24.1

12 Volts

Total Charge Supplied = 84 A·h

a) $84\ A\cdot h = 84\ A(3600 sec)$

$= 3.02 \times 10^5$ Coulombs

b) $\Delta U = q\Delta V = (3.02\times10^5)(12)$

$= 3.63 \times 10^6$ Joules

24.4

$|\vec{F}| = 3.9\times10^{-15}$ Newtons

a) $|\vec{F}| = |q\vec{E}|$

$3.9\times10^{-15} = 1.602\times10^{-19}\ E$

$E = 2.43\times10^4$ N/C or Volts/m

b) $\Delta V = -\int \vec{E}\cdot d\vec{s}$ the electric field is uniform (ie. constant) in the region between the plates

$\Delta V = (-)\int_a^b E\,dy\cos 180^\circ$ $\quad \vec{E}\downarrow \uparrow d\vec{s}\ \theta = 180^\circ$

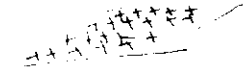
$\Delta V = (-)(-)\ Ey\Big]_a^b$

$\Delta V = (-)(-)\ E(y_b - y_a)$

$\Delta V = (2.43\times10^4)(0.12) = 2.92\times10^3$ Volts

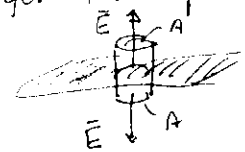
24.5

$\sigma = 0.10\ \mu C/m^2$



want $\Delta V = 50$ Volts

To get the expression for the E-field



$\oint \vec{E}\cdot d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$

$EA_{top} + EA_{bot} = \sigma A/\epsilon_0$

$E = \sigma/2\epsilon_0$

To get the potential difference

$\Delta V = -\int \vec{E}\cdot d\vec{s}$ $\quad \vec{E}\uparrow \uparrow d\vec{s}\ \theta = 0^\circ$

$= -\int_a^b E\,dy\cos 0^\circ$ $\quad \Delta y = y_b - y_a$

$\Delta V = -E\,\Delta y$

we don't care about the sign from the statement of the problem

$|\Delta V| = |E\,\Delta y|$

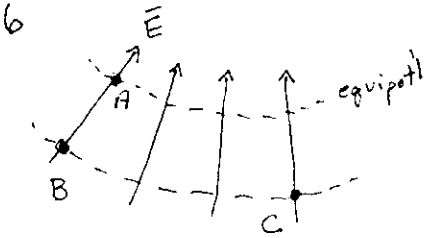
$50 = \frac{\sigma}{2\epsilon_0}\Delta y$

$50 = \frac{0.10\times10^{-6}}{2(8.85\text{-}12)}\Delta y$

$\Delta y = 8.85\times10^{-3}$ m

$= 8.85$ mm

24-6



when electron moves $A \to B$, the electric field does 3.94×10^{-19} J of work

a) $\Delta U_{B \leftarrow A} = q\,\Delta V_{B \leftarrow A}$

$-3.94 \times 10^{-19} = (-1.602-19)\,\Delta V_{B \leftarrow A}$

$\Delta V_{B \leftarrow A} = 2.46$ Volts

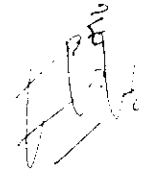
b) C is on the same (equipot'l / equal pot'l energy) surface as B

$\therefore V_C - V_A = 2.46$ Volts

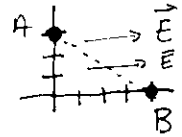
c) B & C are on the same equipot'l surface

$V_C - V_B = 0$

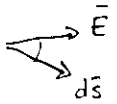
24-7



$\vec{E}$ $E_x = 4x$ $E_y = 0$ $E_z = 0$



$\Delta V = -\int \vec{E} \cdot d\vec{s}$



$\vec{E} \cdot d\vec{s} = E_x\,dx$

$V(x=4) - V(x=0) = -\int_{x=0}^{x=4} (4x)\,dx$

$= -\frac{1}{2} 4x^2 \Big]_0^4$

$= (-)\frac{1}{2} 4\,4^2 - (-)\frac{1}{2} 4\,0^2$

$= -32$ Volts

24-13 $V = 200$ Volts $R = 0.15$ m

Similar to the $\vec{E}$ field cases, the point charge formula for V is valid outside of spheres

$$V = \frac{kQ}{r}$$

a) As $r \to R$

$$V = \frac{kQ}{R}$$

$$200 = \frac{9\times10^9\, Q}{0.15}$$

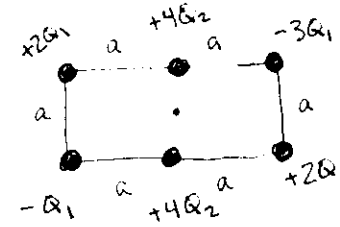
$$Q = 3.33\times10^{-9} \text{ Coulombs}$$

b) charge density

$$\text{charge/Area} = \frac{Q}{4\pi R^2} = \frac{3.33\times10^{-9}}{4\pi(0.15)^2}$$

$$= 1.18\times10^{-8} \text{ Coul/m}^2$$

24-16



$Q_1 = 3.40\,pC$

$Q_2 = 6.00\,pC$

$a = 39\,cm = 0.39\,m$

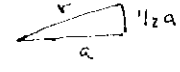
The charges $+4Q_2$ and $+4Q_2$ are both at a distance $\frac{1}{2}a$ away from the center. Their contribution is then

