Chapter 24

Paul Boynton
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Easy:

(2) $\Delta V = 1.2 \times 10^9$ V potential difference between ground and cloud.

$$\Delta U = q(\Delta V) = (-e)(\Delta V) = -1.2 \times 10^9 \text{ eV}$$

$$|\Delta U| = 1.2 \times 10^9 \text{ eV}$$

(4)

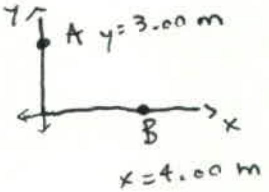
a) $F = 3.9 \times 10^{-15}$ N , $q = -e$, $d = 12$ cm

2 parallel conducting plates with identical but opposite charge

$$E = \frac{F}{q} = \frac{(3.9 \times 10^{-15}\text{ N})}{(-1.6 \times 10^{-19}\text{ C})} = -2.4 \times 10^4 \text{ N/C}$$

b) $V = -E \cdot d = (+2.4 \times 10^4 \text{ N/C})(12 \times 10^{-2}\text{ m}) = 2.9 \times 10^3$ V

(7) $E_y = E_z = 0$, $E_x = (4.00 \text{ N/C})\, x$.



$$V_B - V_A = -\int_A^B \vec{E} \cdot d\vec{s}$$

Need to choose path. Choose L shape to make integral easier. from $y = 3.00$ to $y = 0$ along y axis, then from $x=0$ to $x = 4.00$ m along x axis.

$$\vec{E} \cdot d\vec{y} = 0 \qquad \vec{E} \cdot d\vec{x} = E_x\, dx$$

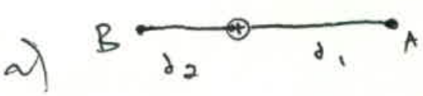
vertical part is 0.

$$V_B - V_A = -\int_0^4 E_x\, dx = -(4.00 \text{ N/C}) \int_0^4 x\, dx = -(4.00 \text{ N/C}) \frac{(4)^2}{2}$$

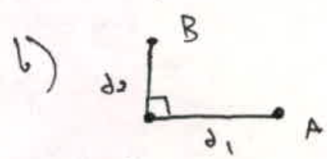
$$V_B - V_A = -32.0 \text{ V}$$

(14) $q = 1.0\ \mu$C , $d_1 = 2.0$ m , $d_2 = 1.0$ m

a)



b)



Same distances for (a) and (b).

$$V_A - V_B = \frac{1}{4\pi\epsilon_0}\frac{q}{d_1} - \frac{1}{4\pi\epsilon_0}\frac{q}{d_2} = \frac{1}{4\pi\epsilon_0} q \left(\frac{1}{d_1} - \frac{1}{d_2}\right)$$

$$V_A - V_B = (8.99 \times 10^9 \text{ Nm}^2/\text{C}^2)(1.0 \times 10^{-6}\text{ C})\left(\frac{1}{2} - 1\right)\text{ m}^{-1} = -4.50 \times 10^3 \text{ V}$$

For both (a) and (b).

dipole moment of NH_3

(21) $1.47\,D$ $\quad 1\,D = 1$ debye unit $= 3.34 \times 10^{-30}\ C\cdot m$, $r = 52.0\ nm$

$$V = \frac{1}{4\pi\epsilon_0}\frac{p\cos\theta}{r^2} \qquad \theta = 0 \text{ when along the axis.}$$

$$V = \frac{1}{4\pi\epsilon_0}\frac{p}{r^2} = \frac{(8.99\times10^{9}\ Nm^2/C^2)(1.47)(3.34\times10^{-30}\ C\cdot m)}{(52.0\times10^{-9}\ m)^2}$$

$$V = 1.63\times10^{-5}\ V$$

(24) $Q = -25.6\ pC$, $R = 3.71\ cm$, $\phi = 120^\circ$, $V = 0$ at ∞.

Potential at P.

Q Arc of plastic.

