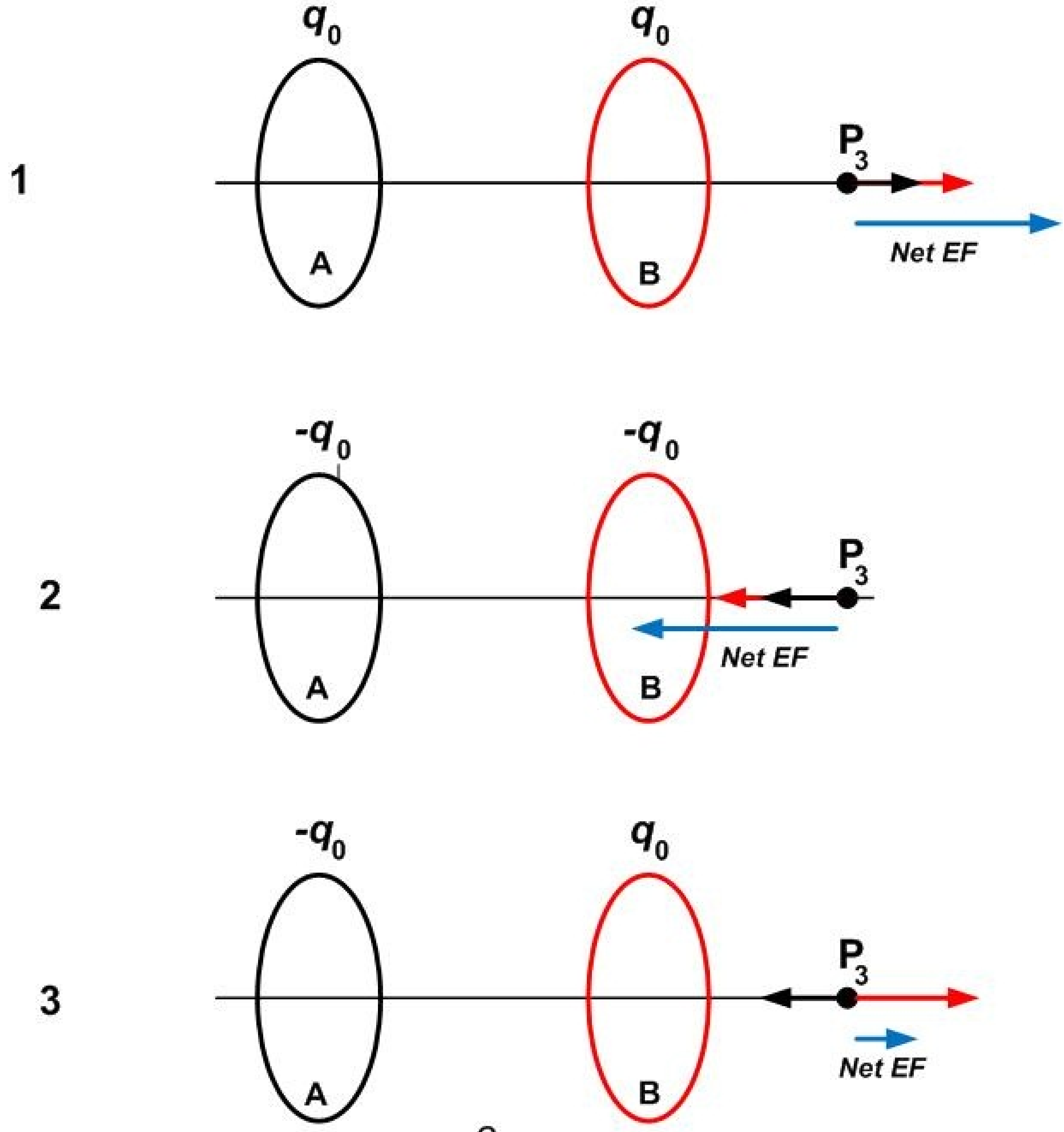
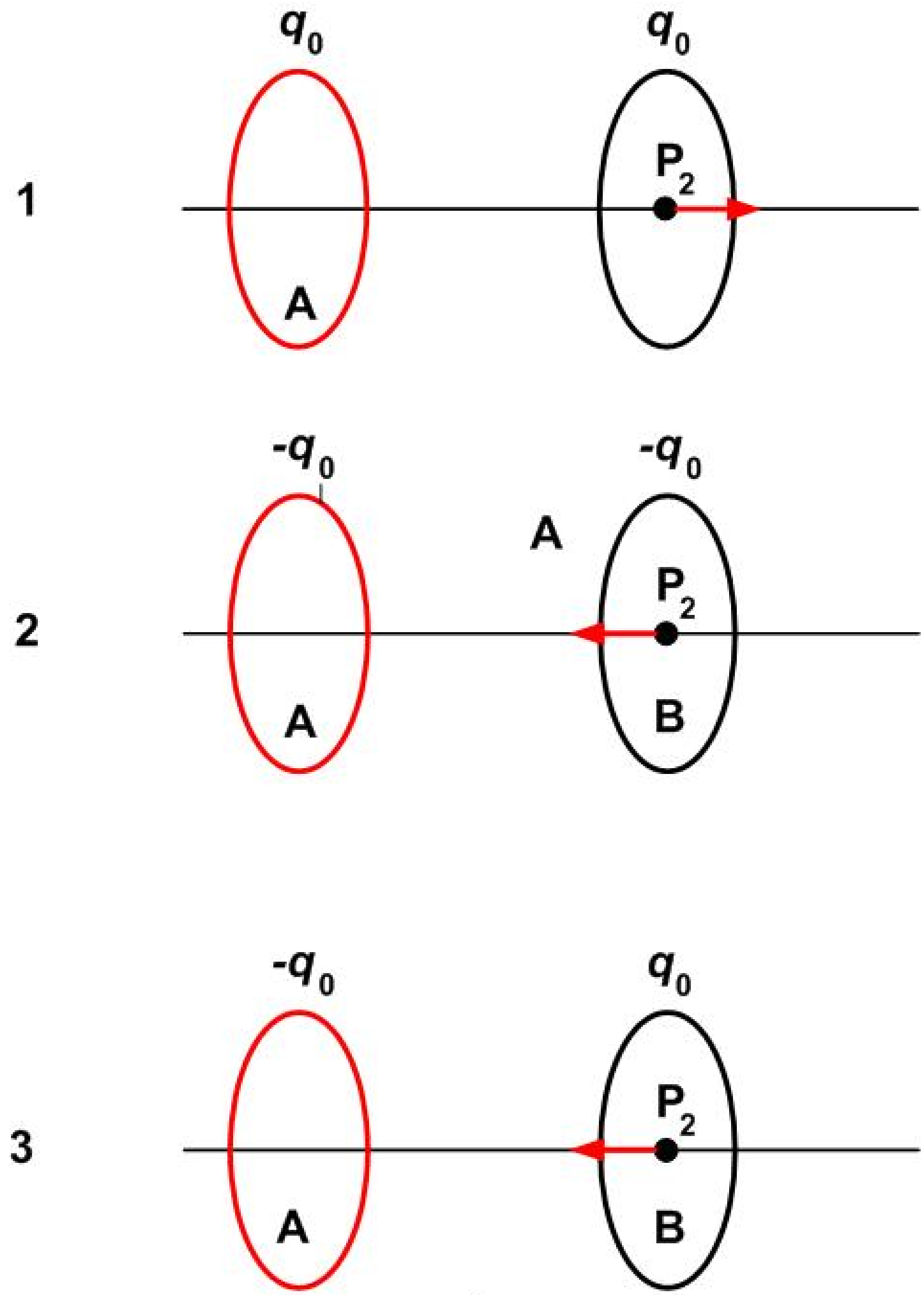