$$\frac{k(+4Q_2)}{\frac{1}{2}a} + \frac{k(+4Q_2)}{\frac{1}{2}a} = \frac{k[+4Q_2+4Q_2]}{\frac{1}{2}a}$$

$$= \frac{(9\times10^9)\,8\,(6\times10^{-12})}{\frac{1}{2}(0.39)}$$

$$= 2.215 \text{ Volts}$$

The charges $+2Q_1$ $-3Q_1$ $+2Q_1$ $-Q_1$ are all at a distance



$$r^2 = (\tfrac{1}{2}a)^2 + a^2$$

$$r^2 = \tfrac{5}{4}a^2$$

$$r = 1.118\,a$$

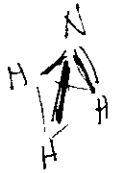
Their contribution is then

$$\frac{k[+2Q_1 + -3Q_1 + 2Q_1 + -Q_1]}{1.118\,a} = 0\,!$$

So that the total potential at the center is

2.215 Volts

24-21 NH_3



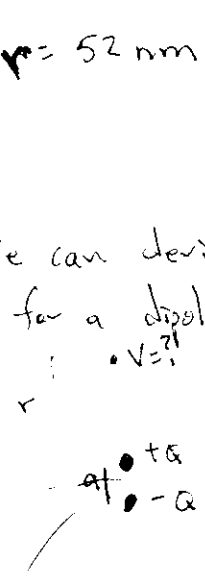
dipole moment $Qa = 1.47$ Debye

$= 1.47(3.34\times10^{-30})$ Cm

$= 4.91\times10^{-30}$ C·m

$r = 52$ nm $= 52\times10^{-9}$ m

We can derive the formula for a dipole



a is separation btw charges

$$V = \frac{k(+Q)}{(r-\frac{1}{2}a)} + \frac{k(-Q)}{r+\frac{1}{2}a}$$

$$= \frac{kQ}{r}\frac{1}{1-\frac{1}{2}\frac{a}{r}} - \frac{kQ}{r}\frac{1}{1+\frac{1}{2}\frac{a}{r}}$$

$$= \frac{kQ}{r}\left\{\frac{1}{1-\frac{1}{2}\frac{a}{r}} - \frac{1}{1+\frac{1}{2}\frac{a}{r}}\right\}$$

$$= \frac{kQ}{r}\left\{\left(1-\frac{1}{2}\frac{a}{r}\right)^{-1} - \left(1+\frac{1}{2}\frac{a}{r}\right)^{-1}\right\}$$

use binomial approx

$(1+ax)^n \approx 1+nax$

$$= \frac{kQ}{r}\left\{\left(1+\frac{1}{2}\frac{a}{r}\right) - \left(1-\frac{1}{2}\frac{a}{r}\right)\right\}$$

$$= \frac{kQ}{r}\frac{a}{r}$$

$$= \frac{k\,Qa}{r^2}$$ which is the formula in the textbook

$$= \frac{(9\times10^{9})(4.91\times10^{-30})}{(52\times10^{-9})^2} = 1.63\times10^{-5} \text{ Volts}$$

24-24

$\phi = 120^\circ$

$Q = -25.6\,pC = -25.6 \times 10^{-12}\,C$

$R = 3.71$ cm

The standard way to do extended objects is to chop the rod up into lots of infinitesmal pieces dQ and then add up the contributions from each piece

$$dV = \frac{k\,dQ}{r}$$

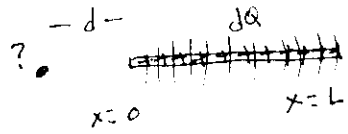
However notice in this problem all the pieces dQ are the same distance from the location of interest. V is a scalar, so there are no vector directions to worry about.

Therefore we can essentially write down the answer

$$V_{Tot} = \frac{k\,Q_{TOT}}{R} = \frac{9\times10^9\,(-25.6\times10^{-12})}{0.0371}$$

$$= -6.21 \text{ Volts}$$

24-28



$d = 2.50$ cm

$Q = 56.1\,fC = 56.1 \times 10^{-15}\,C$

$L = 12$ cm

Chop the rod up into little pieces dQ

$$dV = \frac{k\,dQ}{r}$$

$$V = \int_{\text{left end}}^{\text{right end}} \frac{k\,dQ}{r} = \int \frac{k\,dQ}{x+d}$$

where have set $r = x+d$

Also set $dQ = \lambda\,dx$ $\quad \lambda = \frac{Q}{L}$

$$V = \int_{x=0}^{x=L} \frac{k\lambda\,dx}{x+d}$$

$u = x+d$

$du = dx$

$$= \int_{\text{left}}^{\text{right}} \frac{k\lambda\,du}{u}$$

$$= k\lambda \ln u \Big]_{\text{left}}^{\text{right}}$$

$$= k\lambda \ln(x+d) \Big]_{x=0}^{x=L}$$

$$= k\lambda \left[\ln(L+d) - \ln d\right]$$

$$= k\lambda \ln\left(\frac{L+d}{d}\right)$$

$$= k\frac{Q}{L} \ln\left(\frac{L+d}{d}\right)$$

$$= 9\times10^9 \frac{56.1\times10^{-15}}{0.12} \ln\left(\frac{0.12+0.025}{0.025}\right)$$

$$= 7.40\times10^{-3} \text{ Volts}$$