Name______________________________

Short Answer

1. Light of a wavelength 450 nm is incident on a grating with 600 lines per mm.

a) How many bright spots appear on the wall 3m away from the grating?

b) What is the distance between the center and the second order spot? ($m = 2$)

a) $\lambda = 450\,nm$

$\frac{1}{d} = \frac{600\text{ lines}}{mm}$ $\quad d = \frac{1\,mm}{600\text{ lines}} = 1.667\times10^{-3}\,mm \cdot \frac{1\,m}{1000\,mm} = 1.667\times10^{-6}\,m$

$m\lambda = d\sin\theta$

$m = \frac{d\sin\theta}{\lambda}$ maximum $\theta = 90°$

$= \frac{1.667\times10^{-6}\,m}{450\times10^{-9}\,m}$

$= 3.7$

m must be an integer and it must be less than 3.7 so $m = 3$

$\#\text{ Spots} = 2m+1 = 7$

b) $\sin\theta = m\lambda/d$

$\theta = \sin^{-1}(m\lambda/d) = \sin^{-1}\left(\frac{2(450\,nm)}{1.667\,\mu m}\right)$

$= \sin^{-1}(0.54) = 32.3°$

$\tan\theta = y/D$

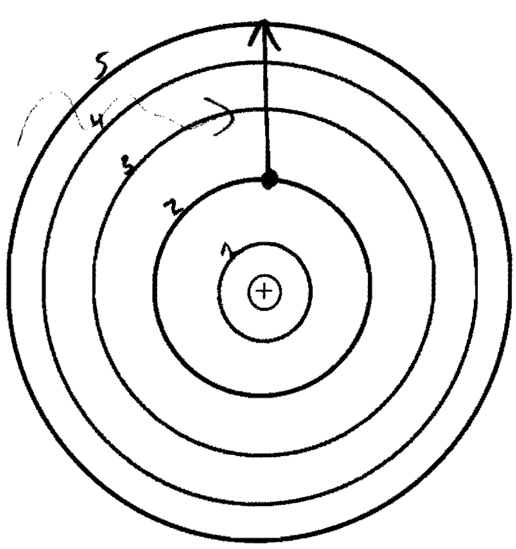
$y = D\tan\theta = 3m\tan 32.3°$

$y = 1.92\,m$

2. In a hydrogen atom, a photon is absorbed causing electron makes a transition between the energy levels 2 and 5 in the atom.

a) What is the energy (in eV) and wavelength (in nm) of the light?

b) In the cartoon of the atom below, draw an arrow indicating the direction of the electron transition that would result from the absorption of this light.



$E_{ph} = E_5 - E_2 = \frac{-13.6\,eV}{5^2} - \frac{-13.6\,eV}{2^2}$

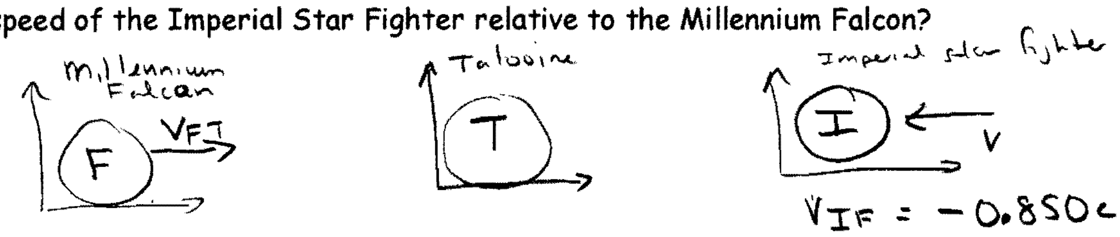
$= -0.544 + 3.4025$

$= 2.86\,eV$

$\frac{hc}{\lambda} = E_{ph} \quad \lambda = \frac{hc}{E_{ph}} = \frac{1240\,eV\cdot nm}{2.86\,eV} = 434\,nm$

Name________________________________

3. Long ago in a galaxy far away there was a small planet named Tatooine. Rapidly approaching the planet from the west is a spaceship named the Millennium Falcon moving at a speed of 0.750 c relative to Tatooine. Approaching the planet from the east is an Imperial Star Fighter moving at a speed of 0.850 c relative to Tatooine. What is the speed of the Imperial Star Fighter relative to the Millennium Falcon?