The whole charge Q is at the same distance from P. Therefore I can say

$$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{R} = \frac{(8.99\times10^{9}\ Nm^2/C^2)(-25.6\times10^{-12}\ C)}{(3.71\times10^{-2}\ m)}$$

$$V = -6.20\ V$$

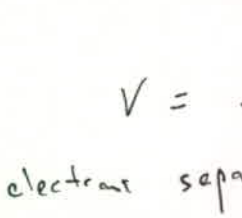
(42) a) 2 electrons separated by 2.00 nm

$$U = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r} = \frac{1}{4\pi\epsilon_0}\frac{e^2}{r} = \frac{(8.99\times10^{9}\ Nm^2/C^2)(1.60\times10^{-19}\ C)^2}{(2.00\times10^{-9}\ m)}$$

$$U = 1.15\times10^{-19}\ J$$

b) separation increases means potential energy decreases due to $\frac{1}{r}$.

(43) $q = 2.30\ pC$, $a = 64.0\ cm$, initially infinitely far apart and at rest.



$E_i = 0$ due to ?

$W = E_f - E_i = E_f$

No kinetic in E_f so only U.

$E_f = U$.

Potential energy works in pairs, so I have to add all of the distinct pairs

$$U = U_{++} + 2U_{+-} + 2U_{+-} + U_{--} = U_{++} + 4U_{+-} + U_{--}$$

$$U = \frac{1}{4\pi\epsilon_0}\left[\frac{q^2}{a\sqrt{2}} + 4\,\frac{(q)(-q)}{a} + \frac{(-q)(-q)}{a\sqrt{2}}\right]$$

$$U = \frac{q^2}{4\pi\epsilon_0 a}\left[\frac{2}{\sqrt{2}} - 4\right] = \frac{q^2}{4\pi\epsilon_0 a}\left[\sqrt{2} - 4\right]$$

$$U = \frac{(12.30\times10^{-12}\ C)^2\,(8.99\times10^{9}\ N\,m^2/C^2)}{(64.0\times10^{-2}\ m)}(\sqrt{2}-4)$$

$$W = E_f = U = -1.92\times10^{-13}\ J$$

$r >> R_1$

(62)  R_1  $2.00R_1$

a) $V_1 = V_2 = V$

b) Note: For those of you in the problem session, I realized
c) the correct method to use to find q. The minimum energy principle is usable but I forgot about the most important part! The following method is much preferred.

Using the fact that $V_1 = V_2 = V$, we will obtain q_1 and q_2. sphere of charge has same $\vec{E}$ as point charge outside sphere so V is the same also outside the sphere.

$$V_1 = \frac{1}{4\pi\epsilon_0}\frac{q_1}{R_1}, \qquad V_2 = \frac{1}{4\pi\epsilon_0}\frac{q_2}{2R_1}$$

$$V = \frac{1}{4\pi\epsilon_0}\frac{q_1}{R_1} \qquad V = \frac{1}{4\pi\epsilon_0}\frac{q_2}{2R_1}$$

$$\frac{1}{4\pi\epsilon_0}\frac{q_1}{R_1} = \frac{1}{4\pi\epsilon_0}\frac{q_2}{2R_1}$$

$$q_1 = \frac{q_2}{2} \Rightarrow \frac{q_1}{q_2} = \frac{1}{2}$$

$$q = q_1 + q_2 = \frac{q_2}{2} + q_2 = \frac{3}{2}q_2$$

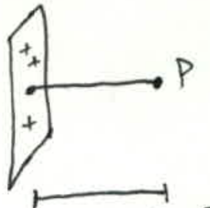
c) $q_2 = \frac{2}{3}q$ so b) $q_1 = \frac{1}{3}q$

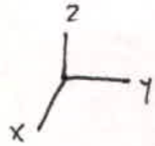
d) $$\frac{\sigma_1}{\sigma_2} = \frac{q_1/A_1}{q_2/A_2} = \frac{q_1 A_2}{q_2 A_1} = \frac{q_1(\cancel{4\pi}(2R_1)^2)}{q_2(\cancel{4\pi}R_1^2)} = \frac{q_1}{q_2}\cdot 4 = \left(\frac{1}{2}\right)(4) = 2$$

Medium : $\sigma = 5.80\ pC/m^2$ infinite nonconducting sheet.

$q = 1.60 \times 10^{-19}\ C$

(9)





$d = 3.56\ cm$

a)

$W = \int \vec{F} \cdot d\vec{s}$ choose the path that goes along the y axis in the $\hat{j}$ direction.

