$\frac{N}{C}$ $g\,m/s^2$

B

Spring 2006

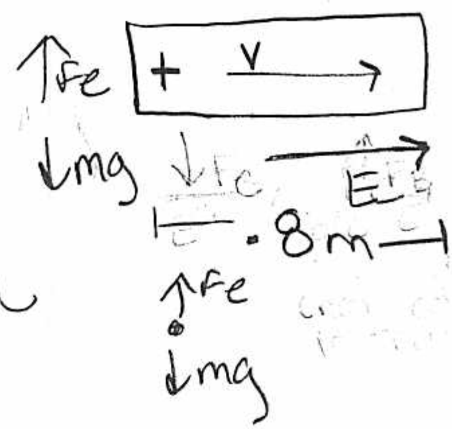
Student #1

[redacted] TA'S NAME [redacted]

Problem [redacted]

CO: 28 g/mol
UV light
E uniform
CO^+ $v = 8\times10^{14}$ m/s
.8m

Picture:



Question: What is direction and magnitude of E?

approach: use Newton's laws to get force on particle and then use $F_e = qE$ to get E

plan solution

$\Sigma F = ma$

$\Sigma F_y = F_e - mg$

$F_e = qE$

$qE - mg = 0$

$qE = mg$

$E = \frac{mg}{q}$

g: $28\frac{g}{mol} \times \frac{1 mol}{} = 28\,g \times \frac{1\,kg}{1000\,g} = .028\,kg$

evaluate answer!

reasonable? yes b/c a large electric field is needed to move a molecule of CO .8m

answer Q? yes → direction of E shown in picture

✓ units ✓

execute plan:

$$E = \frac{(.028\,kg)(9.8\,m/s^2)}{(1.602\times10^{-19}\,C)} = 1.71\times10^{18}\ N/C$$

✓ units:

$kg\frac{m}{s^2} \to N \qquad = \frac{N}{C}$ ✓

B

Spring 2006

Student #2

TA'S NAME

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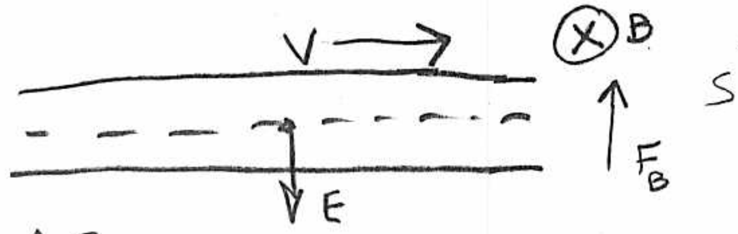

$F_{net} = 0$ $F = ma$

$a = \frac{v^2}{r}$

$F_B + F_E = 0$

$F_B = qV \times B$

$F_E = qE$

$F_B - F_E = 0$, $V \perp E$ so,

$F_B = F_E$

$F_E = qVB$

$qVB - qE = 0$

$qVB = qE$

solve for B, q cancels

and your left w/

$\vec{B} = \frac{\cancel{q} E}{\cancel{q} V} \Rightarrow B = \frac{E}{V} = \frac{E}{8 \times 10^4 \frac{m}{s}}$

$\frac{\Delta V}{\Delta t}$

$a = \frac{V}{t}$ $V = at$

$KE = \frac{1}{2} m v^2$

$a = \frac{v}{t^2}$

$a = \frac{8 \times 10^4 m/s}{1 \times 10^{-5} \cancel{m/s}}$

$\Rightarrow 8 \times 10^9 s$

Knowns

$CO = 7\ 28 \frac{grams}{mol}$

$d = 0.8m$

$V = 8 \times 10^4 \frac{m}{s}$

Questions: calculate direction and magnitude of electric field needed so CO^+ ions will have speed of $8 \times 10^4 \frac{m}{s}$ when exiting.

Approach: Use Newtons Law to relate the magnetic field + electric magnetic field to find $\vec{B}$ + its direction.

