4.8: Potential and Field Relationships (Answers)

Conceptual Questions

17. No. It will be constant, but not necessarily zero.

19. no

21. No; it might not be at electrostatic equilibrium.

23. Yes. It depends on where the zero reference for potential is. (Though this might be unusual.)

25. So that lightning striking them goes into the ground instead of the television equipment.

Problems

59. a. increases; the constant (negative) electric field has this effect, the reference point only matters for magnitude; b. they are planes parallel to the sheet; c. 0.006 m

61. a. from the previous chapter, the electric field has magnitude $\frac{\sigma}{\varepsilon_0}$ in the region between the plates and zero outside; defining the negatively charged plate to be at the origin and zero potential, with the positively charged plate located at **+5mm** in the **z**-direction, V=1.7×104VV=1.7×104Vso the potential is 0 for $z<0, 1.7\times 10^4 V(\frac{z}{5mm})$ for $0\le z\le 5mm, 1.7\times 10^4 V$ for $z>5mm$;

b. $qV=\frac{1}{2}mv^2 \rightarrow v=7.7\times 10^7 m/s$

63. $V=85V$

65. In the region $a\le r\le b, \vec{E}=\frac{kQ}{r^2}\hat{r}$, and **E** is zero elsewhere; hence, the potential difference is $V=kQ(\frac{1}{a}-\frac{1}{b})$.

67. From previous results $V_P-V_R=-2k\lambda ln\frac{s_P}{s_R}$., note that b is a very convenient location to define the zero level of potential: $\Delta V=-2k\frac{Q}{L}ln\frac{a}{b}$.

69. a. $F=5.58\times 10^{-11} N/C$;The electric field is towards the surface of Earth.

b. The coulomb force is much stronger than gravity.

71. We know from the Gauss's law chapter that the electric field for an infinite line charge is $\vec{E}_P=2k\lambda\frac{1}{s}\hat{s}$, and from earlier in this chapter that the potential of a wire-cylinder system of this sort is $V_P=-2k\lambda ln\frac{s_P}{R}$ by integration. We are not given λ, but we are given a fixed V_0; thus, we know that $V_0=-2k\lambda ln\frac{a}{R}$ and hence $\lambda=-\frac{V_0}{2kln(\frac{a}{R})}$. We may substitute this back in to find a. $\vec{E}_P=-\frac{V_0}{ln(\frac{a}{R})}\frac{1}{s}\hat{s}$;

b. $V_P=V_0\frac{ln(\frac{s_P}{R})}{ln(\frac{a}{R})}$;

c. $4.74\times 10^4 N/C$

73. a. $U_1=7.68\times 10^{-18} J, U_2=5.76\times 10^{-18} J$;

b. $U_1+U_2=-1.34\times 10^{-17} J$

75. a. \(\displaystyle U=2.30×10^{−16}J;

b. $\overline{K}=\frac{3}{2}kT\rightarrow T=1.11\times 10^7$

77. a. $1.9\times 10^6 m/s$;

b. $4.2 \times 10^6 m/s$;

c. $5.9 \times 10^6 m/s$;

d. $7.3 \times 10^6 m/s$;

e. $8.4 \times 10^6 m/s$

79. a. $E = 2.5 \times 10^6 V/m < 3 \times 10^6 V/m$ No, the field strength is smaller than the breakdown strength for air.

b. $d = 1.7mm$

81. $K_f = qV_{AB} = qEd \rightarrow E = 8.00 \times 10^5 V/m$

83. a. Energy=$2.00 \times 10^9 J$;

b. $Q = m(c\Delta T + L_\nabla)$ $m = 766kg$;

c. The expansion of the steam upon boiling can literally blow the tree apart.

85. a. $V = \dfrac{kQ}{r} \rightarrow r = 1.80km$;

b. A 1-C charge is a very large amount of charge; a sphere of 1.80 km is impractical.

87. The alpha particle approaches the gold nucleus until its original energy is converted to potential energy. $5.00MeV = 8.00 \times 10^{-13} J$, so $E_0 = \dfrac{qkQ}{r} \rightarrow r = 4.54 \times 10^{-14} m$

(Size of gold nucleus is about $7 \times 10^{-15} m$).

Additional Problems

89. $E_{tot} = 4.67 \times 10^7 J$ $E_{tot} = qV \rightarrow q = \dfrac{E_{tot}}{V} = 3.89 \times 10^6 C$

91. $V_P = k\dfrac{q_{tot}}{\sqrt{z^2+R^2}} \rightarrow q_{tot} = -3.5 \times 10^{-11} C$

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. $V = 9.0 \times 10^3 V$;

b. $-9.0 \times 10^3 V(\dfrac{1.25cm}{2.0cm}) = -5.7 \times 10^3 V$

101. a. $E = \dfrac{KQ}{r^2} \rightarrow Q = -6.76 \times 10^5 C$;

b. $F = ma = qE \rightarrow a = \dfrac{qE}{m} = 2.63 \times 10^{13} m/s^2 (upwards)$;

c. $F = -mg = qE \rightarrow m = \dfrac{-qE}{g} = 2.45 \times 10^{-18} kg$

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. $v^2 = v_0^2 + 2ax \rightarrow x = -\frac{v_0^2}{2a}(v=0)$. Also, $F = ma = qE \rightarrow a = \frac{qE}{m}$,$x = 3.56 \times 10^{-4} m$;

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

d. $v = -(\frac{2qEx}{m})^{1/2} - 5.00 \times 10^6 m/s$ (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 $\vec{\nabla} = \hat{r}\frac{\partial}{\partial r} + \hat{\theta}\frac{1}{r}\frac{\partial}{\partial \theta} + \hat{\varphi}\frac{1}{rsin\theta}\frac{\partial}{\partial \varphi}$ to the potential calculated earlier, $V_P = k\frac{\vec{p}\cdot\hat{r}}{r^2}$ 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 $V_P = k\frac{q\vec{d}\cdot\hat{r}}{r^2} = k\frac{qdcos\theta}{r^2}$.

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

Contributors and Attributions

Samuel J. Ling (Truman State University), Jeff Sanny (Loyola Marymount University), and Bill Moebs with many contributing authors. This work is licensed by OpenStax University Physics under a Creative Commons Attribution License (by 4.0).