$\vec{E} = \frac{\sigma}{2\epsilon_0}\hat{j}$ to the right of the sheet. (+y)

$\vec{F} = q\vec{E}$

$$W = q\int \vec{E} \cdot d\vec{s} = q\int_0^d \left(\tfrac{\sigma}{2\epsilon_0}\hat{j}\right) \cdot (dy\,\hat{j})$$

$$W = \frac{q\sigma}{2\epsilon_0}\int_0^d dy = \frac{q\sigma}{2\epsilon_0} d$$

$$W = \frac{(1.60 \times 10^{-19}\ C)(5.80 \times 10^{-12}\ C/m^2)(3.56 \times 10^{-2}\ m)}{2(8.85 \times 10^{-12}\ C^2/Nm^2)}$$

$$W = 1.87 \times 10^{-21}\ J$$

b)

$W = -\Delta U = -q\Delta V$ $V_i = 0$ ~ at sheet

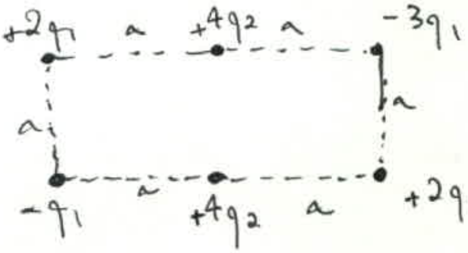
V_f ~ at point P.

$$\Delta V = -\frac{W}{q}$$

$$V_f - V_i = \frac{-W}{q}$$

$$V_f = -\frac{W}{q} = -1.17 \times 10^{-2}\ V$$

(16) $a = 39.0\ cm$, $q_1 = 3.40\ pC$, $q_2 = 6.00\ pC$. $V = 0$ at ∞ , what is V at center of rectangle?



The four corners are the same distance so I can add the charges together for the calculation.

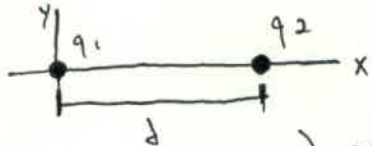
$2q_1 - q_1 - 3q_1 + 2q_1 = 0$. So the corner contributions cancel.

• The 2 middle charges are also at the same distance from the center, $\left(\frac{a}{2}\right)$. add to get $8q_2$.

$$V = \frac{1}{4\pi\epsilon_0}\frac{8q_2}{(a/2)} = \frac{1}{4\pi\epsilon_0}\frac{q_2}{a}\cdot 16 = \frac{(8.99\times10^9\ Nm^2/C^2)(6.00\times10^{-12}C)(16)}{(39.0\times10^{-2}m)}$$

$V = 2.21\ V$

(19) $q_1 = 5e$, $q_2 = -15e$, $d = 24.0$ cm $V = 0$ at ∞.



a) positive and b) negative values of x at which $V = 0$ on the x axis.

2 points, 1 in between charges and 1 in $(-x)$.

a) $$V = \frac{1}{4\pi\epsilon_0}\left[\frac{q_1}{x} + \frac{q_2}{d-x}\right] = 0$$

$$\frac{q_1}{x} = \frac{-q_2}{d-x}$$

$$\frac{5e}{x} = \frac{15e}{d-x} \Rightarrow \quad 15ex = 5ed - 5ex$$

$$x = \frac{d}{4} = 6.00\ cm$$

b) $$V = \frac{1}{4\pi\epsilon_0}\left[\frac{q_1}{(-x)} + \frac{q_2}{d+x}\right] = 0$$

$$\frac{q_1}{x} = \frac{q_2}{d+x}$$

$$\frac{5e}{x} = \frac{-15e}{d+x}$$

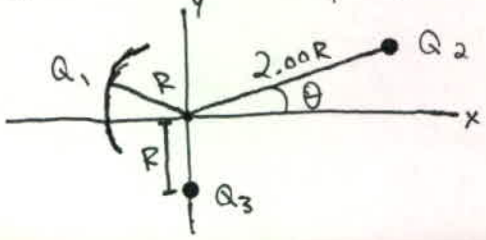
$$5d + 5x = -15x$$

$$20x = -5d$$

$$x = -\frac{d}{4} = -6.00\ cm$$

(29) $Q_1 = +7.21\ pC$

$Q_2 = 4.00\ Q_1$, $Q_3 = -2.00\ Q_1$, $R = 2.00$ m, $\theta = 20.0°$



V at origin.

