18. We find the potential energy of the system of charges by adding the work required to bring the three electrons in from infinity successively. Because there is no potential before the electrons are brought in, for the first electron we have

$W_1 = (-e)V_0 = 0.$

When we bring in the second electron, there will be a potential from the first:

$W_2 = (-e)V_1 = (-e)k(-e)/r_{12} = ke^2/d.$

When we bring in the third electron, there will be a potential from the first two:

$W_3 = (-e)V_2 = (-e)\{[k(-e)/r_{13}] + [k(-e)/r_{23}]\} = 2ke^2/d.$

The total work required is

$W = W_1 + W_2 + W_3 = (ke^2/d) + (2ke^2/d) = 3ke^2/d$

$= 3(9.0\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(1.60\times10^{-19}\ \text{C})^2/(1.0\times10^{-10}\ \text{m}) = \boxed{6.9\times10^{-18}\ \text{J}} = 43\ \text{eV}.$

19. (*a*) We find the electric potentials at the two points:

$V_a = kQ/r_a$

$= (9.0\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(-3.8\times10^{-6}\ \text{C})/(0.70\ \text{m})$

$= -4.89\times10^4\ \text{V}.$

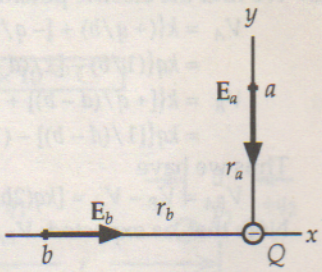
$V_b = kQ/r_b$

$= (9.0\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(-3.8\times10^{-6}\ \text{C})/(0.80\ \text{m})$

$= -4.28\times10^4\ \text{V}.$

Thus the difference is

$V_{ba} = V_b - V_a = -4.28\times10^4\ \text{V} - (-4.89\times10^4\ \text{V}) = \boxed{+6.1\times10^3\ \text{V}.}$



(*b*) We find the electric fields at the two points:

$E_a = kQ/r_a^2$

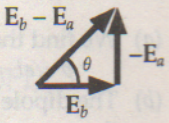
$= (9.0\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(-3.8\times10^{-6}\ \text{C})/(0.70\ \text{m})^2$

$= 6.98\times10^4\ \text{N/C}$ toward Q (down).

$E_b = kQ/r_b^2$

$= (9.0\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(-3.8\times10^{-6}\ \text{C})/(0.80\ \text{m})^2$

$= 5.34\times10^4\ \text{N/C}$ toward Q (right).



As shown on the vector diagram, we find the direction of $\mathbf{E}_b - \mathbf{E}_a$ from

$\tan\theta = E_a/E_b = (6.98\times10^4\ \text{N/C})/(5.34\times10^4\ \text{N/C}) = 1.307,$ or $\theta = \boxed{53°\ \text{N of E.}}$

We find the magnitude from

$|\mathbf{E}_b - \mathbf{E}_a| = E_b/\cos\theta = (5.34\times10^4\ \text{N/C})/\cos 53° = \boxed{8.8\times10^4\ \text{N/C.}}$

20. When the electron is far away, the potential from the fixed charge is zero. Because energy is conserved, we have

$\Delta\text{KE} + \Delta\text{PE} = 0;$

$\frac{1}{2}mv^2 - 0 + (-e)(0 - V) = 0,$ or

$\frac{1}{2}mv^2 = e(kQ/r)$

$\frac{1}{2}(9.11\times10^{-31}\ \text{kg})v^2 = (1.60\times10^{-19}\ \text{C})(9.0\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(-0.125\times10^{-6}\ \text{C})/(0.725\ \text{m}),$

which gives $v = \boxed{2.33\times10^7\ \text{m/s.}}$

21. We find the electric potential energy of the system by considering one of the charges to be at the potential created by the other charge. This will be zero when they are far away. Because the masses are equal, the speeds will be equal. From energy conservation we have

$\Delta\text{KE} + \Delta\text{PE} = 0;$

$\frac{1}{2}mv^2 + \frac{1}{2}mv^2 - 0 + Q(0 - V) = 0,$ or

$2(\frac{1}{2}mv^2) = mv^2 = Q(kQ/r) = kQ^2/r;$

$(1.0\times10^{-6}\ \text{kg})v^2 = (9.0\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(7.5\times10^{-6}\ \text{C})^2/(0.055\ \text{m}),$

which gives $v = \boxed{3.0\times10^3\ \text{m/s.}}$