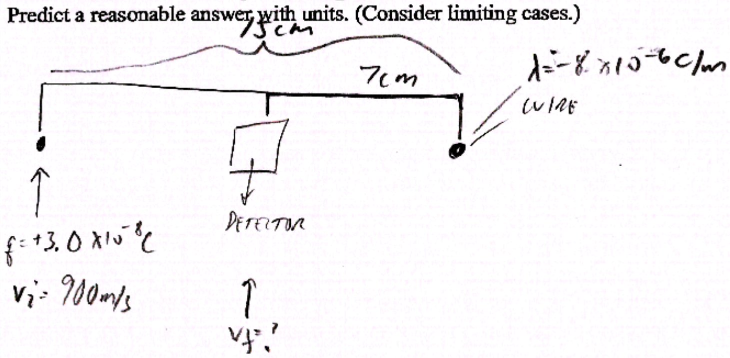
Group Test 2 (25 points) Physics 2049 Spring 2003

GOAL solution: G step (2 student examples)

Gather information:
What is known? What are you looking for?
Predict a reasonable answer with units. (Consider limiting cases.)



GIVENS: $\lambda = -8 \times 10^{-6}$ C/m
$v_i = 900$ m/s OF EMISSION PARTICLE
$X_d = 7$ cm $= .07$ m $=$ POSITION OF DETECTOR FROM WIRE.
$X_p = 15$ cm $= .15$ m $=$ POSITION OF PARTICLE FROM WIRE
$q_r =$ CHARGE OF EMISSION PARTICLE $= +3.0 \times 10^{-8}$ C
$M = 6.0 \times 10^{-9}$ Kg — AVERAGE MASS OF EMISSION PARTICLE

UNKNOWN
$V_f =$ FINAL VELOCITY OF EMISSION PARTICLE

SWAG-

We know the particles initial velocity is 900 m/s, & we know that the electric force on the particle is in the direction of motion b/c the particle will be attracted to the wire, causing positive acceleration ∴ the particle will have a higher final velocity. It would be very unlikely for the final velocity to be near the speed of light. ∴

final Velocity will be greater than 900 m/s & less than 3.0×10^8 m/s

$900\text{ m/s} < V_f < 3.0 \times 10^8\text{ m/s}$ ✓

Gather information:
What is known? What are you looking for?
Predict a reasonable answer with units. (Consider limiting cases.)

Knowns:

$q_1 = 3\times10^{-8}$ C

$v_1 = 900$ m/s

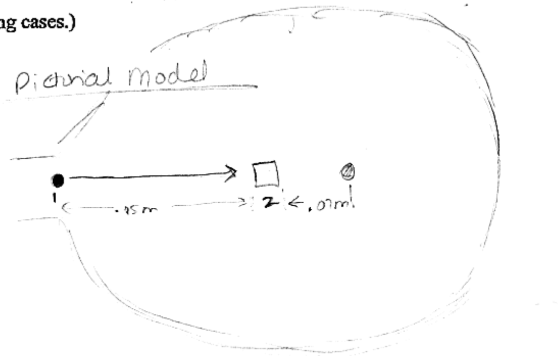
$\lambda = -8.0\times10^{-6}$ C/m

$x_1 = .15$ m

$x_2 = .07$ m

$\Delta x = .08$ m

$m_p = 6.0\times10^{-9}$ kg



what is vf @ dectector

Guess: $900\,\frac{m}{s} > x > 3\times10^{8}\,\frac{m}{s}$

B/c q is positive & λ we know that it's going to speed up and opposite charges attract

Assumptions

- Infinitely long wire ✓
- not going to travel faster than speed of light ✓
- Ultraviolet chamber didn't change properties of particle X
- Gravity is neglected (and all other additional forces acting on the particle apart from electric for
- mass stays constant ✓

Limiting cases

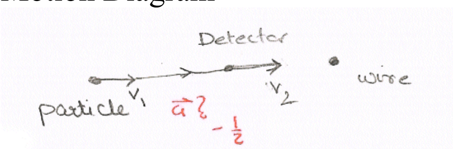
- If charge changed then, E-field + force would change, then magnitude would change
- If both were like charges, then vf would be slower than vi

Dr. Saul's comments: *Note that both G steps have good fundamentals: good diagrams (where known values are defined), clear given information/knowns, clear objective (find v-final), and good guesstimates. The first G-step has a good explanation of the upper and lower limits on the guesstimate; the second has a good description of assumptions and limiting cases (although it helps to say in detail how the limiting case should affect your final answer – for example, "if the charge of the particle were increased, the final velocity should be faster because the force would be larger"). One thing to be careful of is to make sure you list your known values in terms of the units they are given in. Sometimes when you are in a hurry you can make a mistake that throws everything of without realizing it.*