Since the origin is the center of curvature for the arc, we can treat it as just a point charge Q_1 a distance R away.

$$V = \frac{1}{4\pi\epsilon_0}\left(\frac{Q_1}{R} + \frac{Q_3}{R} + \frac{Q_2}{2R}\right) = \frac{1}{4\pi\epsilon_0}\left(\frac{Q_1}{R} - \frac{2Q_1}{R} + \frac{4Q_1}{2R}\right)$$

$$V = \frac{1}{4\pi\epsilon_0}\frac{Q_1}{R} = \frac{(8.99\times10^9\ Nm^2/C^2)(7.21\times10^{-12}\ C)}{(2.00\ m)}$$

$$V = 3.24\times10^{-2}\ V$$

(30)

full circle -> $R_c = 6.0$ cm , $q_c = -3.0\ \mu C$

arc -> $R_A = 4.0$ cm , $q_A = 2.0\ \mu C$ concentric

dipole -> $p = 1.28\times10^{-21}$ C·m perpendicular to radial line.

V at center.

dipole contribution is 0 because $V_D = \frac{1}{4\pi\epsilon_0}\frac{p\cos\theta}{r^2}$ and $\theta = \frac{\pi}{2}$ so $\cos\frac{\pi}{2} = 0$ then $V_D = 0$.

$$V = \frac{1}{4\pi\epsilon_0}\left[\frac{q_c}{R_c} + \frac{q_A}{R_A}\right] = \frac{1}{4\pi\epsilon_0}\left[\frac{-3\times10^{-6}\ C}{6\times10^{-2}\ m} + \frac{2\times10^{-6}\ C}{4\times10^{-2}\ m}\right]$$

$$V = \frac{1}{4\pi\epsilon_0}\left[-5\times10^{-5}\ \frac{C}{m} + 5\times10^{-5}\ \frac{C}{m}\right] = 0$$

$$V = 0$$ (turns out this one was easy)

(37) E at $(3.00\,\hat{i} - 2.00\,\hat{j} + 4.00\,\hat{k})$ m if $V = 2.00\,xyz^2$, V in volts, x, y, z meters.

(3, -2, 4)

$$E_x = -\frac{\partial V}{\partial x},\quad E_y = -\frac{\partial V}{\partial y},\quad E_z = -\frac{\partial V}{\partial z}$$

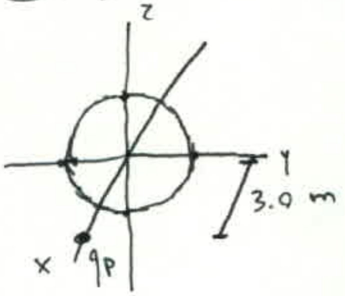
$$E_x = -2yz^2,\quad E_y = -2xz^2,\quad E_z = -4xyz$$

At (3, -2, 4) we have $E_x = (-2)(-2)(4)^2$ $E_y = (-2)(3)(4)^2$ $E_z = (-4)(3)(-2)(4)$

$E_x = 64$ N/C $E_y = -96$ N/C $E_z = 96$ N/C

then $E = \sqrt{E_x^2 + E_y^2 + E_z^2} = 32\sqrt{22}$ N/C $= 150.$ N/C

(46) $q_r = -9.0$ nC thin plastic ring in yz-plane.