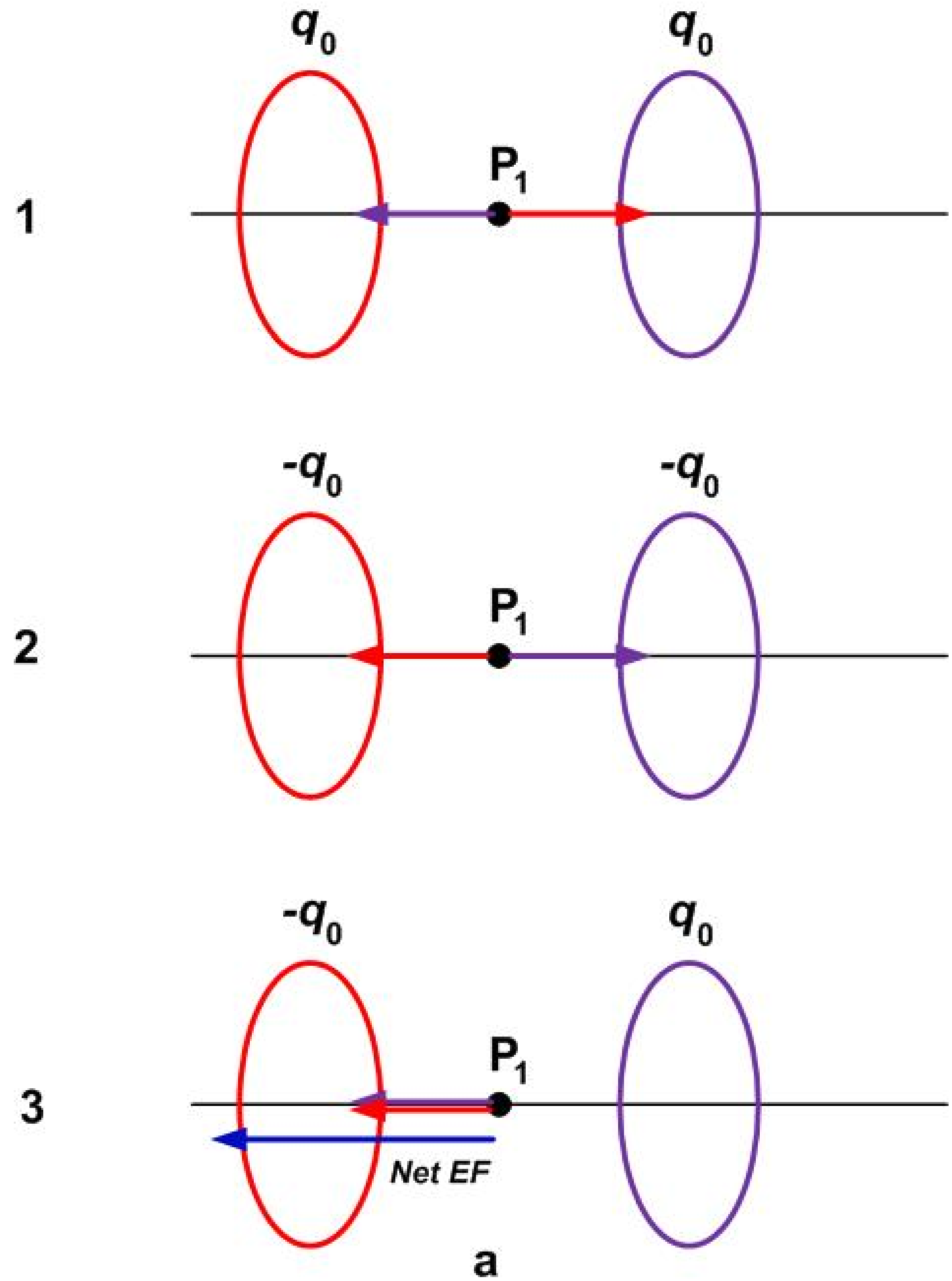
C

Ranking:1 & 2 tie then 3

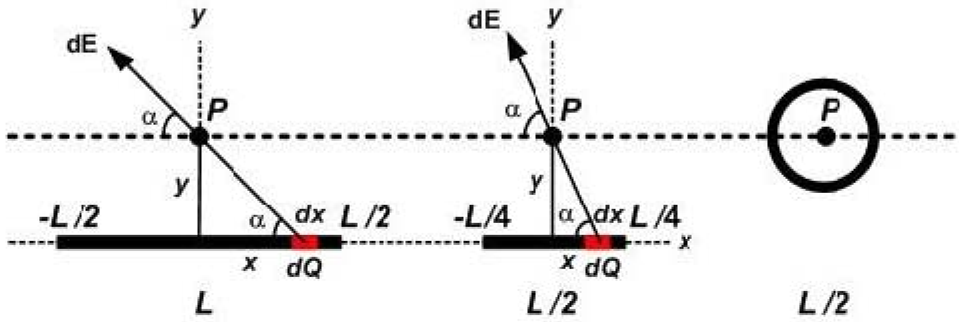


b

Ranking: All tie



Ranking: 3 then 1 & 2 tie (zero)



(*a*) (*b*) (*c*)

$$E = \frac{qy}{2\pi\varepsilon_0 y^2}\frac{1}{\sqrt{L^2+4y^2}} \qquad E = \frac{qy}{\pi\varepsilon_0 y^2}\frac{1}{\sqrt{L^2+16y^2}} \qquad E = 0$$

Problem # 11

$q_1 = 2.1 \times 10^{-8}\, C$; $x_1 = 20\, cm$

$q_2 = -4 q_1$; $x_2 = 70\, cm$

Let x be the coordinate of point where the electric field vanishes.

