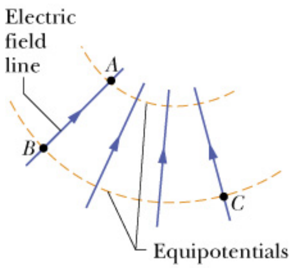
AP Physics, Spring 2018
Electric Potential Solution Set, Cha. 24 #4,5,8,11,12,22,23,25,40,46,57
due Mon. 2/15



4. (a) $V_B - V_A = \Delta U/q = -W/(-e) = -(3.94 \times 10^{-19}\ \text{J})/(-1.60 \times 10^{-19}\ \text{C}) = 2.46\ \text{V}$.

(b) $V_C - V_A = V_B - V_A = 2.46\ \text{V}$.

(c) $V_C - V_B = 0$ (Since C and B are on the same equipotential line).

5. (a) $E = F/e = \left(3.9\times10^{-15}\ \text{N}\right)/\left(1.60\times10^{-19}\ \text{C}\right) = 2.4\times10^{4}\ \text{N/C}$.

(b) $\Delta V = E\Delta s = \left(2.4\times10^{4}\ \text{N/C}\right)\left(0.12\ \text{m}\right) = 2.9\times10^{3}\ \text{V}$.

8. We connect A to the origin with a line along the y axis, along which there is no change of potential (Eq. 24-18: $\int \vec{E}\cdot d\vec{s} = 0$). Then, we connect the origin to B with a line along the x axis, along which the change in potential is

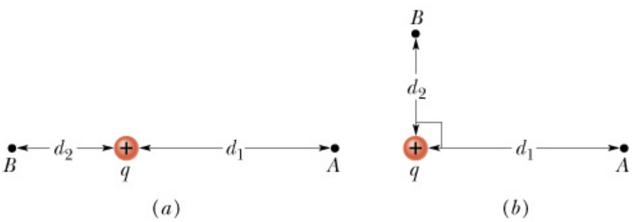
$$\Delta V = -\int_0^{x=4} \vec{E}\cdot d\vec{s} = -4.00\int_0^4 x\,dx = -4.00\left(\frac{4^2}{2}\right)$$

11. (a) The charge on the sphere is

$$q = 4\pi\varepsilon_0 VR = \frac{(200\ \text{V})(0.15\ \text{m})}{8.99\times10^{9}\ \dfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}} = 3.3\times10^{-9}\ \text{C}.$$

(b) The (uniform) surface charge density (charge divided by the area of the sphere) is

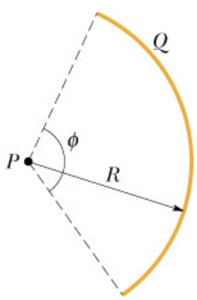
$$\sigma = \frac{q}{4\pi R^2} = \frac{3.3\times10^{-9}\ \text{C}}{4\pi(0.15\ \text{m})^2} = 1.2\times10^{-8}\ \text{C}/\text{m}^2.$$



12. (a) The potential difference is

$$V_A - V_B = \frac{q}{4\pi\varepsilon_0 r_A} - \frac{q}{4\pi\varepsilon_0 r_B} = \left(1.0\times10^{-6}\ \text{C}\right)\left(8.99\times10^{9}\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{1}{2.0\ \text{m}} - \frac{1}{1.0\ \text{m}}\right)$$
$$= -4.5\times10^{3}\ \text{V}.$$

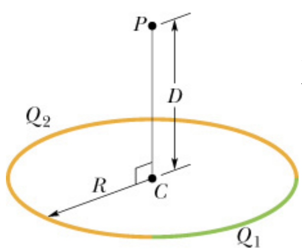
(b) Since $V(r)$ depends only on the magnitude of $\vec{r}$, the result is unchanged.



22. The potential is (in SI units)

$$V_P = \frac{1}{4\pi\varepsilon_0}\int_{\text{rod}} \frac{dq}{R} = \frac{1}{4\pi\varepsilon_0 R}\int_{\text{rod}} dq = \frac{-Q}{4\pi\varepsilon_0 R} = -\frac{(8.99\times10^{9})(25.6\times10^{-12})}{3.71\times10^{-2}} = -6.20\ \text{V}.$$

We note that the result is exactly what one would expect for a point-charge $-Q$ at a distance R. This "coincidence" is due, in part, to the fact that V is a scalar quantity.



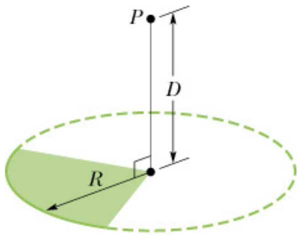
23. (a) All the charge is the same distance R from C, so the electric potential at C is (in SI units)

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{R} - \frac{6Q_1}{R}\right] = -\frac{5Q_1}{4\pi\varepsilon_0 R} = -\frac{5(8.99\times10^{9})(4.20\times10^{-12})}{8.20\times10^{-2}} = -2.30\ \text{V},$$

where the zero was taken to be at infinity.