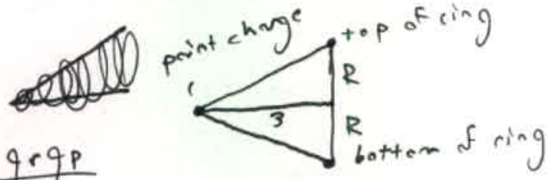


$q_P = -6.0$ pC at $x = 3.0$ m

ring radius $R = 1.5$ m

key is external force for sign of ΔU. For W.

$$W = U_f - U_i$$



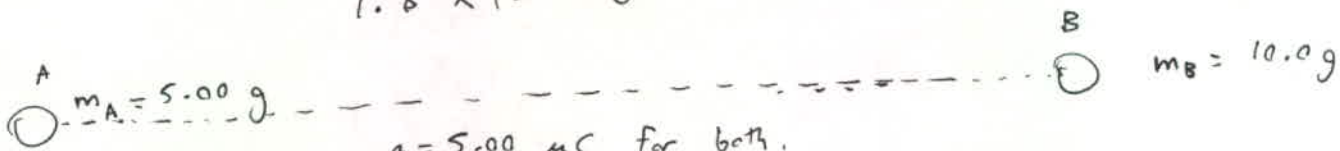
when point charge is ~~at~~ origin → $U_f = \dfrac{q_r q_p}{4\pi\epsilon_0 R}$ $\qquad U_i = \dfrac{q_r q_p}{4\pi\epsilon_0 r}$ $\qquad r = \sqrt{3^2 + R^2}$

$$W = U_f - U_i = \frac{q_r q_p}{4\pi\epsilon_0}\left(\frac{1}{R} - \frac{1}{\sqrt{3^2+R^2}}\right)$$

$$W = (-9.0\times10^{-9}\text{ C})(-6.0\times10^{-12}\text{ C})(8.99\times10^{9}\text{ Nm}^2/\text{C}^2) \cdot \left(\frac{1}{1.5} - \frac{1}{\sqrt{11.25}}\right)\text{m}^{-1}$$

$$W = 1.80\times10^{-10}\text{ J}$$
$$1.8\times10^{-10}\text{ J}$$

(53)



$q = 5.00\ \mu$C for both.

$d = 1.00$ m length of string → nonconducting

$d \gg R$.

a) $U = \dfrac{1}{4\pi\epsilon_0}\dfrac{q^2}{d} = \dfrac{(8.99\times10^9\text{ Nm}^2/\text{C}^2)(5.00\times10^{-6}\text{ C})^2}{1.00\text{ m}} = 0.225$ J

b) $F = \dfrac{1}{4\pi\epsilon_0}\dfrac{q^2}{d^2} = \dfrac{U}{d} = \dfrac{U}{1\text{ m}} = 0.225$ N

$a_A = \dfrac{F}{m_A}$, $a_B = \dfrac{F}{m_B} = \dfrac{F}{10^{-2}\text{ kg}} = 22.5\text{ m/s}^2$

$a_A = \dfrac{F}{5\times10^{-3}\text{ kg}} = \dfrac{2F}{10^{-2}\text{ kg}} = 45.0\text{ m/s}^2$

c) U is split between the 2 metal spheres KE.

$$U = KE_A + KE_B$$
$$U = \tfrac{1}{2}m_A v_A^2 + \tfrac{1}{2}m_B v_B^2$$

Need another equation to solve for the pair of v_A and v_B.

Momentum is conserved, so we can use that equation.

$\sum \vec{p}_i = \sum \vec{p}_f$ mass A moves to the left, B to the right. Initially neither move, so $p_i = 0$.

$$0 = \vec{p}_A + \vec{p}_B$$

$$0 = -p_A + p_B$$

$$p_B = p_A$$

$$m_B v_B = m_A v_A$$

$$v_B = \frac{m_A}{m_B} v_A = \frac{1}{2} v_A$$

$$U = \frac{1}{2} m_A v_A^2 + \frac{1}{2} m_B \left(\frac{v_A}{2}\right)^2 = \frac{1}{2} m_A v_A^2 + \frac{1}{8} m_B v_A^2$$

$$v_A^2 = \frac{8U}{4m_A + m_B} = \frac{8U}{3\times10^{-2}\,kg}$$

$$|v_A| = \sqrt{\frac{8U}{3\times10^{-2}\,kg}} = 7.74\ m/s$$

$$|v_B| = \frac{|v_A|}{2} = 3.87\ m/s$$

(67)  $R = 15\ cm$, $q = 3.0\times10^{-8}\ C$, metal sphere.

a) at surface, $E = \frac{1}{4\pi\epsilon_0}\frac{q}{R^2} = \frac{(8.99\times10^9\ Nm^2/C^2)(3.0\times10^{-8}\ C)}{(15\times10^{-2}\ m)^2} = 1.2\times10^4\ N/C$

b) $V = 0$ at ∞, what is V at surface?