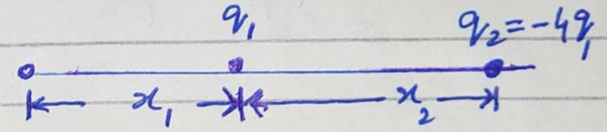
i) For $x > 70\, cm$; No possibility

ii) For $20\, cm < x < 70\, cm$; not possible

iii) For $x < 20\, cm$; Possible

A pt. of zero field must be closer to q_1 than q_2. It must be to the left of q_1.

$$E = \frac{1}{4\pi\varepsilon_0}\left[\frac{|q_2|}{(x-x_2)^2} - \frac{|q_1|}{(x-x_1)^2}\right] = 0$$



$$\frac{|q_2|}{(x-x_2)^2} - \frac{|q_1|}{(x-x_1)^2} = 0$$

$$\frac{|q_2|}{(x-x_2)^2} = \frac{|q_1|}{(x-x_1)^2} \Rightarrow$$

(2)

$$\frac{|q_2|}{|q_1|} = \frac{(x-x_2)^2}{(x-x_1)^2} \Rightarrow \frac{(x-x_2)^2}{(x-x_1)^2} = \frac{4q_1}{q_1} = 4$$

$$\frac{x-x_2}{x-x_1} = \pm 2 \Rightarrow \frac{x-70}{x-20} = \pm 2$$

$x-70 = 2(x-20)$

$x-70 = 2x-40$

$x = -30$ cm

$x < x_1$

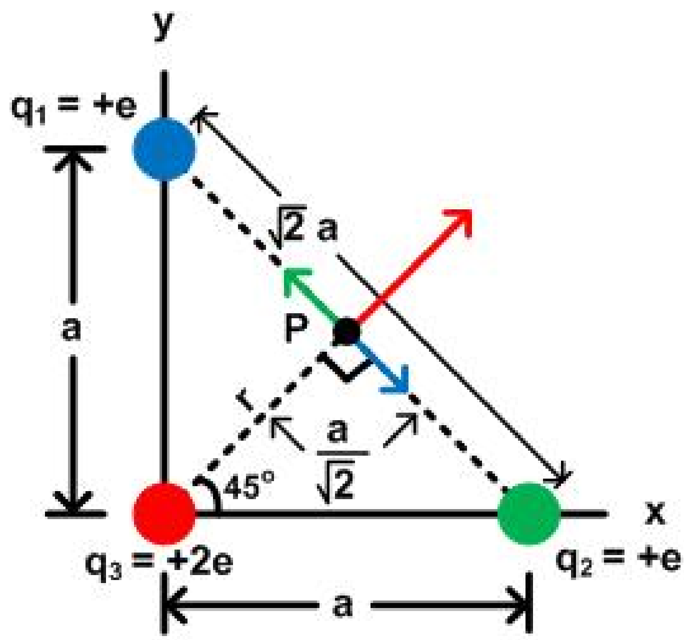
$x-70 = -2(x-20)$

$x-70 = -2x+40$

$3x = 110$

$x = 36.66$ cm

$x_1 < x < x_2$



Problem:15

Problem # 15

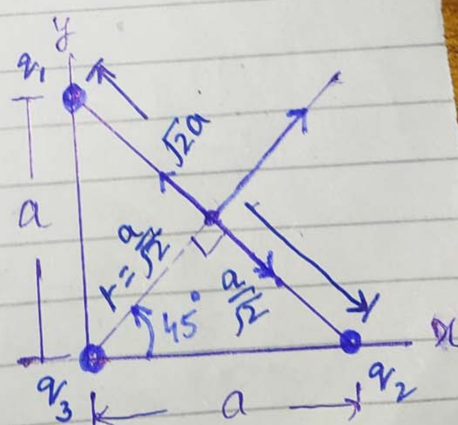
By symmetry contributions from the two charges $|q_1| = |q_2| = +e$ cancel eachother

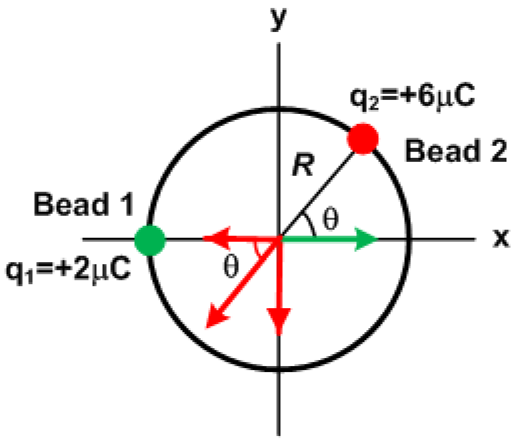
a) $|E_{net}| = \frac{1}{4\pi\varepsilon_0} \frac{|q_3|}{r^2} = \frac{1}{4\pi\varepsilon_0} \frac{2e}{(a/\sqrt{2})^2}$

$= \frac{1}{4\pi\varepsilon_0} \frac{4e}{a^2} = 9\times10^{9}\ N\text{-}m^2/C^2 \cdot 4\times 1.6\times10^{-19}\ C/(6\times10^{-6}m)^2$

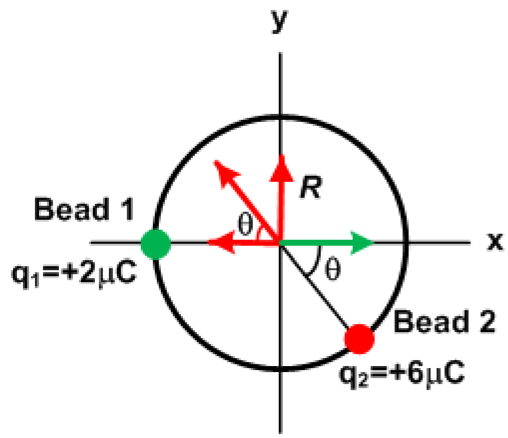
$= 160\ N/C$

b) The field points 45° counter clockwise from x-axis.





Problem: 16(a)



Problem: 16(b)

Problem # 16

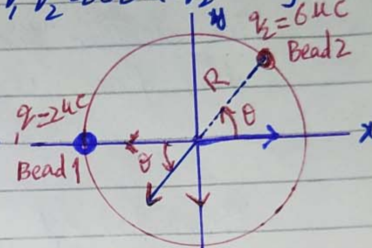
(a) $E_{net,x} = \left(\frac{q_1}{4\pi\varepsilon_0 R^2} - \frac{q_2\cos\theta}{4\pi\varepsilon_0 R^2}\right)$; $E_{net,y} = -\frac{q_2\sin\theta}{4\pi\varepsilon_0 R^2}$

