Chapter 24

24.1 A particular 12V car battery can send a total charge of 84 Ah through a circuit from one terminal to the other. (a) How many coulombs of charge does this represent? (b) If this entire charge undergoes a potential difference of 12V, how much energy is involved.

$$q = 84A \cdot h \cdot \frac{3600s}{1h} = 3.024 \times 10^5 C$$
$$\Delta U = q\Delta V = 3.024 \times 10^5 C \cdot 12V = 3.63 \times 10^6 J$$

24.5 Two large, parallel, conducting plates are 12 cm apart and have charges of equal magnitude and opposite sign on their facing surfaces. An electrostatic force of $3.9 \times 10^{-15} N$ acts on an electron placed anywhere between the two plates (Neglect fringing.) (a) Find the electric field at the position of the electron. (b) What is the potential difference between the plates.

Since the force on an electron is known everywhere, we can find the field

$$F = qE$$
$$E = \frac{F}{q} = \frac{3.9 \times 10^{-15} N}{1.6 \times 10^{-19} C} = 2.4375 \times 10^4 N/C$$

Since the field is due to parallel plates, we can now calculate the potential difference between the plates from the field.

$$\begin{aligned} V &= E \cdot d \\ &= 24{,}375 \frac{N}{C} \cdot 0.12m \\ &= 2925V \end{aligned}$$

24.7 An infinite nonconducting sheet has a surface charge density $\sigma = 5.80 pC/m^2$. (a) How much work is done by the electric field due to the sheet if a particle of charge $q = 1.60 \times 10^{-19} C$ is moved from the sheet to a point P at a distance $d = 3.56cm$ from the sheet. (b) If the electric potential V is defined to be zero on the sheet, what is V at P?

$$E = \frac{\sigma}{2\varepsilon_0}$$

$$W = F \cdot d = qEd = \frac{q\sigma d}{2\varepsilon_0} = 1.87 \times 10^{-21} J$$

$$V(z) - V_0 = -\int_0^z \frac{\sigma}{2\varepsilon_0} dz$$

$$V(z) - V_0 = \frac{\sigma}{2\varepsilon_0} z$$

$$V(z) = V_0 - \frac{\sigma}{2\varepsilon_0} z = 0 - 0.0167 = -0.01167V$$

24.8 A graph of the x component of the electric field as a function of x in a region of space is shown in Fig. 24-30. The scale of the vertical axis is set by $E_{xs} = 20N/C$. The y and z components of the electric field are zero in this region. If the electric potential at the origin is 10V, (a) what is the electric potential at $x = 2.0m$ (b) What is the greatest positive value of the electric potential for points on the x axis for which $0.0 \le x \le 6.0$ and (c) for what value of x is the electric potential zero.

The change in the potential is given by.

$$V(x) - V_0 = -\int_0^x E_x\, dx$$

This is just minus the area under the curve. We can compute the area from the picture. (a) At $x = 2.0m$, Here $V_0 = 10V$ is the potential at the origin,

$$V(2.0m) - V_0 = -(\frac{1}{2} \cdot 2m \cdot -20N/C)$$

$$V(2.0m) = V_0 - (\frac{1}{2} \cdot 2m \cdot -20N/C) = 10V + 20V = 30V$$

The maximum positive potential occurs where the maximum negative area occurs. This would be at $x = 3.0m$ for this graph.

$$V(3.0m) - V_0 = -(\frac{1}{2} \cdot 3m \cdot -20N/C)$$

$$V(3.0m) = V_0 - (\frac{1}{2} \cdot 3m \cdot -20N/C) = 10V + 30V = 40V$$

The zero in the potential occurs when the net area is +10

$$V(6.0m) - V_0 = -(\frac{1}{2} \cdot 3m \cdot -20N/C)$$

$$\begin{aligned} V(6.0m) &= V_0 - (\frac{1}{2} \cdot 3m \cdot -20N/C + \frac{1}{2} \cdot 1m \cdot +20N/C + 2 \cdot +20N/C) \\ &= 10V - (-30V + 10V + 40V) \\ &= 0V \end{aligned}$$

24.12 Consider a point charge $q = 1.0\mu C$, point A at a distance $d_1 = 2.0m$ from q and point B at a distance $d_2 = 1.0m$. (a) If these points are diametrically opposite each other as in 24-31a, what is the electric potential difference $V_A - V_B$? (b) What is the electric potential difference if points A and B are located as in 25-31b.

