Homework week 4

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1. $\boxed{\text{SSM}}$ ***REASONING AND SOLUTION*** Combining Equations 19.1 and 19.3, we have

$$W_{AB} = \text{EPE}_A - \text{EPE}_B = q_0(V_A - V_B) = (+1.6\times10^{-19}\,\text{C})(0.070\,\text{V}) = \boxed{1.1\times10^{-20}\ \text{J}}$$

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2. ***REASONING*** When the electron moves from the ground to the cloud, the change in its electric potential energy is $\Delta(\text{EPE}) = \text{EPE}_{\text{cloud}} - \text{EPE}_{\text{ground}}$. (Remember that the change in any quantity is its final value minus its initial value.) The change in the electric potential energy is related to the change ΔV in the potential by $\Delta(\text{EPE}) = q_0\Delta V$ (Equation 19.4), where q_0 is the charge on the electron. This relation will allow us to find the change in the electron's potential energy.

SOLUTION The difference in the electric potentials between the cloud and the ground is $\Delta V = V_{\text{cloud}} - V_{\text{ground}} = 1.3 \times 10^8$ V, and the charge on an electron is $q_0 = -1.60 \times 10^{-19}$ C. Thus, the change in the electron's electric potential energy when the electron moves from the ground to the cloud is

$$\Delta(\text{EPE}) = q_0\,\Delta V = \left(-1.60\times10^{-19}\ \text{C}\right)\left(1.3\times10^{8}\ \text{V}\right) = \boxed{-2.1\times10^{-11}\ \text{J}}$$

4. ***REASONING*** Equation 19.1 indicates that the work done by the electric force as the particle moves from point A to point B is $W_{AB} = \text{EPE}_A - \text{EPE}_B$. For motion through a distance s along the line of action of a constant force of magnitude F, the work is given by Equation 6.1 as either $+Fs$ (if the force and the displacement have the same direction) or $-Fs$ (if the force and the displacement have opposite directions). Here, $\text{EPE}_A - \text{EPE}_B$ is given to be positive, so we can conclude that the work is $W_{AB} = +Fs$ and that the force points in the direction of the motion from point A to point B. The electric field is given by Equation 18.2 as $\mathbf{E} = \mathbf{F}/q_0$, where q_0 is the charge.

SOLUTION a. Using Equation 19.1 and the fact that $W_{AB} = +Fs$, we find

$$W_{AB} = +Fs = \text{EPE}_A - \text{EPE}_B$$

$$F = \frac{\text{EPE}_A - \text{EPE}_B}{s} = \frac{9.0\times10^{-4}\ \text{J}}{0.20\ \text{m}} = \boxed{4.5\times10^{-3}\ \text{N}}$$

As discussed in the reasoning, the direction of the force is $\boxed{\text{from } A \text{ toward } B}$.

b. From Equation 18.2, we find that the electric field has a magnitude of

$$E = \frac{F}{q_0} = \frac{4.5\times10^{-3}\ \text{N}}{1.5\times10^{-6}\ \text{C}} = \boxed{3.0\times10^{3}\ \text{N/C}}$$

The direction is the same as that of the force on the positive charge, namely $\boxed{\text{from } A \text{ toward } B}$.

5. ***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 $W_{\text{AB}} = q_0(V_A - V_B)$. 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

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

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

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

23. $\boxed{\text{SSM}}$ ***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

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