The magnitude is the square root of the sum of the components - squared

$$E^2 = \left(\frac{q_1}{4\pi\varepsilon_0 R^2} - \frac{q_2\cos\theta}{4\pi\varepsilon_0 R^2}\right)^2 + \left(\frac{-q_2\sin\theta}{4\pi\varepsilon_0 R^2}\right)^2$$

$$= \frac{1}{16\pi^2\varepsilon_0^2 R^4}\left[q_1^2 + q_2^2\cos^2\theta - 2q_1q_2\cos\theta + q_2^2\sin^2\theta\right]$$

$$E^2 = \frac{q_1^2 + q_2^2 - 2q_1q_2\cos\theta}{16\pi^2\varepsilon_0^2 R^4}$$



$$16\pi^2\varepsilon_0^2 R^4 E^2 = q_1^2 + q_2^2 - 2q_1q_2\cos\theta$$

$$2q_1q_2\cos\theta = q_1^2 + q_2^2 - 16\pi^2\varepsilon_0^2 R^4 E^2$$

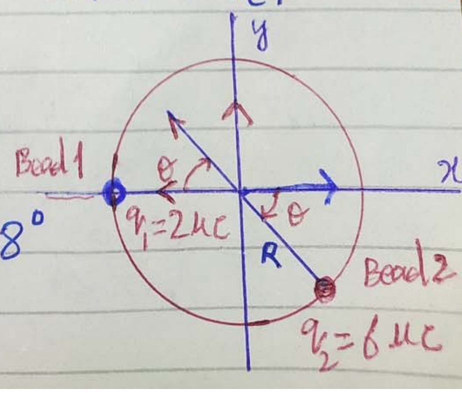
$$\cos\theta = \frac{q_1^2 + q_2^2 - 16\pi^2\varepsilon_0^2 R^4 E^2}{2q_1q_2}$$

$R = 0.5\ m$; $q_1 = 2\times10^{-6}C$; $q_2 = 6\times10^{-6}C$

$16\pi^2\varepsilon_0^2 = 1/(9\times10^9)^2$; $E = 2\times10^5\ N/C$

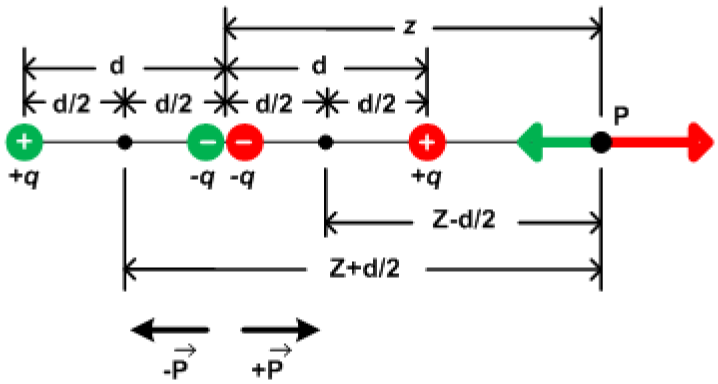
$$\cos\theta = 4\times10^{-12}C^2 + 36\times10^{-12}C^2 - \frac{(0.5)^4(4\times10^{10}\ N^2/C^2)}{81\times10^{18}\ N^2 m^4/C^4} \Big/ 24\times10^{-12}C^2$$

$\theta = 67.8^\circ$



(b) By Symmetry

$\theta = -67.8^\circ$

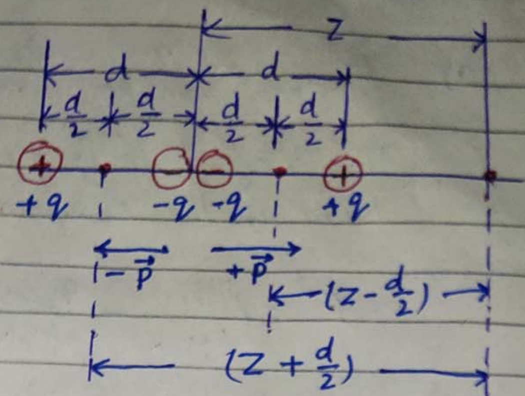


Problem: 21

Problem # 21

The expression for the electric field of a dipole at a pt. on dipole axis at distance z from dipole center is

$$E = \frac{1}{2\pi\varepsilon_0}\frac{qd}{z^3}$$



The electric field produced by right dipole of the pair is

$$E_R = \frac{1}{2\pi\varepsilon_0}\frac{qd}{(z-\frac{d}{2})^3} = \frac{1}{2\pi\varepsilon_0} qd\left(z-\frac{d}{2}\right)^{-3}$$

Similarly

$$E_L = \frac{-1}{2\pi\varepsilon_0}\frac{qd}{(z+\frac{d}{2})^3} = \frac{-qd\left(z+\frac{d}{2}\right)^{-3}}{2\pi\varepsilon_0}$$

$$E = E_R - E_L = \frac{qd}{2\pi\varepsilon_0}\left[\left(z-\frac{d}{2}\right)^{-3} - \left(z+\frac{d}{2}\right)^{-3}\right]$$

$$(1\pm x)^{-n} = 1 \mp \frac{nx}{1!} + \frac{n(n+1)}{2!}x^2 \mp \cdots \qquad x^2<1$$

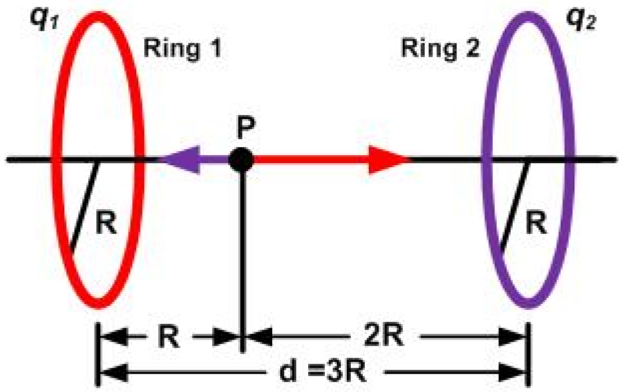
$$\left(z-\frac{d}{2}\right)^{-3} = z^{-3}\left(1-\frac{d}{2z}\right)^{-3} = z^{-3}\left[1+\frac{3(\frac{d}{2z})}{1!}+\frac{3(4)(\frac{d}{2z})^2}{2!}+\cdots\right]$$

$$= \frac{1}{z^3}+\frac{3d}{2z^4} \qquad z \gg d$$

$$\left(z+\frac{d}{2}\right)^{-3} = z^{-3}\left(1+\frac{d}{2z}\right)^{-3} = z^{-3}\left[1-\frac{3(\frac{d}{2z})}{1!}+\frac{3(4)(\frac{d}{2z})^2}{2!}+\cdots\right]$$

$$E = \frac{qd}{2\pi\varepsilon_0}\left[\frac{1}{z^3}+\frac{3d}{2z^4}-\frac{1}{z^3}+\frac{3d}{2z^4}\right]$$

