# 3.10: The Electric Potential (Answers)

## Conceptual Questions

**1.** No. We can only define potential energies for conservative fields.

**3.** No, though certain orderings may be simpler to compute.

**5.** The electric field strength is zero because electric potential differences are directly related to the field strength. If the potential difference is zero, then the field strength must also be zero.

**7.** Potential difference is more descriptive because it indicates that it is the difference between the electric potential of two points.

**9.** They are very similar, but potential difference is a feature of the system; when a charge is introduced to the system, it will have a potential energy which may be calculated by multiplying the magnitude of the charge by the potential difference.

**11.** An electron-volt is a volt multiplied by the charge of an electron. Volts measure potential difference, electron-volts are a unit of energy.

## Problems

**29.** a. $U = 3.4 J$;

b. $\frac{1}{2}mv^2 = kQ_1Q_2(\frac{1}{r_i} - \frac{1}{r_f}) \rightarrow v = 750 m/s$

**31.** $U = 4.36 \times 10^{-18} J$

**33.** $\frac{1}{2}m_e v_e^2 = qV$, $\frac{1}{2}m_H v_H^2 = qV$, so that $\frac{m_e v_e^2}{m_H v_H^2} = 1$ or $\frac{v_e}{v_H} = 42.8$.

**35.** $1V = 1J/C; 1J = 1N \cdot m \rightarrow 1V/m = 1N/C$

**37.** a. $V_{AB} = 3.00 kV$;

b. $V_{AB} = 7.50 kV$

**39.** a. $V_{AB} = Ed \rightarrow E = 5.63 kV/m$;

b. $V_{AB} = 563 V$

**41.** a. $\Delta K = q\Delta V$ and $V_{AB} = Ed$, so that $\Delta K = 800 keV$;

b. $d = 25.0 km$

**43.** One possibility is to stay at constant radius and go along the arc from $P_1$ to $P_2$, which will have zero potential due to the path being perpendicular to the electric field. Then integrate from a to b: $V_{ab} = \alpha ln(\frac{b}{a})$

**45.** $V = 144 V$

**47.** $V = \frac{kQ}{r} \rightarrow Q = 8.33 \times 10^{-7} C$ ; The charge is positive because the potential is positive.

**49.** a. $V = 45.0 MV$;

b. $V = \frac{kQ}{r} \rightarrow r = 45.0 m$;

c. $\Delta U = 132 MeV$

**51.** $V = kQ/r$; a. Relative to origin, find the potential at each point and then calculate the difference. $\Delta V = 135 \times 10^3 V$;

b. To double the potential difference, move the point from 20 cm to infinity; the potential at 20 cm is halfway between zero and that at 10 cm.

## Additional Problems

**89.** $E_{tot}=4.67\times10^{7}J$ $E_{tot}=qV\rightarrow q=\dfrac{E_{tot}}{V}=3.89\times10^{6}C$

**91.** $V_P=k\dfrac{q_{tot}}{\sqrt{z^2+R^2}}\rightarrow q_{tot}=-3.5\times10^{-11}C$

**93.** $V_P=-2.2GV$

**95.** Recall from the previous chapter that the electric field $E_P=\dfrac{\sigma_0}{2\varepsilon_0}$ is uniform throughout space, and that for uniform fields we have $E=-\dfrac{\Delta V}{\Delta z}$ for the relation. Thus, we get $\dfrac{\sigma}{2\varepsilon_0}=\dfrac{\Delta V}{\Delta z}\rightarrow\Delta z=0.22m$ for the distance between 25-V equipotentials.

**97.** a. Take the result from Example 7.13, divide both the numerator and the denominator by x, take the limit of that, and then apply a Taylor expansion to the resulting log to get: $V_P\approx k\lambda\dfrac{L}{x}$ ;

b. which is the result we expect, because at great distances, this should look like a point charge of $q=\lambda L$

**99.** a. $V=9.0\times10^{3}V$ ;

b. $-9.0\times10^{3}V(\dfrac{1.25cm}{2.0cm})=-5.7\times10^{3}V$

**101.** a. $E=\dfrac{KQ}{r^2}\rightarrow Q=-6.76\times10^{5}C$ ;

b. $F=ma=qE\rightarrow a=\dfrac{qE}{m}=2.63\times10^{13}m/s^2(upwards)$ ;

c. $F=-mg=qE\rightarrow m=\dfrac{-qE}{g}=2.45\times10^{-18}kg$

**103.** If the electric field is zero ¼ from the way of $q_1$ and $q_2$, then we know from $E=k\dfrac{Q}{r^2}$ that $|E_1|=|E_2|\rightarrow\dfrac{Kq_1}{x^2}=\dfrac{Kq^2}{(3x)^2}$ so that $\dfrac{q_2}{q_1}=\dfrac{(3x)^2}{x^2}=9$ ; the charge $q_2$ is 9 times larger than $q_1$.

**105.** a. The field is in the direction of the electron’s initial velocity.

b. $v^2=v_0^2+2ax\rightarrow x=-\dfrac{v_0^2}{2a}(v=0)$ . Also, $F=ma=qE\rightarrow a=\dfrac{qE}{m}$ ,$x=3.56\times10^{-4}m$;

c. $v_2=v_0+at\rightarrow t=-\dfrac{v_0m}{qE}(v=0),\therefore t=1.42\times10^{-10}s$ ;

d. $v=-(\dfrac{2qEx}{m})^{1/2}-5.00\times10^{6}m/s$ (opposite its initial velocity)

## Challenge Problems

**107.** Answers will vary. This appears to be proprietary information, and ridiculously difficult to find. Speeds will be 20 m/s or less, and there are claims of $10^{-7}$ grams for the mass of a drop.

**109.** Apply $\vec{E}=-\vec{\nabla}V$ with $\vec{\nabla}=\hat{r}\dfrac{\partial}{\partial r}+\hat{\theta}\dfrac{1}{r}\dfrac{\partial}{\partial\theta}+\hat{\varphi}\dfrac{1}{rsin\theta}\dfrac{\partial}{\partial\varphi}$ to the potential calculated earlier, $V_P=k\dfrac{\vec{p}\cdot\hat{r}}{r^2}$ with $\vec{p}=q\vec{d}$, and assume that the axis of the dipole is aligned with the **z**-axis of the coordinate system. Thus, the potential is $V_P=k\dfrac{q\vec{d}\cdot\hat{r}}{r^2}=k\dfrac{qdcos\theta}{r^2}$ .

$$\vec{E}=2kqd(\frac{cos\theta}{r^3})\hat{r}+kqd(\frac{sin\theta}{r^3})\hat{\theta}$$

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