GOAL solution: O step (1 composite student example)

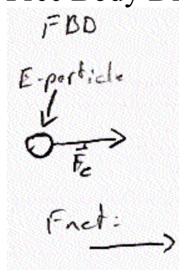
Diagrams:

Motion Diagram



Motion diagram should include Delta v diagram to indicate direction of the acceleration vector and should show the a-vector

Free Body Diagram (optional => bonus points)



It's always a good idea to include a free-body diagram in problems with forces. Note that this one indicates the type of force and the direction of the net force. It would be even better if the force subscript included the object exerting the force and the object being acted on.

Physics Principles & Plan:

Principles

1. Work-energy relationship $W_{net} = \Delta KE$ ✓
2. Gauss's law $\Phi_{net} = \frac{q_{enc}}{\epsilon_0}$, $EA = \frac{q_{enc}}{\epsilon_0}$ ✓
3. $W = \int \vec{F} \cdot d\vec{s}$ definition of work ✓
4. $F = Eq$ electrostatic force, ✓
5. ~~$\Delta KE = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$~~

Step 1.
Use Gauss' law to find the E field of the wire (eq. 2) ✓

Step 2.
Use Efield to find Force on on Emission particle (eq. 4) ✓

Step 3.
Use definition of work & the force from step 2 and the displacement to find the work done on the particle. (eq. 3) ✓

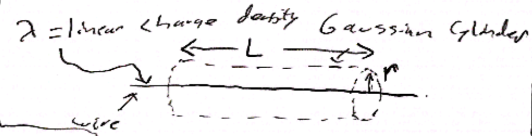
Step 4. Use (eq. 1) & (eq. 5) to set up an equality relating V_f to Work ✓

Step 5. Solve for V_f plug in values and solve. ✓

Dr. Saul's comments: *Good identification of key physics principles and a good step-by-step plan to show how those principles can be used (The ΔKE equation is crossed out because it is not a major principle-note that the group did not lose points for including it). Most experts in science and technology always try to plan out their problem solving approaches when attacking problems beyond what is familiar and easy. I would like you to try this too. Some of you are, but some of you are still doing the analysis before writing down your plan.* NOTE: *Sometimes you will need to change your plan as you are doing your analysis and find that you forgot something. That's OK as long as you add corrections to your plan in the O-step. Just make sure they are marked as corrections to your original plan.*

GOAL solution: A step (1 student example)

Analyze the problem:
Identify and show general physics equations.
Add constraints that specify condition that restrict the problem.
Solve for the unknown variable in terms of the known variables.
Substitute known values, calculate answer, round appropriately.



why?

$$\Delta V = -\int \vec{E}\cdot d\vec{r} = -\frac{W}{q_{particle}} = -\frac{\Delta KE}{q_{particle}}$$

$$\Phi_{cyl} = \oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$$

$$q_{enc} = \lambda \cdot L$$

$$|\vec{A}| = 2\pi r L \qquad \theta = 0$$

$$|\vec{E}||\vec{A}| = \frac{q_{enc}}{\varepsilon_0}$$

$$|\vec{E}| = \frac{q_{enc}}{A\varepsilon_0} = \frac{\lambda \cancel{L}}{2\pi r \cancel{L}\, \varepsilon_0}$$ ✓

$$-\int_{r_i}^{r_f} \frac{\lambda}{2\pi r\varepsilon_0}\, dr = \frac{\frac{1}{2}mv_i^2 - \frac{1}{2}mv_f^2}{q_{particle}}$$

$$\frac{-\lambda}{2\pi\varepsilon_0}\left(\ln|r_f| - \ln|r_i|\right) = \frac{\frac{1}{2}mv_i^2 - \frac{1}{2}mv_f^2}{q_{particle}}$$

$$\frac{-\lambda\, q_{particle}}{2\pi\varepsilon_0}\left(\ln|r_f| - \ln|r_i|\right) = \frac{m}{2}\left(v_i^2 - v_f^2\right)$$

$$\frac{-\cancel{2}\lambda\, q_{particle}}{\cancel{2}\pi m\varepsilon_0}\left(\ln|r_f| - \ln|r_i|\right) = v_i^2 - v_f^2$$

$$\sqrt{\left(\frac{\lambda\, q_{particle}}{\pi m \varepsilon_0}\left(\ln\frac{r_f}{r_i}\right) + v_i^2\right)} = v_f$$