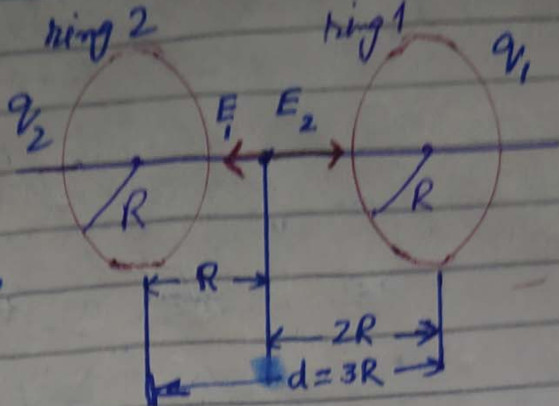
$$= \frac{6qd^2}{4\pi\varepsilon_0 z^4} = \frac{3(2qd)}{4\pi\varepsilon_0 z^4} = \frac{3Q}{4\pi\varepsilon_0 z^4}$$



Problem: 23

5

Problem # 23



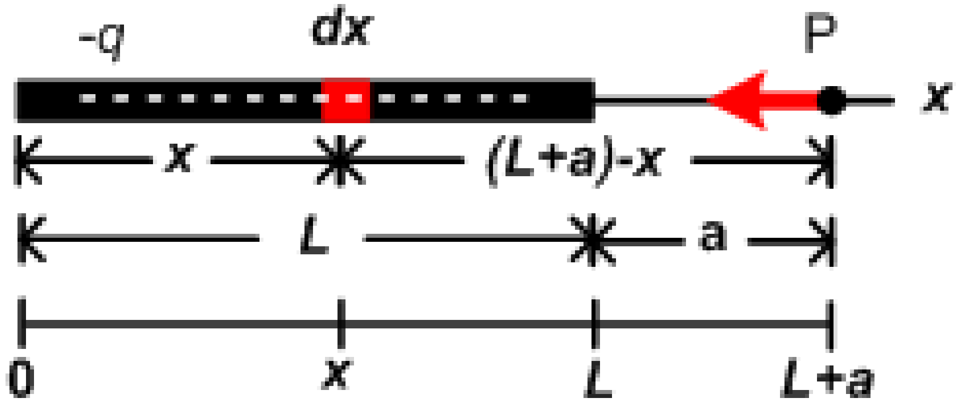
The expression for the electric field of a charged ring a distance z on the central axis is

$$E = \frac{qz}{4\pi\varepsilon_0 (z^2+R^2)^{\frac{3}{2}}}$$

$$E_{ring\,2} = E_{ring\,1}$$

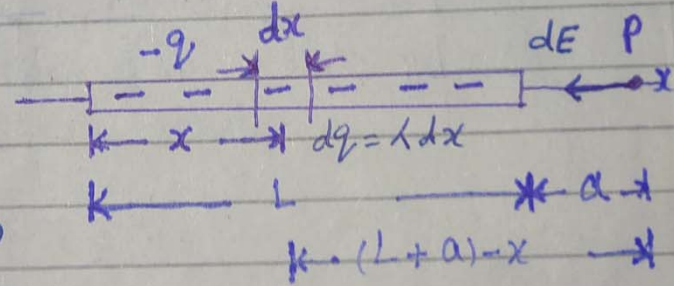
$$\frac{q_1 R}{\cancel{4\pi\varepsilon_0}(R^2+R^2)^{\frac{3}{2}}} = \frac{q_2 (2R)}{\cancel{4\pi\varepsilon_0}\left[R^2+(2R)^2\right]^{\frac{3}{2}}}$$

$$\frac{q_1}{q_2} = \frac{2(2R^2)^{\frac{3}{2}}}{(5R^2)^{3/2}} = 2\left[\frac{2}{5}\right]^{\frac{3}{2}} \approx 0.506$$



Problem: 31

Problem # 31



a)

$$\lambda = \frac{-q}{L} = \frac{-4.23\times10^{-15}\,C}{0.0815m}$$

$$= -5.19\times10^{-14}\ C/m$$

b) Let dx be an infintesimal length of rod at x. The charge in this segment is

$$dq = \lambda dx$$

$$dE_x = \frac{1}{4\pi\varepsilon_0}\frac{dq}{(L+a-x)^2} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda dx}{(L+a-x)^2}$$

6

$$E_x = \frac{\lambda}{4\pi\varepsilon_0}\int_0^L \frac{dx}{(L+a-x)^2} = \frac{-\lambda}{4\pi\varepsilon_0}\int_0^L (L+a-x)^{-2}(-dx)$$

$$= -\frac{\lambda}{4\pi\varepsilon_0}\left[\frac{(L+a-x)^{-2+1}}{-2+1}\Big|_0^L\right] = \frac{\lambda}{4\pi\varepsilon_0}\left[a^{-1} - (L+a)^{-1}\right]$$

$$= \frac{\lambda}{4\pi\varepsilon_0}\left[\frac{1}{a} - \frac{1}{L+a}\right] = \frac{\lambda}{4\pi\varepsilon_0}\left[\frac{L+a-a}{a(L+a)}\right]$$

$$= \frac{\lambda}{4\pi\varepsilon_0}\frac{L}{a(L+a)} = -\frac{q}{4\pi\varepsilon_0 a(L+a)} \; ; \boxed{-q = \lambda L}$$

$-q = -4.23 \times 10^{-15}\, C$; $L = 0.0815\, m$

$a = 0.12\, m$

$$E_x = -1.57 \times 10^{-3}\, N/C$$

c) The negative sign shows that the field points in the $-x$-direction or $180°$ counterclockwise from +ve x-axis.

d) If a is much larger than L, the quantity $L+a$ in the denominator can be approximated by a $a \gg L$; $L + a \simeq a$

Since $a = 50\, m \gg L = 0.085\, m$

$$E_x = -\frac{1}{4\pi\varepsilon_0}\frac{q}{a(L+a)} = -\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2(1+\frac{L}{a})}$$

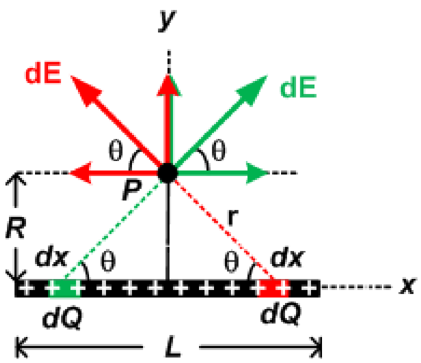
$$E_x = -\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2} = -1.5 \times 10^{-8}\, N/m$$

$$|E_x| = 1.52 \times 10^{-8}\, N/C$$

e)