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{R} = E\cdot R = 1.8\times10^3\ V$$

c) $V_f - V_R = -500$

$$V_f = V_R - 500 \qquad V_f = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

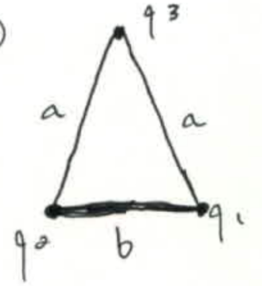
$$\frac{1}{4\pi\epsilon_0}\frac{q}{r} = V_R - 500$$

$$r = \frac{q}{4\pi\epsilon_0}\frac{1}{V_R - 500} = \frac{(3.0\times10^{-8}\ C)(8.99\times10^9\ Nm^2/C^2)}{1298\ V}$$

$r = 0.21\ m$ is the distance from the center.

distance from surface $L = r - R = 5.8\ cm$

(74)

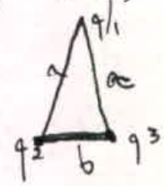


$q_1 = 10\,\mu C$, $q_2 = -20\,\mu C$, $q_3 = 30\,\mu C$

$a = 10$ cm, $b = 6.0$ cm

$W = U_f - U_i$

a) exchange positions of q_1 and q_3 and b) q_1 and q_2



$$U_f = \frac{1}{4\pi\epsilon_0}\left[\frac{q_1q_3}{a} + \frac{q_1q_2}{a} + \frac{q_2q_3}{b}\right]$$

$$U_i = \frac{1}{4\pi\epsilon_0}\left[\frac{q_1q_3}{a} + \frac{q_2q_3}{a} + \frac{q_1q_2}{b}\right]$$

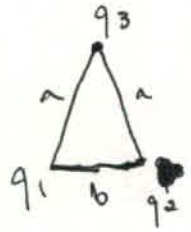
$$W = U_f - U_i = \frac{1}{4\pi\epsilon_0}\left[\frac{q_2(q_1-q_3)}{a} + \frac{q_2(q_3-q_1)}{b}\right] = \frac{q_2}{4\pi\epsilon_0}\left[\frac{(q_1-q_3)}{a} - \frac{(q_1-q_3)}{b}\right]$$

$q_1 - q_3$

$$W = (8.99\times10^9\ Nm^2/C^2)(-20\times10^{-6}\ C)(-20\times10^{-6}\ C)\left[\frac{1}{.1} - \frac{1}{.06}\right] m^{-1}$$

$W = -24$ J

b)



$$U_f = \frac{1}{4\pi\epsilon_0}\left[\frac{q_1q_3}{a} + \frac{q_2q_3}{a} + \frac{q_1q_2}{b}\right] = U_i$$

Good symmetry here.

so $W = U_f - U_i = 0$

Hard:

(11) Nonconducting sphere $R = 2.31$ cm $q = 3.50$ fC uniform.

$V_0 = 0$ at sphere's center.

$V_0 = V_i = 0$, so

$$V = -\int_{r=0}^{r} \vec{E}\cdot d\vec{s} = -\int_{r=0}^{r} E\hat{r}\cdot dr\hat{r} = -\int_{r=0}^{r} E\,dr$$

a) $r = 1.45$ cm b) $r = R$

Inside the nonconducting sphere $(r \leq R)$, we have

$$E = \left(\frac{q}{4\pi\epsilon_0 R^3}\right) r$$

so $$V = -\int_0^r \left(\frac{q}{4\pi\epsilon_0 R^3}\right) r\, dr$$

$$V = \frac{-q}{4\pi\epsilon_0 R^3} \int_0^r r\, dr = \frac{-q r^2/2}{4\pi\epsilon_0 R^3}$$