$V_{IF} = -0.850c$

$V_{FT} = 0.750c$

$V_{TF} = -0.750c$

$V_{IF} = ?$

$$V_{IF} = \frac{V_{IT} + V_{TF}}{1 + \frac{V_{IT} V_{TF}}{c^2}} = \frac{-0.850c + (-0.750c)}{1 + \frac{(-0.850c)(-0.750c)}{c^2}}$$

$$= \frac{-1.6c}{1 + 0.6375} = \boxed{-0.977c = V_{IF}}$$

4. ^{213}Bi is an unstable isotope Using the periodic table

a) Write down the equation for the beta minus decay of this isotope.

b) Write down the equation for the alpha decay of this isotope

a) $^{213}_{83}Bi \longrightarrow {}^{0}_{-1}e + {}^{213}_{84}Po + \bar{\nu}$

b) $^{213}_{83}Bi \rightarrow {}^{209}_{81}Tl + {}^{4}_{2}He$

Name______________________

5. Light of wavelength 480 nm is incident on a metal. Electrons are ejected from the metal with a maximum kinetic energy of 0.5 eV.
a) What is the work function of the metal?
b) What is the threshold frequency?
c) Will light of wavelength 532 nm eject electrons? Why or why not?

a) $\lambda = 480\,nm \quad KE = 0.5\,eV$

$KE = \frac{hc}{\lambda} - \phi \qquad \phi = \frac{hc}{\lambda} - KE = \frac{1240\,eV\cdot nm}{480\,nm} - 0.5\,eV$

$= 2.58\,eV - 0.5\,eV = \boxed{2.08\,eV = \phi}$

b) At the threshold KE=0

$KE = hf - \phi = 0 \quad hf = \phi \quad f = \frac{\phi}{h} = \frac{2.08\,eV}{4.14\times10^{-15}\,eV\cdot s}$

$\boxed{f_0 = 5.02\times10^{14}\,Hz}$

c) $hf_0 = \frac{hc}{\lambda} \qquad \lambda_0 = \frac{1240\,eV\cdot nm}{2.08\,eV} = 596\,nm$

yes 532 nm is higher energy than 596 nm

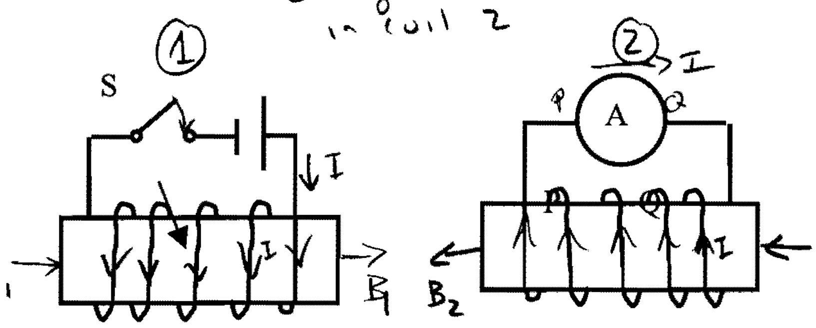
OR

$KE = \frac{hc}{\lambda} - \phi = \frac{1240\,eV\cdot nm}{532\,nm} - 2.08\,eV = 2.33\,eV - 2.08\,eV = +0.25\,eV$

Yes + KE

7. In the figure below, the switch S is initially open. Next it is closed. In what direction does the current flow through the ammeter in the coil on the right when the switch S is closed, P to Q or Q to P? Sketch the current direction and magnetic field direction for both coils.

Closing the switch increases the magnetic flux in coil 2



B_1 is increasing to the right.