$V = \frac{d}{t} = \frac{0.8m}{t}$

$KE = \frac{1}{2}(28g)(8 \times 10^4 \frac{m}{s})^2$

$KE = 8.96 \times 10^{11}$

$t = \frac{0.8m}{8 \times 10^4 m/s} = 1 \times 10^{-5} \frac{m}{s}$

Student #3

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[redacted] TA'S NAME [redacted]

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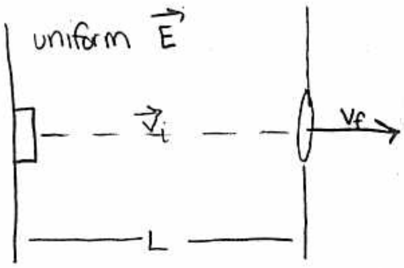
[redacted]

Focus the Problem

Diagram:



$v_f = 8 \times 10^4$ m/s

$L = 0.8$ m

Question:

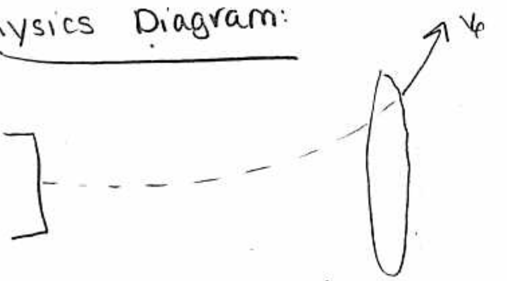
What is the direction & magnitude of the electric field such that the final velocity of the ion is 8×10^4 m/s?

Approach:

Use $\vec{E} = \frac{\vec{F}}{q_0}$, dynamics, Newton's Laws ($F=ma$), & Kinematics to determine $\vec{E}$ field; find magnitude 1st then decide direction

Planning the Solution:

Physics Diagram:



$\vec{E} = \frac{\vec{F}}{q_0}$ $\quad F = ma \quad$ $a = \frac{v^2}{R}$

$E_f - E_{in} = 0$

$\Rightarrow E_f = E_i$

Solving the Problem:

1) $a = \frac{v^2}{R}$ } know all but a

2) plug ① into $F=ma$

$\Rightarrow F = \frac{mv^2}{R}$

3) $E = \frac{F}{q}$

$\Rightarrow E = \frac{mv^2}{qR}$

Evaluating the Solution

$E = \frac{mv^2}{qR}$ } don't know m

$\Rightarrow$ use CO 28 g/mol:
we will arbitrarily use 1 mol of substance:

$$\frac{28\,g}{mol} \cdot \frac{1\,mol}{1} \cdot \frac{1\,kg}{1000\,g} = 0.028\,kg$$

$$\Rightarrow E = \frac{mv^2}{qR}$$

$m = 0.028$ kg
$v = 8 \times 10^4$ m/s
$q = -1.602 \times 10^{-19}$ C
$R = 0.8$ m

$$E = \frac{(0.028\,kg)(8 \times 10^4 \frac{m}{s})^2}{(-1.602 \times 10^{-19}\,C)(0.8\,m)} = -1.398 \times 10^{27} \frac{N}{C}$$

implies $\vec{E}$ field is inverted
$\Rightarrow$ $\vec{E}$ direction must be downward

$\vec{E}$ direction: downward
E magnitude: $1.398 \times 10^{27} \frac{N}{C}$

Checking the Answer:

units:

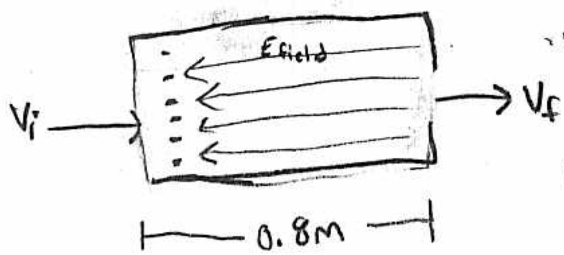
$$E = \frac{N}{C} \Rightarrow E = \frac{kg \cdot \frac{m^2}{s^2}}{C \cdot m} = \frac{N \cdot \cancel{m}}{C \cdot \cancel{m}} = \frac{N}{C} \checkmark$$