At $r = 1.45$ cm,

$$V = \frac{-(3.50 \times 10^{-15}\, C)(1.45 \times 10^{-2}\, m)^2 (8.99 \times 10^9\, Nm^2/C^2)}{2\,(2.31 \times 10^{-2}\, m)^3}$$

$$V = -2.68 \times 10^{-4}\ V$$

b) At $r = R$,

$$V = \frac{-q R^2/2}{4\pi\epsilon_0 R^3} = \frac{-q}{4\pi\epsilon_0} \frac{1}{2R}$$

$$V = \frac{-(3.50 \times 10^{-15}\, C)(8.99 \times 10^9\, Nm^2/C^2)}{2\,(2.31 \times 10^{-2}\, m)}$$

$$V = -6.81 \times 10^{-4}\ V$$

(32) $\lambda = bx$ nonuniform linear charge distribution, b const.
from $x = 0$ to $x = 0.20$ m $= x_{max}$, $b = 20\, nC/m^2$, $V = 0$ at ∞.
V at a) the origin and b) the point $y = 0.15$ m $= y_{max}$ on the y axis.

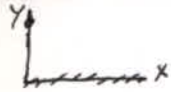
$$V = \frac{1}{4\pi\epsilon_0} \int \frac{dq}{r} \qquad dq = \lambda\, dx$$

a) $$V = \frac{1}{4\pi\epsilon_0} \int_0^{x_{max}} \frac{\lambda\, dx}{x} = \frac{1}{4\pi\epsilon_0} \int_0^{x_{max}} \frac{bx}{x}\, dx = \frac{b}{4\pi\epsilon_0} \int_0^{x_{max}} dx$$

$$V = \frac{b\, x_{max}}{4\pi\epsilon_0}$$

$$V = (20 \times 10^{-9}\, C/m^2)(0.20\, m)(8.99 \times 10^9\, Nm^2/C^2)$$

origin $\quad V = 36\ V$



b) $r = \sqrt{x^2 + y_{max}^2}$

$$V = \frac{1}{4\pi\epsilon_0}\int_0^{x_{max}} \frac{b\,x}{\sqrt{x^2+y_{max}^2}}\,dx$$

$u = x^2 + y_{max}^2$

$du = 2x\,dx$

$x = 0 \to u = y_{max}^2$

$x = x_{max} \to u = x_{max}^2 + y_{max}^2$

$$V = \frac{b}{4\pi\epsilon_0}\int_{y_{max}^2}^{x_{max}^2+y_{max}^2} \frac{du/2}{\sqrt{u}}$$

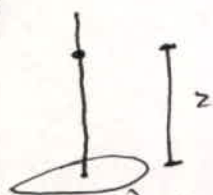
$$V = \frac{b}{4\pi\epsilon_0}\,\cancel{\tfrac{2}{2}}\sqrt{u}\,\Big]_{y_{max}^2}^{x_{max}^2+y_{max}^2} = \frac{b}{4\pi\epsilon_0}\left[\sqrt{x_{max}^2+y_{max}^2} - y_{max}\right]$$

$$V = (20\times10^{-9}\ C/m^2)(8.99\times10^{9}\ Nm^2/C^2)\left[\sqrt{.2^2+.15^2}+.15\right] m$$

$y = 0.15$ m $\qquad V = 72$ V

(99) $V = \frac{1}{4\pi\epsilon_0}\frac{q}{\sqrt{z^2+R^2}}$

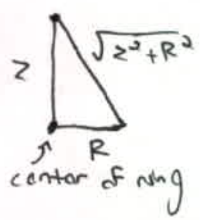
a) show



thin ring charge q, radius R.

No integral even required.

All points on the ring are an equal distance from the point we wish to calculate potential at. That distance is $\sqrt{z^2+R^2}$



Then we can immediately write

$V = \frac{1}{4\pi\epsilon_0}\frac{q}{\sqrt{z^2+R^2}}$ since the whole charge q is at this distance $\sqrt{z^2+R^2}$ from the point in question.

b) we see from the symmetry that there will only be a z component.

(Also $\frac{\partial V}{\partial x} = \frac{\partial V}{\partial y} = 0$)

$$E = E_z = -\frac{\partial V}{\partial z} = \frac{-q}{4\pi\epsilon_0}\frac{(-\frac{1}{2})(2z)}{(z^2+R^2)^{3/2}} = \frac{q}{4\pi\epsilon_0}\frac{z}{(z^2+R^2)^{3/2}} \quad \checkmark$$

checks out with book's version.