The potential at points A and B only depend on how far those points are from q, not the direction.

$$
\begin{aligned}
V_A - V_B &= \frac{q}{4\pi\varepsilon_0 r_A} - \frac{q}{4\pi\varepsilon_0 r_B} \\
&= \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r_A} - \frac{1}{r_B}\right) \\
&= \frac{1\times10^{-6}C}{4\pi\varepsilon_0}\left(\frac{1}{2m} - \frac{1}{1m}\right) \\
&-4.5\times10^{3}V
\end{aligned}
$$

The result is the same for both (a) and (b).

24.15 In Fig 24-33, what is the net potential at point P due to the four point charges if V=0 at infinity.

$$
\begin{aligned}
V &= \frac{+q}{4\pi\varepsilon_0 d} + \frac{+q}{4\pi\varepsilon_0 d} + \frac{-q}{4\pi\varepsilon_0 d} + \frac{-q}{4\pi\varepsilon_0 2d} \\
&= \frac{+q}{4\pi\varepsilon_0 d} + \frac{-q}{4\pi\varepsilon_0 2d} = \frac{+q}{4\pi\varepsilon_0 \cdot 2d} \\
&= 5.62\times10^{-4}V
\end{aligned}
$$

24.16 Two particles, of charges q_1 and q_2 are separated by distance d in Fig. 24-33. The net electric field due to the particles is zero at $x = d/4$. With $V = 0$ at infinity, locate (in terms of d) any point on the x axis (other than at infinity) at which the electric potential due to the particles is zero.

The only way that the field can be zero at $x = d/4$ is for both particles to have the same sign charge (both positive or both negative). If both particles have the same sign charge, the potentials that they produce will always have the same sign. This means that they can never “cancel” out --so there is no point, except at infinity, where the potential goes to zero.

24.19 The ammonia molecule NH_3 has a permanent electric dipole moment equal to 1.47D Calculate the electric potential due to an ammonia molecule at a point 52nm away along the axis of the dipole

$$
V = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2} = \frac{1.47\times3.34\times10^{-30}\cos0^\circ}{4\pi\varepsilon_0(52\times10^{-9})^2} = 1.63\times10^{-5}V
$$

24.21 (a) Figure 25-36a shows a positively charged plastic rod of length L and uniform charge density λ. Setting V=0 at infinity and considering Fig 25-13 and Eq 25-35, find the electric potential at point P without written calculation. (b) Find the potential due to the second rod.

This problem is the problem worked out in the book with different limits... We can work it again.

Write an expression for the electric potential due to a small charge dq at the point p?

$$dV = \frac{dq}{4\pi\varepsilon_0 r} = \frac{dq}{4\pi\varepsilon_0\sqrt{x^2+d^2}}$$

Write an expression for the dq and the r in terms of x and the distance y.

$$dq = \lambda dx$$

The potential at the point indicated?

$$V = \int_{-L/2}^{L/2} \frac{\lambda dx}{4\pi\varepsilon_0\sqrt{x^2+d^2}} = \frac{\lambda}{4\pi\varepsilon_0}\int_{-L/2}^{L/2} \frac{dx}{\sqrt{x^2+d^2}}$$
$$= \frac{\lambda}{4\pi\varepsilon_0}\cdot \ln\left[\frac{L/2+\sqrt{(L/2)^2+d^2}}{-L/2+\sqrt{(L/2)^2+d^2}}\right]$$

The potential for the second drawing is zero, since the equal and opposite charge contributions cancel exactly.

24.23 A plastic rod has been formed into a circle of radius R. It has a positive charge +Q uniformly distributed along one quarter of its circumference and a negative charge of -6Q uniformly distributed along the rest of the circumference. With V=0 at infinity, what is the electric potential at the center of the circle and (b) at point P, which is on the central axis of the circle at a distance z form the center?

We will begin with (b) since (a) is a special case of b. We proceed in the usual way by defining r and dq for bits of charge on the rod. We then integrate and simplify.

$$dV = \frac{dq}{4\pi\varepsilon_0 r} = \frac{dq}{4\pi\varepsilon_0\sqrt{R^2+z^2}}$$

$$dq = \lambda dl = \lambda R d\theta$$

$$\lambda_+ = \frac{+Q}{2\pi R/4}$$

$$\lambda_- = \frac{-6Q}{6\pi R/4}$$

$$V = \int_0^{\pi/2} \frac{\lambda_+ R d\theta}{4\pi\varepsilon_0\sqrt{R^2+z^2}} + \int_{\pi/2}^{2\pi} \frac{\lambda_- R d\theta}{4\pi\varepsilon_0\sqrt{R^2+z^2}}$$

$$= \frac{\lambda_+ R}{4\pi\varepsilon_0\sqrt{R^2+z^2}}\left[\frac{\pi}{2} - 0\right] + \frac{\lambda_- R}{4\pi\varepsilon_0\sqrt{R^2+z^2}}\left[2\pi - \frac{\pi}{2}\right]$$