To oppose the change B_2 is induced to the left

Name________________________________

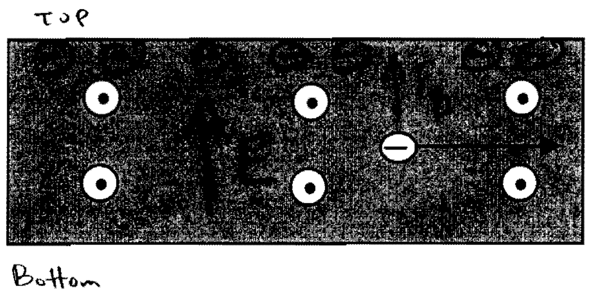
8. While performing surgery on a Jawa on Tatooine, we need to measure the fluid flow in the Jawa's artery. We place her so that her artery is in a magnetic field of 4.0T pointing direct out of the page as seen below. The negative ions in the artery flow to the right.

a) In the sketch below, first show the direction of the magnetic force on the negative ions

b) Next draw in a vector indicating the direction of the Electric field. What causes this field?

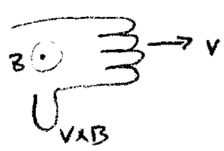
c) Which side of the artery is at a higher potential (left, right, top, bottom, above page, below page)?

d) If we measure the potential difference to be 1.0 Volts across her tentacle of diameter 5.0 cm, what is the velocity of the fluid flow?



a) F_B points up

$v \times B$ is down, the charge is negative, so $F_B \uparrow$



b) negative charges are forced to the top of the artery creating a charge separation and a resulting electric field

E points in the direction a + charge would go. ⊕ attracted to ⊖

so E ↑

c) Bottom will have a higher potential since the top is negative

d) $F_E = F_B$

$qE = qvB$

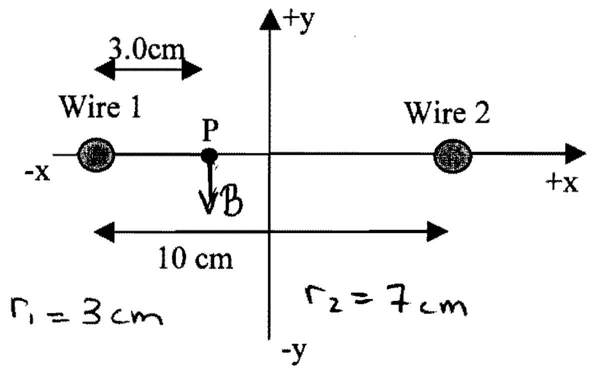
$E = vB$

$\frac{V}{d} = vB$

$v = \frac{V}{dB}$ → $v = \frac{V}{dB} = \frac{(1.0V)}{(0.05m)4.0T} = 5 m/s$

Name______________________________

9. Two long straight parallel wires separated by 10.0 cm carry **currents of equal magnitude**, but heading in **opposite** directions. The wires are shown perpendicular to the plane of this page. Point P is 3.0 cm from wire 1, and the magnetic field at P is 1.5 x10^{-4} T directed in the negative y direction. Calculate the current in wire 1 and its direction.



$I_1 = I_2$ $\qquad B = \frac{\mu_0 I}{2\pi r}$

If I_1 is into the page, B_1 at P is in the negative y direction AND I_2 would have to point out of the page resulting in B_2 pointing in the $-y$ direction, So the fields ADD

$B_1 = \frac{\mu_0 I_1}{2\pi r_1}$ $\quad B_2 = \frac{\mu_0 I_2}{2\pi r_2}$

$B = B_1 + B_2 = \frac{\mu_0 I_1}{2\pi r_1} + \frac{\mu_0 I_2}{2\pi r_2}$ and $I_1 = I_2$

