Physics 214, Section 1
Gladden
HW02 Solutions

CHAPTER 17: Electric Potential

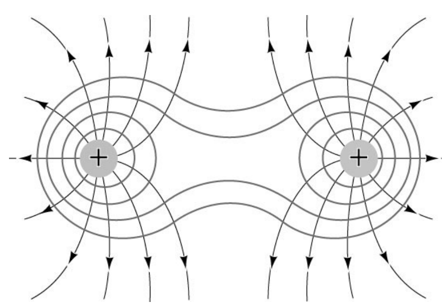
Answers to Questions

3. (*a*) Electric potential, a scalar, is the electric potential energy per unit charge at a point in space. Electric field, a vector, is the electric force per unit charge at a point in space.
(*b*) Electric potential energy is the work done against the electric force in moving a charge from a specified location of zero potential energy to some other location. Electric potential is the electric potential energy per unit charge.

8. There is no general relationship between the value of V and the value of $\mathbf{E}$. Instead, the magnitude of $\mathbf{E}$ is equal to the rate at which V decreases over a short distance. Consider the point midway between two positive charges. $\mathbf{E}$ is 0 there, but V is high. Or, consider the point midway between two negative charges. $\mathbf{E}$ is also 0 there, but V is low, because it is negative. Finally, consider the point midway between positive and negative charges of equal magnitude. There $\mathbf{E}$ is not 0, because it points towards the negative charge, but V is zero.

9. Two equipotential lines cannot cross. That would indicate that a region in space had two different values for the potential. For example, if a 40-V line and a 50-V line crossed, then the potential at the point of crossing would be both 40 V and 50 V, which is impossible. Likewise, the electric field is perpendicular to the equipotential lines. If two lines crossed, the electric field at that point would point in two different directions simultaneously, which is not possible.

10. The equipotential lines are drawn so that they are perpendicular to the electric field lines where they cross.



Solutions to Problems

3. The kinetic energy gained is equal to the work done on the electron by the electric field. The potential difference must be positive for the electron to gain potential energy. Use Eq. 17-2b.

$$V_{ba} = -\frac{W_{ba}}{q} \rightarrow W_{ba} = -qV_{ba} = -\left(-1.60\times10^{-19}\,\text{C}\right)\left(2.3\times10^{4}\,\text{V}\right) = \boxed{3.7\times10^{-15}\,\text{J}}$$

$$= -\left(-1\,e\right)\left(2.3\times10^{4}\,\text{V}\right) = \boxed{2.3\times10^{4}\,\text{eV}}$$

5. The magnitude of the electric field can be found from Eq. 17-4b.

$$E = \frac{V_{ba}}{d} = \frac{220\,\text{V}}{5.8\times10^{-3}\,\text{m}} = \boxed{3.8\times10^{4}\,\text{V/m}}$$

10. By the work energy theorem, the total work done, by the external force and the electric field together, is the change in kinetic energy. The work done by the electric field is given by Eq. 17-2b.

$$W_{\text{external}} + W_{\text{electric}} = \text{KE}_{\text{final}} - \text{KE}_{\text{initial}} \rightarrow W_{\text{external}} - q\left(V_b - V_a\right) = \text{KE}_{\text{final}} \rightarrow$$

$$\left(V_b - V_a\right) = \frac{W_{\text{external}} - \text{KE}_{\text{final}}}{q} = \frac{15.0\times10^{-4}\,\text{J} - 4.82\times10^{-4}\,\text{J}}{-8.50\times10^{-6}\,\text{C}} = \boxed{-1.20\times10^{2}\,\text{V}}$$

15. Use Eq. 17-5 to find the charge.

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r} \rightarrow Q = \left(4\pi\varepsilon_0\right)rV = \left(\frac{1}{8.99\times10^{9}\,\text{N·m}^2/\text{C}^2}\right)\left(0.15\,\text{m}\right)\left(125\,\text{V}\right) = \boxed{2.1\times10^{-9}\,\text{C}}$$

20. By energy conservation, all of the initial potential energy will change to kinetic energy of the electron when the electron is far away. The other charge is fixed, and so has no kinetic energy. When the electron is far away, there is no potential energy.