$$= \frac{\lambda_+ R}{4\pi\varepsilon_0\sqrt{R^2+z^2}}\left[\frac{\pi}{2}\right] + \frac{\lambda_- R}{4\pi\varepsilon_0\sqrt{R^2+z^2}}\left[\frac{3\pi}{2}\right]$$

$$= \frac{\frac{+Q}{2\pi R/4}\cdot R}{4\pi\varepsilon_0\sqrt{R^2+z^2}}\left[\frac{\pi}{2}\right] + \frac{\frac{-6Q}{6\pi R/4}\cdot R}{4\pi\varepsilon_0\sqrt{R^2+z^2}}\left[\frac{3\pi}{2}\right]$$

$$= \frac{+Q}{4\pi\varepsilon_0\sqrt{R^2+z^2}} + \frac{-6Q}{4\pi\varepsilon_0\sqrt{R^2+z^2}}$$

$$= \frac{-5Q}{4\pi\varepsilon_0\sqrt{R^2+z^2}}$$

We set z=0 to get the solution to part (a).

$$V = \frac{-5Q}{4\pi\varepsilon_0 R}$$

24.25 (a) Figure 24-39a shows a nonconducting rod of length $L = 6.00 cm$ and uniform charge linear charge density $\lambda = +3.68 pC/m$. Take $V = 0$ at infinity. What is V at point P at distance $d = 8.00 cm$ along the rod's perpendicular bisector. (b) Figure 24-39b shows an identical rod except that one half is now negatively charged. What is V at P?

This problem is the problem worked out in the book with different limits... We can work it again.

Write an expression for the electric potential due to a small charge dq at the point p?

$$dV = \frac{dq}{4\pi\varepsilon_0 r} = \frac{dq}{4\pi\varepsilon_0\sqrt{x^2+d^2}}$$

Write an expression for the dq and the r in terms of x and the distance y.

$$dq = \lambda dx$$

The potential at the point indicated?

$$V = \int_{-L/2}^{L/2} \frac{\lambda dx}{4\pi\varepsilon_0 \sqrt{x^2 + d^2}} = \frac{\lambda}{4\pi\varepsilon_0} \int_{-L/2}^{L/2} \frac{dx}{\sqrt{x^2 + d^2}}$$
$$= \frac{\lambda}{4\pi\varepsilon_0} \cdot \ln\left[\frac{L/2 + \sqrt{(L/2)^2 + d^2}}{-L/2 + \sqrt{(L/2)^2 + d^2}} \right]$$

The potential for the second drawing is zero, since the equal and opposite charge contributions cancel exactly.

24.28 Figure 24-44 shows a thin plastic rod of length L = 12.0 cm and a uniform positive charge of $Q = 56.1\ fC$ lying on the x-axis. With V=0 at infinity, find the electric potential at point P1 on the axis at a distance $d = 2.50\,cm$ from one end of the rod.

This problem is the problem worked out in the book with different limits... We can work it again.

Write an expression for the electric potential due to a small charge dq at the point p?

$$dV = \frac{dq}{4\pi\varepsilon_0 r} = \frac{dq}{4\pi\varepsilon_0 (x + d)}$$

Write an expression for the dq and the r in terms of x and the distance y.

$$dq = \lambda dx$$
$$\lambda = \frac{56.1\,fC}{0.12m} = 4.675 \times 10^{-13} C/m$$

The potential at the point indicated?

$$V = \int_{0}^{L} \frac{\lambda\, dx}{4\pi\varepsilon_0 (x + d)} = \frac{\lambda}{4\pi\varepsilon_0} \int_{-L/2}^{L/2} \frac{dx}{(x + d)}$$
$$= \frac{\lambda}{4\pi\varepsilon_0} \cdot \ln\left[\frac{L + d}{d} \right]$$
$$= 7.39 \times 10^{-3} V$$

24.30 Find the potential at the point indicated. This is just problem 25 with different limits.

Write an expression for the electric potential due to a small charge dq at the point p?

$$dV = \frac{dq}{4\pi\varepsilon_0 r} = \frac{dq}{4\pi\varepsilon_0 (x+d)}$$

Write an expression for the dq and the r in terms of x and the distance y.

$$dq = \lambda dx$$

The potential at the point indicated?

$$V = \int_0^L \frac{\lambda\, dx}{4\pi\varepsilon_0 (x+d)} = \frac{\lambda}{4\pi\varepsilon_0} \int_0^L \frac{dx}{(x+d)}$$

$$= \frac{\lambda}{4\pi\varepsilon_0} \cdot \ln\left[\frac{(L+d)}{d}\right]$$