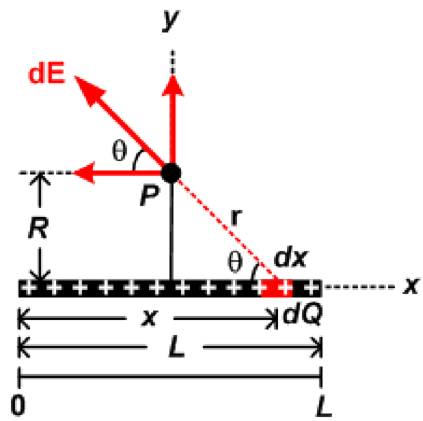
$$E_x = -\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2} = -1.52 \times 10^{-8}\, N/C$$

$$|E_x| = 1.52 \times 10^{-8}\, N/C$$

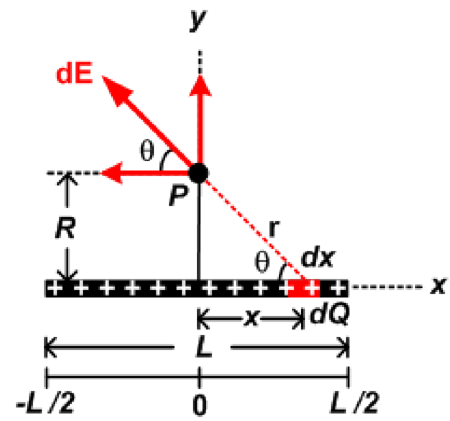


y
dE
dE
θ
θ
P
R
r
dx
θ
θ
dx
x
dQ
dQ
L

Problem: 32

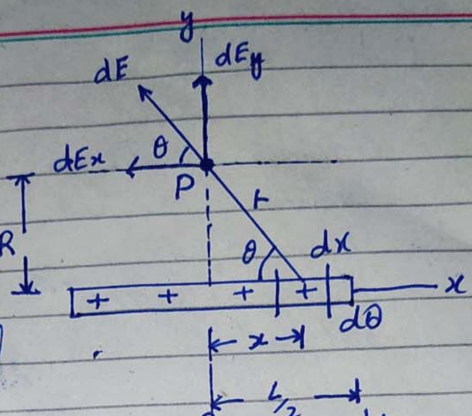


y
dE
θ
P
R
r
θ
dx
x
x
dQ
L
0
L



y
dE
θ
P
R
r
θ
dx
x
x
dQ
L
-L /2
0
L /2

Problem # 32



a)

$\lambda = Q/L$

Infintesimal element dx contains charge

$dQ = \lambda\, dx$

By symmetry all horizontal field components cancell.
We need only sum (integrate) the vertical components.

Symmetry also allows us to integrate these contributions over only half the rod ($0 \le x \le L/2$) and then simply double the result.

$$dE_y = dE \sin\theta = \frac{1}{4\pi\varepsilon_0}\frac{dQ}{r^2} \quad ; \quad \sin\theta = R/r = \frac{R}{(x^2+R^2)^{1/2}}$$

$$|\vec{E}| = |E_y| = \int_0^L dE_y = \int_{-L/2}^{L/2} dE_y = 2\int_0^{L/2} dE_y$$

$$|\vec{E}| = 2\int_0^{L/2} dE_y = 2\int_0^{L/2} dE\sin\theta = 2\int_0^{L/2} \frac{1}{4\pi\varepsilon_0}\frac{dQ}{(x^2+R^2)}\cdot\frac{R}{(x^2+R^2)^{1/2}}$$

$$= \frac{1}{2\pi\varepsilon_0}\int_0^{L/2}\frac{R\lambda\, dx}{(x^2+R^2)^{3/2}} = \frac{\lambda R}{2\pi\varepsilon_0}\int_0^{L/2}\frac{dx}{(x^2+R^2)^{3/2}}$$

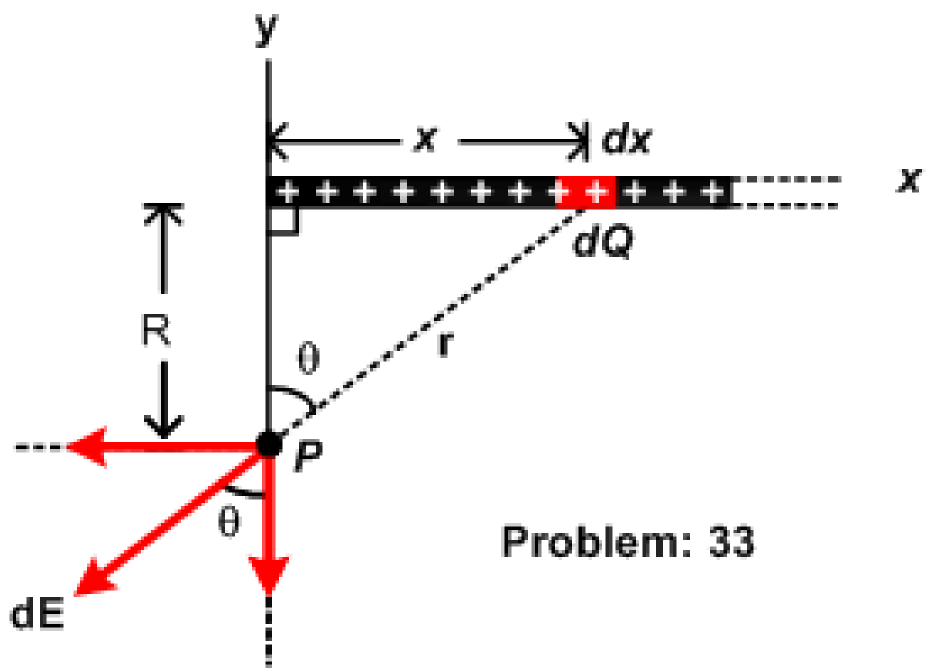
$$= \frac{\lambda R}{2\pi\varepsilon_0}\left[\frac{x}{R^2(x^2+R^2)^{\frac{1}{2}}}\Bigg|_0^{L/2}\right]$$

$$= \frac{(Q/L)R}{2\pi\varepsilon_0}\left[\frac{L/2}{R^2\left(R^2+\frac{L^2}{4}\right)^{1/2}}\right] = \frac{Q}{2\pi\varepsilon_0 R\sqrt{L^2+4R^2}}$$

$Q = 7.81\times10^{-12}\,C$; $L = 0.145\,m$; $R = 0.06\,m$

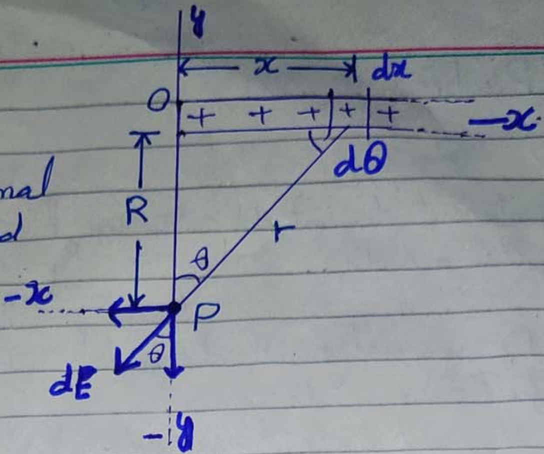
$|\vec{E}| = 12.4\ N/C$

b) $\vec{E}$ Points in +y direction or 90° counterclockwise



Problem: 33

8



Problem # 33

Consider infinitesimal section of the rod of length dx, a distance x from left end.