Student #4

TA'S NAME [redacted]

Problem 1, Page 1 of 1

$v_i = 0$ $\quad$ $v_f = 8\times10^4\,m/s$



What is the magnitude of the electric field?

$$F_E = qE = ma$$

$$E = \frac{ma}{q}$$

$$V_f^2 = V_i^2 + 2a\Delta x$$

$$(8\times10^4)^2 = (0)^2 + 2a(0.8)$$

$$6.4\times10^9 = 1.6a$$

$$a = 4\times10^9\,m/s$$

$$28\frac{g}{mol}\left|\frac{1\ mol}{6.022\times10^{23}\ molecules}\right| = 4.65\times10^{-23}g$$

$m =$ mass of Co Molecule $(28g/mol)$

$q =$ charge of an electron

$$E = \frac{(4.65\times10^{-23}g)(4\times10^9\,m/s)}{(1.602\times10^{-19}C)} = 1.161\times10^6\,N/c$$

$$\frac{g\cdot\frac{m}{s}}{c} = \frac{N}{c}$$ units ✓

Student #5
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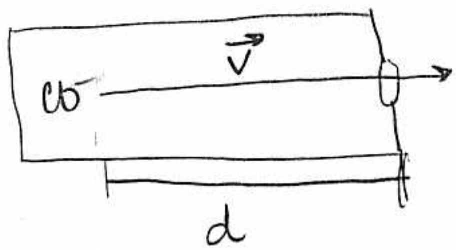
Spring 2006 **B**

TA'S NAME [redacted]

Problem 1, Page 1 of 1



Question: Find the direction and magnitude of the electric field needed to move the CO molecules through the hole at 8×10^4 m/s

$d = .8$ m
$\vec{v} = 8 \times 10^4$ m/s

Approach: use conservation of energy
assume gravity to be negligible in comparison to electric force

System: CO^+, box, Earth
t_i = when CO^+ molecule is at rest
t_f = when CO^+ molecule is leaving the box
$E_i = -\int \vec{F} \cdot d\vec{s}$
$E_f = \frac{1}{2} m v^2$
$E_{input} = q_0 \vec{E}$
$E_{output} = 0$

Quantitative Relationships

$\vec{E} = \dfrac{\vec{F}}{q_0}$ $\qquad PE = -\int \vec{F} \cdot d\vec{s}$ $\qquad E_f - E_i = E_{in} - E_{out}$

$KE = \frac{1}{2} m v^2$

$\sum F = 0$

page 2

We want the velocity and field parallel to make this motion.

$$-\int \vec{F} \cdot d\vec{s} = -q\vec{E}d\cos 0^\circ = -qEd$$

Now all that's left is

$$\frac{1}{2}mv^2 + q\vec{E}d = q_0\vec{E}$$

$$\frac{1}{2}mv^2 = q_0\vec{E}(1-d)$$

$$\vec{E} = \frac{\frac{1}{2}mv^2}{q(1-d)}$$

$$m_{CO^+} = 28\frac{g}{mol} \cdot \frac{mol}{6.022 \times 10^{23} \text{ ions}}$$

$$m_{CO^+} = 4.65 \times 10^{-23} \text{ g/ion} = 4.65 \times 10^{-26} \text{ kg}$$

$q_0 = 1.602 \times 10^{-19} C$ because it has a +1 charge

$$\vec{E} = \frac{\frac{1}{2}(4.65 \times 10^{-20} kg)(8 \times 10^4 m/s)^2}{1.602 \times 10^{-19} C \; (1-.8m)}$$

units $\frac{N}{C}$ ✓

$$\vec{E} = 4.64 \times 10^9 \text{ N/C}!$$

That is ridiculously high for the field but then again making a particle move from rest to 8,000 m/s in less than a meter is ridiculous too.