$$E_{\text{initial}} = E_{\text{final}} \rightarrow \text{PE}_{\text{initial}} = \text{KE}_{\text{final}} \rightarrow \frac{k\left(-e\right)\left(Q\right)}{r} = \tfrac{1}{2}mv^2 \rightarrow$$

$$v = \sqrt{\frac{2k\left(-e\right)\left(Q\right)}{mr}} = \sqrt{\frac{2\left(8.99\times10^{9}\,\text{N·m}^2/\text{C}^2\right)\left(-1.60\times10^{-19}\,\text{C}\right)\left(-1.25\times10^{-7}\,\text{C}\right)}{\left(9.11\times10^{-31}\,\text{kg}\right)\left(0.325\,\text{m}\right)}}$$

$$= \boxed{3.49\times10^{7}\,\text{m/s}}$$

21. By energy conservation, all of the initial potential energy of the charges will change to kinetic energy when the charges are very far away from each other. By momentum conservation, since the initial momentum is zero and the charges have identical masses, the charges will have equal speeds in

opposite directions from each other as they move. Thus each charge will have the same kinetic energy.

$$E_{\text{initial}} = E_{\text{final}} \rightarrow \text{PE}_{\text{initial}} = \text{KE}_{\text{final}} \rightarrow \frac{kQ^2}{r} = 2\left(\tfrac{1}{2}mv^2\right) \rightarrow$$

$$v = \sqrt{\frac{kQ^2}{mr}} = \sqrt{\frac{\left(8.99\times10^9\,\text{N}\cdot\text{m}^2/\text{C}^2\right)\left(9.5\times10^{-6}\,\text{C}\right)^2}{\left(1.0\times10^{-6}\,\text{kg}\right)\left(0.035\,\text{m}\right)}} = \boxed{4.8\times10^3\,\text{m/s}}$$

32. The voltage is found from Eq. 17-7.

$$Q = CV \rightarrow V = \frac{Q}{C} = \frac{16.5\times10^{-8}\,\text{C}}{9.5\times10^{-9}\,\text{F}} = \boxed{17.4\,\text{V}}$$

36. Let Q_1 and V_1 be the initial charge and voltage on the capacitor, and let Q_2 and V_2 be the final charge and voltage on the capacitor. Use Eq. 17-7 to relate the charges and voltages to the capacitance.

$$Q_1 = CV_1 \quad Q_2 = CV_2 \quad Q_2 - Q_1 = CV_2 - CV_1 = C\left(V_2 - V_1\right) \rightarrow$$

$$C = \frac{Q_2 - Q_1}{V_2 - V_1} = \frac{18\times10^{-6}\,\text{C}}{24\,\text{V}} = \boxed{7.5\times10^{-7}\,\text{F}}$$

42. Use Eq. 17-9 to calculate the capacitance with a dielectric.

$$C = K\varepsilon_0\frac{A}{d} = \left(2.2\right)\left(8.85\times10^{-12}\,\text{C}^2/\text{N}\cdot\text{m}^2\right)\frac{\left(5.5\times10^{-2}\,\text{m}\right)^2}{\left(1.8\times10^{-3}\,\text{m}\right)} = \boxed{3.3\times10^{-11}\,\text{F}}$$

47. The capacitance can be found from the stored energy using Eq. 17-10.

$$\text{PE} = \tfrac{1}{2}CV^2 \rightarrow C = \frac{2\left(\text{PE}\right)}{V^2} = \frac{2\left(1200\,\text{J}\right)}{\left(5.0\times10^3\,\text{V}\right)^2} = \boxed{9.6\times10^{-5}\,\text{F}}$$

48. The two charged plates form a capacitor. Use Eq. 17-8 to calculate the capacitance, and Eq. 17-10 for the energy stored in the capacitor.

$$C = \frac{\varepsilon_0 A}{d} \qquad \text{PE} = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{Q^2 d}{\varepsilon_0 A} = \frac{1}{2}\frac{\left(4.2\times10^{-4}\,\text{C}\right)^2\left(1.5\times10^{-3}\,\text{m}\right)}{\left(8.85\times10^{-12}\,\text{C}^2/\text{N}\cdot\text{m}^2\right)\left(8.0\times10^{-2}\,\text{m}\right)^2} = \boxed{2.3\times10^3\,\text{J}}$$