppose that one charge is at C and the other charge is held fixed at B. The charge at C is then moved to position A. According to Equation 19.4, the work W_{CA} done by the electric force as the charge moves from C to A is $W_{CA} = q(V_C - V_A)$, where, from Equation 19.6, $V_C = kq/d$ and $V_A = kq/r$. From the figure at the right we see that $d = \sqrt{r^2 + r^2} = \sqrt{2}r$. Therefore, we find that



$$W_{CA} = q\left(\frac{kq}{\sqrt{2}r} - \frac{kq}{r}\right) = \frac{kq^2}{r}\left(\frac{1}{\sqrt{2}} - 1\right)$$

SOLUTION Substituting values, we obtain

$$W_{CA} = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(3.0\times10^{-6}\ \text{C})^2}{0.500\ \text{m}}\left(\frac{1}{\sqrt{2}} - 1\right) = \boxed{-4.7\times10^{-2}\ \text{J}}$$

19. SSM ***REASONING*** Initially, the three charges are infinitely far apart. We will proceed as in Example 8 by adding charges to the triangle, one at a time, and determining the electric potential energy at each step. According to Equation 19.3, the electric potential energy EPE is the product of the charge q and the electric potential V at the spot where the charge is placed, EPE = qV. The total electric potential energy of the group is the sum of the energies of each step in assembling the group.

SOLUTION Let the corners of the triangle be numbered clockwise as 1, 2 and 3, starting with the top corner. When the first charge (q_1 = 8.00 μC) is placed at a corner 1, the charge has no electric potential energy, $\text{EPE}_1 = 0$. This is because the electric potential V_1 produced by the other two charges at corner 1 is zero, since they are infinitely far away.

Once the 8.00-μC charge is in place, the electric potential V_2 that it creates at corner 2 is

$$V_2 = \frac{kq_1}{r_{21}}$$

where r_{21} = 5.00 m is the distance between corners 1 and 2, and q_1 = 8.00 μC. When the 20.0-μC charge is placed at corner 2, its electric potential energy EPE_2 is

$$\text{EPE}_2 = q_2 V_2 = q_2\left(\frac{kq_1}{r_{21}}\right)$$

$$= \left(20.0\times10^{-6}\ \text{C}\right)\left[\frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(8.00\times10^{-6}\ \text{C}\right)}{5.00\ \text{m}}\right] = 0.288\ \text{J}$$

The electric potential V_3 at the remaining empty corner is the sum of the potentials due to the two charges that are already in place on corners 1 and 2:

$$V_3 = \frac{kq_1}{r_{31}} + \frac{kq_2}{r_{32}}$$

where q_1 = 8.00 μC, r_{31} = 3.00 m, q_2 = 20.0 μC, and r_{32} = 4.00 m. When the third charge
(q_3 = −15.0 μC) is placed at corner 3, its electric potential energy EPE_3 is

$$\text{EPE}_3 = q_3 V_3 = q_3\left(\frac{kq_1}{r_{31}} + \frac{kq_2}{r_{32}}\right) = q_3 k\left(\frac{q_1}{r_{31}} + \frac{q_2}{r_{32}}\right)$$

$$= \left(-15.0\times10^{-6}\ \text{C}\right)\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(\frac{8.00\times10^{-6}\ \text{C}}{3.00\ \text{m}} + \frac{20.0\times10^{-6}\ \text{C}}{4.00\ \text{m}}\right) = -1.034\ \text{J}$$

The electric potential energy of the entire array is given by

$$\text{EPE} = \text{EPE}_1 + \text{EPE}_2 + \text{EPE}_3 = 0 + 0.288\ \text{J} + (-1.034\ \text{J}) = \boxed{-0.746\ \text{J}}$$