B

Student #6
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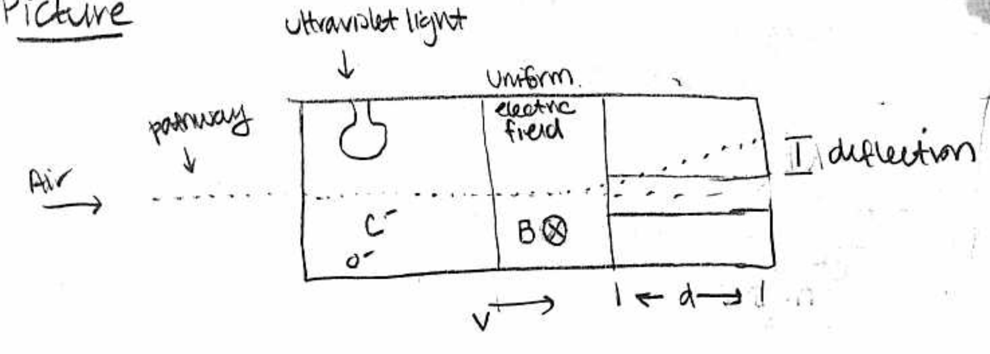
TA'S NAME [redacted]

Problem 1, Page 1 of 2

Picture



Knowns
$d = .8\,m$
$V_f = 8\times10^4\ m/s$
CO molecules = 28 g/mol

Problem: Need to calculate direction & magnitude of electric field needed so that CO^+ ions which are created at one end of the chamber will have a velocity/speed of $8\times10^4\ m/s$ when they exit

Target: E of electric field and direction

Using right hand rule the direction of the magnitude is into the page

Approach: Use $\vec{E} = \vec{F}/q_0$ to find the electric field
$\vec{F} = \vec{E}q$

Use KE to relate the two to velocity & mass

Also use Coulombs Law $F = k_e \frac{q^2}{r^2}$ to find charges.
Use these together to find the magnitude of electric field

Also $V = V_f - V_i$ $V_i = 0$ so $V = V_f$

Also $V = k_e \frac{q}{r}$

Also $KE = \frac{1}{2}mv_f^2$ so $v_f = \sqrt{\frac{2}{m}}$

So

Physics

$F = Eq$ & $F = k_e \frac{q^2}{r^2}$

$k_e \frac{q^2}{r^2} = Eq$

$q \cdot \frac{k_e q^2}{r^2} = E$ gives us the electric field

Also can use $PE = k_e \frac{q^2}{r}$ to find what potential should be

$q \cdot \frac{k_e q^2}{r^2} = E$ units: $\frac{[\text{charge}]\frac{[N][\cancel{\text{length}}]^2}{[\text{charge}]^2}}{[\text{length}]^2} = [N]$

units check!

$$\frac{[1.602 \times 10^{-19}\ C] \cdot [8.99 \times 10^9\ \frac{Nm^2}{C^2}] \cdot [1.602 \times 10^{-19}\ C]^2}{[.8]^2} = E$$

$= 3.60 \times 10^{-47}$ very small

Now to give a final velocity of 8×10^4

Student #7
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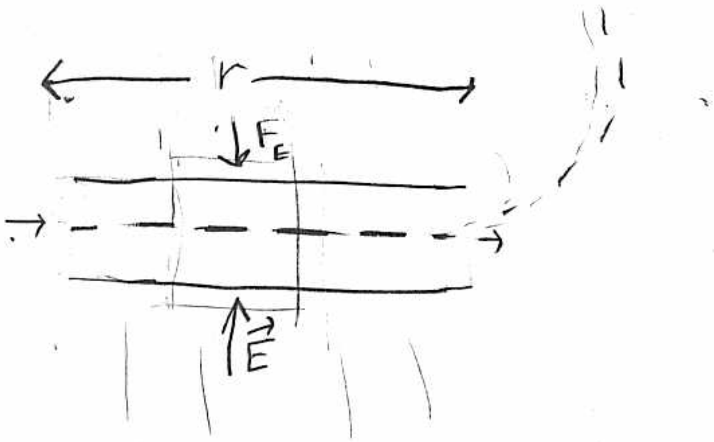
_______________ TA'S NAME_

Problem 1, Page 1 of 1



Knowns

CO molecules = 28g/mol

$V = 8\times10^4$ m/s

$q = 1.602\times10^{-19}$

$r = 0.8$m.