$$v_f = \sqrt{\frac{(-8.0\times10^{-6}\,C/m)(3.0\times10^{-8}\,C)}{\pi(6.0\times10^{-9}\,kg)(8.85\times10^{-12}\,\frac{C^2}{Nm^2})}\left(\ln\frac{.07\,m}{.15\,m}\right) + (900\,m/s)^2}$$

$$v_f = 1380\ m/s \approx 1400\ m/s$$ ✓

Dr. Saul comments: *This is a pretty good solution. Note that a Gaussian surface is drawn for calculation of the E-field. The rest of the symbolic solution is well organized and easy to follow. It is easy to see how the definition of electric potential and the work-energy theorem are used. There are only two points that could stand improvement. One, since DV is defined in terms of the Work done by the electric force and the work-energy theorem depends on the net Work, it is important to explicitly state how they are related, i.e. that since the only significant force is the electric force, We = Wnet. Two, there is a sign error with regards to the charge density and with the ln function. Fortunately both errors cancel out.*

GOAL solution: L step
(2 student examples)

Dr. Saul comments: *Note how both L-steps show some thought about if the answer is reasonable and why the problem was assigned. The groups compare their answer with their guestimate and look at limiting cases. Note how much easier it is to talk about the limiting cases when you have the symbolic solution right in front of you. The L-step on the right looks at initial KE and λ. The L-step below looks at changing the initial position and the charge on the emission particle. This is also a good unit check and a couple sentences on why this was problem was assigned. These are both excellent L-steps, but both would be improved by saying more about how this problem uses ideas from before and shows a real world application. One might even include a thought about other applications that might use these same physics principles.*

We knew the v would increase and it did.

$V_f > V_i$ ✓

$$V_f = \left[\frac{\lambda q_i}{\pi \varepsilon_0 M} \left(\ln|x_1| - \ln|x_2| \right) + v_i^2 \right]^{1/2}$$

If the initial KE, increased our final velocity would increase. Also If the charge or the charge density increased we would expect the Force to increase and thus the velocity and it would ✓

$$\left[\frac{m}{s}\right] = \left[\frac{\left[\frac{C}{m}\right][C]}{\pi \left[\frac{C^2}{N \cdot m^2}\right](kg)} \left(\frac{1}{m}\right) + \frac{m^2}{s^2} \right]^{1/2}$$

$$\left[\frac{m}{s}\right] \quad \left[\frac{\cancel{kg}\frac{m^2}{s^2}}{\cancel{kg}} + \frac{m^2}{s^2} \right]^{1/2} = \left(\left(\frac{m}{s}\right)^2 + \left(\frac{m}{s}\right)^2 \right)^{1/2}$$

$$\left[\frac{m}{s}\right] = \left[\frac{m}{s}\right]$$ ✓

We learned to check units, because our equation was messed up. We also learned how to use Gauss' Law to find an E-field and relate it to force + W. Then use the Work to integrate and find how the force acts on a charge that varies with distance. We put all of our knowledge together in this problem. ✓

$|\vec{v}_f| \approx 1400$ m/s which falls in with our prediction that $900 \text{ m/s} < |\vec{v}_f| < c = 3.0 \times 10^8$ m/s ✓

Unit ☑

$$\frac{m}{s} \stackrel{?}{=} \sqrt{\frac{\left(\frac{C}{m}\right)(C)}{(kg)\left(\frac{C^2}{Nm^2}\right)} + \left(\frac{m}{s}\right)^2} = \sqrt{\frac{\overbrace{\cancel{C^2} \cdot \cancel{N} m^2}^{m/s^2}}{\cancel{kg} \cdot \cancel{C^2} \cdot m} + \left(\frac{m}{s}\right)^2}$$

$$= \sqrt{\frac{m^2}{s^2} + \frac{m^2}{s^2}} \Rightarrow \frac{m}{s}$$ ☑ ✓

Limiting Case(s) & Modification(s)

- If $r_f = r_i$ then $\ln\left(\frac{r_f}{r_i}\right) = 0$ and $\Delta V_{i \to f} = 0$ ✓
- If $q_{particle} = 0$, then $|\vec{v}_f| = |\vec{v}_i|$, which would be expected because the particle would experience no electrostatic force, therefore no acceleration. ✓

Why was problem assigned?

This problem was designed to test us on all of the physics concepts we have learned so far, as it required the knowledge + application of Coulomb's Law for E-fields, Gauss' Law, E-fields of continuous charge distributions, Electric Potential, Work-Energy Thm., + the Conservation of Energy. ✓