$dQ = \lambda dx$

The magnitude of the field it produces at P is

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dQ}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda dx}{r^2}$$

$$dE_x = -\frac{1}{4\pi\varepsilon_0}\frac{\lambda dx}{r^2}\sin\theta \; ; \; dE_y = -\frac{1}{4\pi\varepsilon_0}\frac{\lambda dx}{r^2}\cos\theta$$

$$\frac{R}{r} = \cos\theta \Rightarrow r = R/\cos\theta$$

$$\frac{x}{R} = \tan\theta \Rightarrow x = R\tan\theta \Rightarrow dx = R\sec^2\theta\, d\theta = \frac{R\,d\theta}{\cos^2\theta}$$

$$x = 0 \; ; \; 0 = R\tan\theta \; ; \; \tan\theta = 0 \; ; \; \theta = 0$$

$$x = \alpha \; ; \; \alpha = R\tan\theta \; ; \; \tan\theta = \alpha \; ; \; \theta = 90$$

$$dE_x = -\frac{\lambda}{4\pi\varepsilon_0}\cdot\frac{\cancel{R}\,d\theta}{\cancel{\cos^2\theta}}\cdot\frac{\cancel{\cos^2\theta}}{R^{\cancel{2}}}\cdot\sin\theta = -\frac{\lambda}{4\pi\varepsilon_0 R}\sin\theta\, d\theta$$

$$E_x = \int_0^{90} dE_x = -\frac{\lambda}{4\pi\varepsilon_0 R}\int_0^{90}\sin\theta\, d\theta = \frac{\lambda}{4\pi\varepsilon_0 R}\left[\cos\theta\Big|_0^{90}\right] = -\frac{\lambda}{4\pi\varepsilon_0 R} \quad \text{— (I)}$$

$$E_y = \int_0^{90} dE_y = -\int_0^{90}\frac{\lambda}{4\pi\varepsilon_0}\cdot\frac{\cancel{R}\,d\theta}{\cancel{\cos^2\theta}}\cdot\frac{\cancel{\cos^2\theta}}{R^{\cancel{2}}}\cdot\cos\theta = -\frac{\lambda}{4\pi\varepsilon_0 R}\int_0^{90}\cos\theta\, d\theta$$

$$E_y = -\frac{\lambda}{4\pi\varepsilon_0 R}\left[\sin\theta\Big|_0^{90}\right] = -\frac{\lambda}{4\pi\varepsilon_0 R} \quad \text{— (II)}$$

We notice $E_x = E_y$. Thus E makes an angle $45°$ with the rod for all values of R

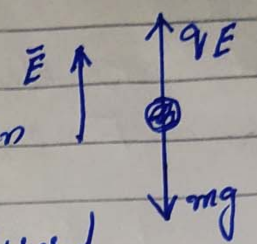
Problem # 44

a)

$$F = qE = mg \Rightarrow E = \frac{mg}{q} = \frac{6.64\times10^{-27}kg \times 9.8\,m/s^2}{2\times1.6\times10^{-19}C}$$

$$E = 2.03\times10^{-7}\ N/C$$

b)



gravity is always downward then $F = qE$ must Point upward.
$q>0$ this implies $\vec{E}$ must Point upward

Problem # 46

$$\vec{F} = q\vec{E} = m\vec{a} \Rightarrow \vec{E} = \frac{\vec{F}}{q} = \frac{m\vec{a}}{(-e)} =$$

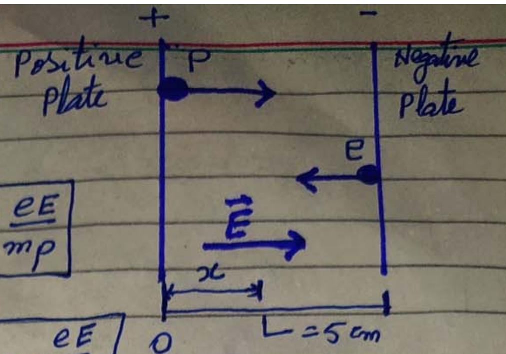
With east being the $\hat{i}$ direction

$$\vec{E} = -\left(\frac{9.11\times10^{-31}kg}{1.6\times10^{-19}C}\right)\left(1.80\times10^{9}\,m/s^2\right)\hat{i} = -0.0102\tfrac{N}{C}\hat{i}$$

a) magnitude of $\vec{E} = 0.0102\ N/C$

b) $\vec{E}$ is directed in the westward or $-\hat{i}$ or.

Problem # 53



For proton

$$F = m_p a_p = eE \Rightarrow \boxed{a_p = \frac{eE}{m_p}}$$

For electron

$$F = m_e a_e = -eE \Rightarrow \boxed{a_e = -\frac{eE}{m_e}}$$

Let after time t electron & proton pass each other

Coordinate of proton after time t is

$$x_p = x_i + v_i t + \frac{1}{2} a t^2$$

$$x_i = 0\ ;\ V_i = 0\ ;\ a = a_p$$

$$x_p = \frac{1}{2} a_p t^2$$

Coordinate of electron after time t is

$$x_e = x_i + v_i t + \frac{1}{2} a t^2$$

$$x_i = L\ ;\ V_i = 0\ ;\ a = a_e$$

$$x_e = L + \frac{1}{2} a_e t^2$$

When they pass each other their coordinates are same $x_p = x_e = x$

$$x_p = x_e \Rightarrow \frac{1}{2} a_p t^2 = L + \frac{1}{2} a_e t^2 \Rightarrow \frac{1}{2}(a_p - a_e) t^2 = L$$

$$(a_p - a_e) t^2 = 2L \Rightarrow \boxed{t^2 = \frac{2L}{(a_p - a_e)}}$$

$$x = x_p = \frac{1}{2} a_p t^2 = \frac{1}{2} a_p \frac{2L}{(a_p - a_e)} = \frac{a_p L}{(a_p - a_e)}$$