Question: What is the direction & magnitude of the electric field needed so that CO^+ ions created @ rest @ one end will have a speed of 8×10^4 m/s when they exit

Approach: Newton, apply to Electric field & trajectorys.

useful equations

$\vec{E} = \frac{\vec{F}}{q_0} \Rightarrow F_E = q\vec{E}$

would travel in circle w/ radius r & will be constant through 'plates'

$\vec{F} = \frac{v^2}{r}$

$= \frac{(8\times10^4 \text{ m/s})^2}{0.8\text{m}}$

$F = 8.0\times10^9$

$\vec{E} = \frac{8.0\times10^9}{1.602\times10^{-19}} = 4.99\times10^{28}$

hmm... seems too big. do-over?

suppose we use $\Sigma F = ma$ where $m = \frac{28g}{mol} \times \frac{1 \text{ mol}}{6.022\times10^{23}} = 4.65\times10^{-23}$

but wait $\Sigma F = 0$ because the Electric field is constant.....
no, acceleration is constantly increasing

so, velocity is changing.

$\Delta V = 8\times10^4$ m/s²

$\frac{dv}{dt} = 8\times10^4$ m/s² $= a$

so if that were true

$\Sigma F = ma$

would be

$(4.65 \times 10^{-23})(8 \times 10^{4}) = 3.72 \times 10^{-18}$

so...

$F_E = qE$

$3.72 \times 10^{-18} = (1.602 \times 10^{-19})\, E$

$23.22 = \vec{E}$

well, thats smaller

if $\vec{E} = \frac{\vec{F}}{q}$ $F = kg\, m/s^2$ than E has units

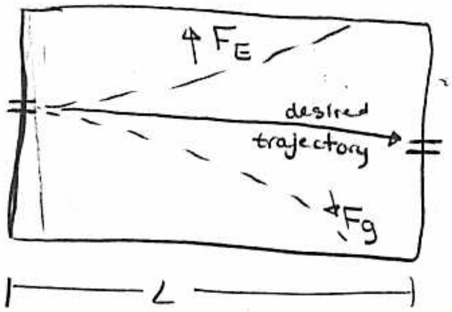
$q = C$ $kg \cdot \frac{m}{s^2 \cdot C}$

$23.22\ kg \cdot m/s^2 \cdot C$

Student #8 [redacted] TA'S NAME [redacted]

Problem 1, Page 1 of 1 [redacted]

picture:



$q = e \ (=+1.602\times10^{-19}\,C)$

$v_i = 0\ m/s$

$v_f = 8\times10^4\ m/s$

$m = 28\,g/mol$

$L = 0.8\,m$

Question: What magnitude and direction of an electric field should be used for charged particles to reach a velocity of 8×10^4 m/s and experience no net force to make it through the hole on the other side?

Approach: Use Newton's Laws to find the value of F_E and then use that information to solve for $\vec{E}$.

$F_{total} = F_E + F_g = \emptyset \rightarrow F_g = |-F_E| \longrightarrow mg = qE$

and $\vec{E} = \dfrac{\vec{F}_E}{q_0}$ $\quad \vec{F}_E = q\vec{E}$

$\boxed{E = \dfrac{mg}{q}}$

$F_g = mg \rightarrow m: \dfrac{28\,\cancel{g}}{\cancel{mol}\ CO}\cdot\dfrac{1\,\cancel{mol}}{6.02\times10^{23}\ molecule}\cdot\dfrac{1\,kg}{1000\,\cancel{g}} = 4.65\times10^{-26}\ kg/molecule$

$F_g = (4.65\times10^{-26}\,kg)(9.8\,m/s^2) = 4.56\times10^{-25}\,N$

$4.56\times10^{-25}\,N = qE \rightarrow E = \dfrac{4.56\times10^{-25}\,N}{q} = \dfrac{4.56\times10^{-25}\,N}{1.602\times10^{-19}\,C}$

$\boxed{E = 2.85\times10^{-6}\ \frac{N}{C}\ \text{straight upward}}$

check units: $\frac{N}{C}$ is correct for

P Spring 2006 B

N Student #9 ________________ TA'S NAME [redacted]

Problem # 1, Page 1 of 1.