(b) All the charge is the same distance from P. That distance is $\sqrt{R^2 + D^2}$, so the electric potential at P is (in SI units)

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{\sqrt{R^2+D^2}} - \frac{6Q_1}{\sqrt{R^2+D^2}}\right] = -\frac{5Q_1}{4\pi\varepsilon_0\sqrt{R^2+D^2}}$$
$$= -\frac{5(8.99\times10^{9})(4.20\times10^{-12})}{\sqrt{(8.20\times10^{-2})^2 + (6.71\times10^{-2})^2}} = -1.78\ \text{V}.$$



25. The disk is uniformly charged. This means that when the full disk is present each quadrant contributes equally to the electric potential at *P*, so the potential at *P* due to a single quadrant is one-fourth the potential due to the entire disk. First find an expression for the potential at *P* due to the entire disk. We consider a ring of charge with radius *r* and (infinitesimal) width *dr*. Its area is $2\pi r\,dr$ and it contains charge $dq = 2\pi\sigma r\,dr$. All the charge in it is a distance $\sqrt{r^2+D^2}$ from *P*, so the potential it produces at *P* is

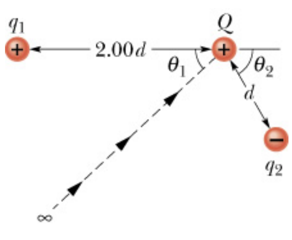
$$dV = \frac{1}{4\pi\varepsilon_0}\frac{2\pi\sigma r dr}{\sqrt{r^2+D^2}} = \frac{\sigma r dr}{2\varepsilon_0\sqrt{r^2+D^2}}.$$

The total potential at *P* is

$$V = \frac{\sigma}{2\varepsilon_0}\int_0^R \frac{r dr}{\sqrt{r^2+D^2}} = \frac{\sigma}{2\varepsilon_0}\sqrt{r^2+D^2}\Big|_0^R = \frac{\sigma}{2\varepsilon_0}\left[\sqrt{R^2+D^2}-D\right].$$

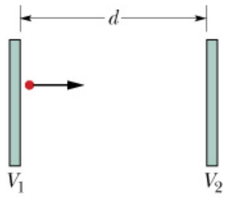
The potential V_{sq} at *P* due to a single quadrant is (in SI units)

$$V_{sq} = \frac{V}{4} = \frac{\sigma}{8\varepsilon_0}\left[\sqrt{R^2+D^2}-D\right] = \frac{(7.73\times10^{-15})}{8(8.85\times10^{-12})}\left[\sqrt{(0.640)^2+(0.259)^2}-0.259\right]$$
$$= 4.71\times10^{-5}\text{ V.}$$



40. The work required is

$$W = \Delta U = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1Q}{2d}+\frac{q_2Q}{d}\right] = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1Q}{2d}+\frac{(-q_1/2)Q}{d}\right] = 0.$$



46. (a) The electric field between the plates is leftward in Fig, 24-50 since it points towards lower values of potential. The force (associated with the field, by Eq. 23-28) is evidently leftward, from the problem description (indicating deceleration of the rightward moving particle), so that $q > 0$ (ensuring that $\vec{F}$ is parallel to $\vec{E}$); it is a proton.

(b) We use conservation of energy:

$$K_0 + U_0 = K + U \quad \Rightarrow \quad \frac{1}{2} m_p v_0^2 + qV_1 = \frac{1}{2} m_p v^2 + qV_2 \ .$$

Using $q = +1.6 \times 10^{-19}$ C, $m_p = 1.67 \times 10^{-27}$ kg, $v_0 = 90 \times 10^3$ m/s, $V_1 = -70$ V and $V_2 = -50$ V, we obtain the final speed $v = 6.53 \times 10^4$ m/s. We note that the value of d is not used in the solution.

57. (a) The magnitude of the electric field is

$$E = \frac{\sigma}{\varepsilon_0} = \frac{q}{4\pi\varepsilon_0 R^2} = \frac{\left(3.0\times10^{-8}\,\text{C}\right)\left(8.99\times10^9\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)}{\left(0.15\,\text{m}\right)^2} = 1.2\times10^4\ \text{N/C}.$$

(b) $V = RE = (0.15\text{ m})(1.2 \times 10^4\text{ N/C}) = 1.8 \times 10^3$ V.

(c) Let the distance be x. Then

$$\Delta V = V(x) - V = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{R+x} - \frac{1}{R}\right) = -500\,\text{V},$$

which gives

$$x = \frac{R\Delta V}{-V - \Delta V} = \frac{(0.15\,\text{m})(-500\,\text{V})}{-1800\,\text{V} + 500\,\text{V}} = 5.8\times10^{-2}\,\text{m}.$$