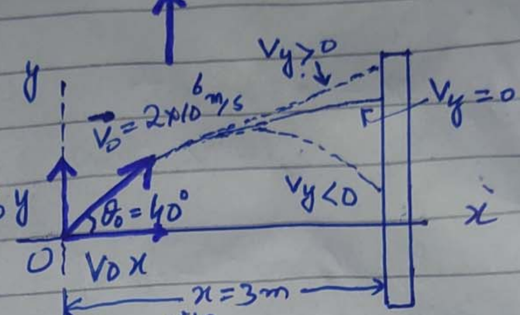
$$= \frac{eE/m_p L}{\left(\frac{eE}{m_p} + \frac{eE}{m_e}\right)} = \frac{eEL}{m_p eE\left(\frac{1}{m_p} + \frac{1}{m_e}\right)} = \left(\frac{m_e}{m_e + m_p}\right) L = 2.7 \times 10^{-5}\ m$$

$$= 2.7 \times 10^{-3}\ cm$$

$$= 0.0027\ cm$$

Problem # 54

$\vec{E} = 5\ \text{N/C}\ \hat{j}$



$V_x = V_{0x} = V_0 \cos\theta_0$

$= 2\times10^{6}\ \text{m/s} \times 0.766$

$$\boxed{V_x = 1.53\times10^{6}\ \text{m/s}}$$

$V_y = V_i + at \qquad V_i = V_0 y = V_0 \sin 40 \ ; \quad F = -eE = ma \Rightarrow a = \frac{-eE}{m}$

$$a = -\frac{eE}{m} = \frac{-1.6\times10^{-19}\,\text{C} \times 5\ \text{N/C}}{9.1\times10^{-31}\,\text{kg}} = -8.79\times10^{11}\ \text{m/s}^2$$

$V_f = V_y$

In x-direction no force $\Rightarrow$ no acceleration $\Rightarrow$ constant velocity

$S = vt \qquad V = V_{0x} = V_x = 1.53\times10^{6}\ \text{m/s} \ \ \& \ S = x = 3\text{m}$

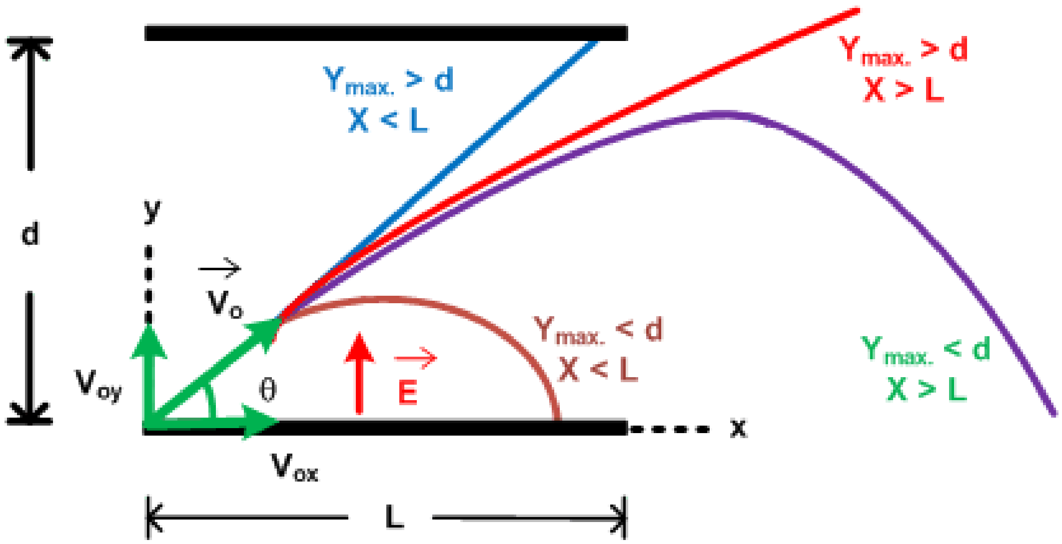
$$t = \frac{S}{V} = \frac{x}{V_{0x}} = \frac{3}{1.53\times10^{6}\ \text{m/s}} = 1.96\times10^{-6}\,\text{s} = 1.96\ \mu\text{s}$$

$$V_y = V_0 \sin 40^\circ + (-8.79\times10^{11}\ \text{m/s}^2)(1.96\times10^{-6}\text{s})$$

$$= 1.28\times10^{6} - 17.2\times10^{5} = (12.8 - 17.2)\times10^{5}$$

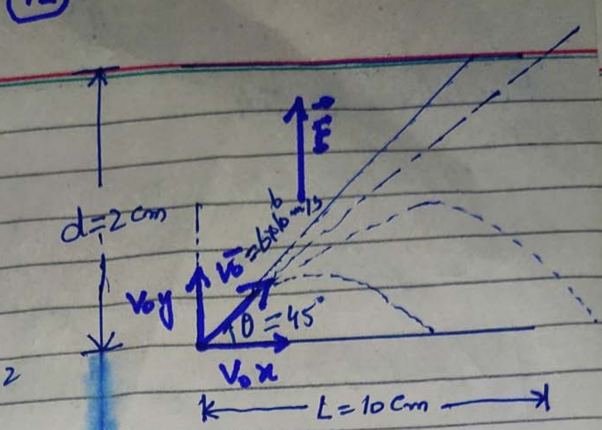
$$= -4.36\times10^{5}\ \text{m/s}$$

$$\vec{V} = V_x\hat{i} + V_y\hat{j} = (1.53\times10^{6}\ \text{m/s})\hat{i} - (4.36\times10^{5}\ \text{m/s})\hat{j}$$



Problem: 84

Problem # 84



a) $x = V_0 \cos\theta t$

$V_{0x} = V_x = V_0 \cos\theta$

$y = V_0 \sin\theta t - \frac{1}{2} a t^2$

$V_y = V_0 \sin\theta - at$

First we find greatest y coordinate attained by electron
The greatest y coordinate occurs when

$V_y = 0$

$V_y = 0 = V_0 \sin\theta - at \Rightarrow t = \left(\frac{V_0}{a}\right)\sin\theta$

$F = ma = eE \Rightarrow a = \frac{eE}{m} = \frac{1.6\times10^{-19}C \times 2\times10^{3} N/C}{9.1\times10^{-31} kg} = 3.51\times10^{14}\ m/s^2$

$y_{max} = V_0 \sin\theta \times \frac{V_0 \sin\theta}{a} - \frac{1}{2}\frac{V_0^2 \sin^2\theta}{a^2} = \frac{1}{2}\frac{V_0^2 \sin^2\theta}{a2}$

$= \frac{(6\times10^6 m/s)^2 \sin^2 45}{2(3.15\times10^{14} m/s^2)} = 2.56\times10^{-2} m = 2.56\ cm$

$y_{max} = 2.56\ cm > d = 2\ cm$ electron might hit upper plate

b) No we find x coordinate of the position of the electron when $y = d$

$d = V_0 \sin\theta t - \frac{1}{2} a t^2 \Rightarrow \frac{1}{2} a t^2 - V_0 \sin\theta t + d = 0$

$t = V_0 \sin\theta \pm \sqrt{V_0^2 \sin^2\theta - 2ad}\ / a$

$V_0 \sin\theta = 6\times10^6 m/s \times \sin 45 = 4.24\times10^6 m/s$

$t = 6.43\times10^{-9} s$

$x = V_0 \cos\theta t = (6\times10^6 m/s)\cos 45 \times 6.43\times10^{-9} s = 2.72\times10^{-2} m$

$x = 2.72$ cm This is less than L so electron hits the upper plate at $x = 2.72$ cm