CO^+
get created at end

$V = 8 \times 10^4$ m/s

$r = 0.8$ m

$CO = 28$ g/mol

Question.

- Calculate the direction and magnitude of the electric field needed so that ions created at rest at one end will have a speed of 8×10^4 m/s when the exit the othe side.

Approach

Use coulom's Law. to find out the magnitube of the electric field

Direction should be. right side

Solution.

$$F = K_e \frac{q_1 q_2}{r^2} \qquad K_e = 9.00 \times 10^9 \frac{N \cdot m^2}{C^2}$$

$$\vec{F} = q \vec{v} \times \vec{B}$$

$$F =$$

$$B = \frac{F}{qv} = \frac{K_e q_1 \cancel{q_2}}{r^2} \cdot \frac{1}{\cancel{q} v} = \frac{K_e q}{r^2 \cdot v} = \frac{9.00 \times 10^9 \frac{N \cdot m^2}{C^2} \times 28\,g/mol}{0.64\,m^2 \cdot 8 \times 10^4\,m/s} = 4.92 \times 10^6 \frac{N \cdot g\,s}{C^2 \cdot m}$$

Unit ✓ kind of weird unit

answer ✓

reasonable?. ✓ yes

B

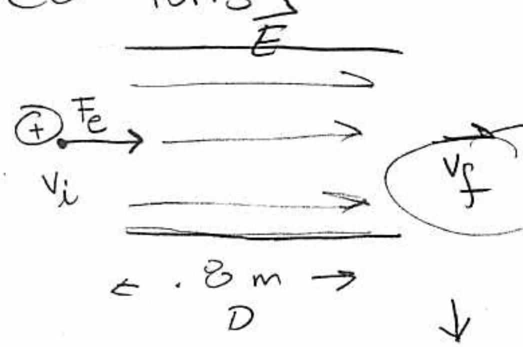
Student # 10

Spring 2006

[redacted] TA'S NAME [redacted]

Problem 1, Page 1 of 1

Question: What is the electric field needed to accelerate Co^+ ions to 8×10^4 m/s in a distance of .8 m?



find this

- want to cause force in +X direction
  ↳ direction needs to be? Direction of exit

HAVE:
q - charge of particle
m - mass of particle

Newton: $\Sigma F_{tot} = F_e = qE = ma$

Kinematics: Find a

$\Delta V = a \Delta t$

$V_i = 0 \quad V_f = 8 \times 10^4$ m/s $\therefore \Delta V = 8 \times 10^4$ m/s

use distance: $\frac{D}{V} = t$

$.8 \text{ m} \cdot \frac{s}{8 \times 10^4 \text{ m}} = 64{,}000 \text{ s}$

$a = \frac{\Delta V}{\Delta t} = \frac{8 \times 10^4 \text{ m/s}}{64{,}000 \text{ s}}$ $\quad a = 1.25 \text{ m/s}^2$

Back to Newton: $qE = ma$

solve for E: $E = \frac{ma}{q}$

Plug in #'s

$E = \frac{(4.0 \times 10^{-26} \text{ kg})(1.25 \text{ m/s}^2)}{1.602 \times 10^{-19} \text{ C}}$

Mass of Co^+ particle (m)

12 protons: $12(1.67 \times 10^{-27} \text{ kg})$
12 neutrons: $12(1.67 \times 10^{-27} \text{ kg})$
11 electrons: $11(9.11 \times 10^{-31} \text{ kg})$

4.0×10^{-26} kg

$\boxed{E = 3.13 \times 10^{-7} \text{ volts} \text{ in the direction of the exit hole}}$

volts ?

Charge (q)

$+1 = 1.602 \times 10^{-19}$ C

Student #11
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B

Spring 2006

[redacted] TA'S NAME [redacted]

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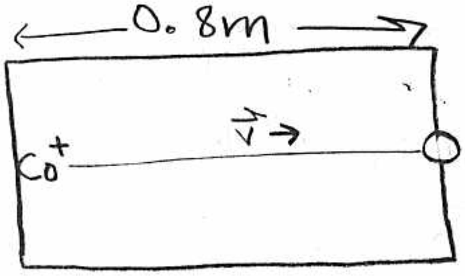
$v_i = 0$



$s = 0.8$ m
$v_f = 8 \times 10^4$ m/s
$m_{co} = 28$ g/mol

Question: Calculate the direction and magnitude of the electric field needed so that CO+ ions created at rest at one end will have a speed of 8×10^4 m/s when they exit the other side

Approach: Use conservation of energy

system: Co^+ particle

intial time: right as CO^+ enters the box

final time: right as CO^+ leaves the box

$E_i = 0 \quad v_i = 0$

$E_f = \frac{1}{2}mv^2$ $\quad$ E_{in} = electric potential energy

$E_{out} = 0$

Electric potential energy $= \Delta V q = -q\int \vec{E} \cdot ds$

because the electric field is constant

$PE_e = -qE\int ds$

$PE_e = -qES$ ← just want magnitude so can leave negative sign off

$E_f - E_i = E_{in} - E_{out}$

$\frac{1}{2}mv^2 = qEs$

$E = \dfrac{\frac{1}{2}mv^2}{qs}$

check units

$\frac{1}{2}mv^2 \rightarrow$ energy units

$\underbrace{E \cdot s}_{V} \cdot \underbrace{q}_{C}$ = energy units

units ok ✓

$$|E| = \frac{\frac{1}{2}mv^2}{qS} = \qquad J = n \cdot m$$

$CO - e^- = CO^+$

$.028\,Kg - 9.11 \times 10^{-31}\,Kg = 0.028\,Kg$

$$|E| = \frac{\frac{1}{2}(0.028\,Kg)(8 \times 10^4\,m/s)^2}{(1.602 \times 10^{-19}\,C)(0.8\,m)}$$

$$\boxed{|E| = 6.99 \times 10^{26}\ N/C}$$

units ✓

$$\frac{Kg \cdot m^2/s^2}{C \cdot \cancel{m}} = N/C$$

evaluate

✓ units OK

✓ seems like a rather large magnitude for an electric field but it would make sense because it takes a lot to accelerate a Co^+ particle from rest to $8 \times 10^4\ m/s$ in such a short distance

The Electric field should be pointing right because it is the only force on the Co^+ particle and since the particle is being accelerated to the right, the force should be to the right.

Student #12

TA'S NAME [redacted]

Problem #1, Page ____ of ____

Knowns:

$m = CO = 28 g/mol$

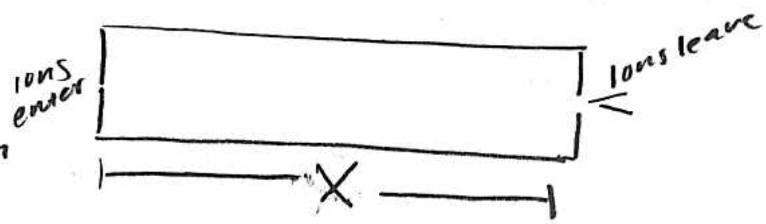
$V_i = 0$

$V_f = 8 \times 10^4 m/s$

$X = 0.8 m$

$q = \oplus$

Question: What's the direction + magnitude of $\vec{E}$ so CO^+ will have end speed of $8 \times 10^4 m/s$?



Assumptions:
$\vec{a}$ is in x direction

Approach:
Use kinematics to + Newton's laws to relate F + charge.

~~Energy~~

~~E_I : time just before particle enters $\vec{E}$.~~ $\Delta X = \frac{1}{2}$

~~E_I = Electric PE~~

~~E_F : time as particle exits $\vec{E}$?~~

~~E_F : Electric PE, Kinetic Energy~~

$F_E = F_N$

$F_N = ma = 0$ (since a is constant)

$F_E = \vec{E}q$

$\vec{E}q = ma$

$a = v^2/r$ (since deflected particles are similar to those in a circular path)

$F_E = K_E \frac{q_1 q_2}{r^2}$

$F_E = ma$

$k_E \frac{q}{r} = m\left(\frac{v^2}{r}\right)$

$qk_E = m\left(\frac{v^2}{r}\right)r$

$qk_E = mv^2$

$q = \frac{mv^2}{K_E}$

$q = \frac{(.028 kg)(8 \times 10^4 m/s^2)}{8.99 \times 10^9 \frac{Nm^2}{c^2}} = 2.49 \times 10^{-7} \frac{kgs^2}{\frac{Nm}{c^2}}$

$F = E \cdot q$

* Assume that all initial quantities are before entering of $\vec{E}$. All final quantities are just after leaving $\vec{E}$.

Kinematics:

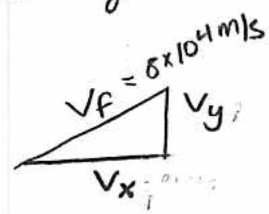
282.84 m/s

$V_{iy} = 0 m/s$ $\quad a_{iy} = 0$ $\quad t_i = 0$

$V_{Fy} = ?$ $\quad a_{Fy} = a$

$V_{ix} = 0 m/s$ $\quad a_{ix} = 0$ $\quad t_F = ?$

$V_{Fx} = 8 \times 10^4 m/s$ $\quad a_{Fx} = a$



What is V_y?

Equations:

$\Delta X = \frac{1}{2} a_{xF} (\Delta t)^2 + V_{xF} t_i$

$V_y^2 + V_x^2 = V_f^2$

$V_y = \sqrt{V_F - V_x}$

$V_y = \sqrt{8 \times 10^4 m/s}$

$V_{y_F} = 282.84 m/s$

V_{yF}

Unknowns:
a_{xf}, t

* The answer should be in volts + should be a fairly small number, since the molecules traveling through it are relatively small.

B

Student #13

TA'S NAME [redacted]

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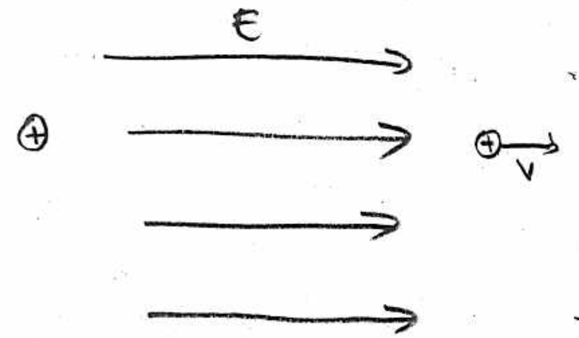

$\Delta x = 0.8\,m$

$V_0 = 0$

$V_f = 8 \times 10^4\ m/s$

$m = 28\ g/mol$

$$\frac{28\,g}{1\,\cancel{mol}}\left|\frac{1\,\cancel{mol}}{6.022\times10^{23}\text{ atoms}}\right|\frac{1\,kg}{1000\,g} =$$

$m = 4.65 \times 10^{-26}\ kg$

Question: Find E field so that $V_f = 8\times10^4\ m/s$.

$\vec{E}$ field points in the same direction as desired velocity (can ignore gravitational force)

$\overset{+}{\bullet} \xrightarrow[F_e]{} \quad qE = F_e = ma$

$$E = \frac{ma}{q} \qquad V_f^2 = \cancel{V_i^2}^{\,0} + 2a\Delta x$$

$$a = \frac{V_f^2}{2\Delta x}$$

$$E = \frac{m V_f^2}{q\,2\Delta x} \equiv \frac{[kg]\cdot[m]^{\cancel{2}}}{[s]^2[C][\cancel{m}]} = \frac{N}{C} \qquad \frac{V}{m} = \frac{N}{C} \qquad N = \frac{kg\,m}{s^2}$$

units ok ✓

$$\boxed{E = 1162\ \frac{N}{C}}$$