solve for I

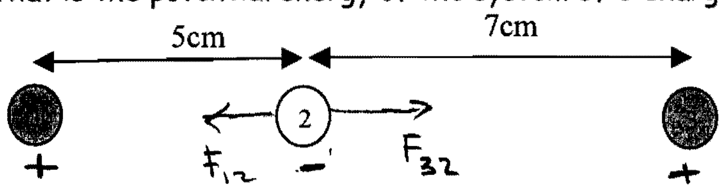
$$\rightarrow B = \frac{\mu_0 I}{2\pi r_1} + \frac{\mu_0 I}{2\pi r_2} = I\left(\frac{\mu_0 \quad r_2}{2\pi r_1 r_2} + \frac{\mu_0 \quad r_1}{2\pi r_2 r_1}\right) = I\left[\frac{\mu_0 (r_2 + r_1)}{2\pi r_1 r_2}\right]$$

$$I = B\left[\frac{2\pi r_1 r_2}{\mu_0 (r_2 + r_1)}\right] = 1.5\times10^{-4}T\left[\frac{2\pi\,(0.03m)(0.07m)}{(4\pi\times10^{-7}\,Tm/A)(0.1m)}\right] = \boxed{15.75A = I}$$

10. There are three charges assembled as seen below. q1= +3μC, q2=-5μC and q3=+7μC

a) What is the force on charge 2 due to the other charges?

b) What is the potential energy of the system of 3 charges?



Direction of the force is NOT given by the equation

$$\sum \vec{F} = \vec{F}_{12} + \vec{F}_{32} = -\frac{kq_1q_2}{r_{12}^2} + \frac{kq_3q_2}{r_{32}^2} = k\left(\frac{q_3q_2}{r_{32}^2} - \frac{q_1q_2}{r_{12}^2}\right)$$

$$= 8.988\times10^{+9}\,C^2/Nm^2\left[\frac{(7\times10^{-6}c)(5\times10^{-6}c)}{(0.07m)^2} - \frac{(3\times10^{-6}c)(5\times10^{-6}c)}{(0.05m)^2}\right] = 10.24N$$

sign of U is given by the eq.

$$U = \frac{kq_1q_2}{r_{12}} + \frac{kq_2q_3}{r_{23}} + \frac{kq_1q_3}{r_{13}} = 8.99\times10^{+9}\frac{Nm^2}{C^2}\left[\frac{(3\times10^{-6}c)(-5\times10^{-6}c)}{(0.05m)} + \frac{(-5\times10^{-6}c)(7\times10^{-6}c)}{(0.07m)} + \frac{(3\times10^{-6}c)(7\times10^{-6}c)}{(0.12m)}\right]$$

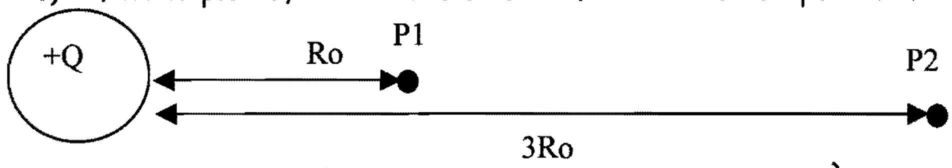
-3×10^{-10} $\quad -5\times10^{-10}$ $\quad + \quad 1.75\times10^{-10}$

$= -5.62\,J$

Name________________________________

11. There is a positive charge of +Q located a distance Ro from point P1 in space. The electric field at point P1 is 100 N/C, and the electric potential at point P1 is 25 V.

a) What is the distance Ro?
b) If we triple Ro, what is the electric potential at the new point P2?
c) If we triple Ro, what is the electric field at the new point P2?



a) $E = \frac{kq}{r^2}$ $V = \frac{kq}{r}$

$Er^2 = kq = Vr$

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

$R_o = \frac{25V}{100 N/C} = 0.25m$

b) $V_1 = \frac{kq}{R_o}$ $V_2 = \frac{kq}{3R_o}$

$\frac{V_2}{V_1} = \frac{R_o}{3R_o}$

$V_2 = \frac{1}{3}V_1 = 8.3V$

c) $E_1 = \frac{kq}{R_o^2}$ $E_2 = \frac{kq}{(3R_o)^2}$

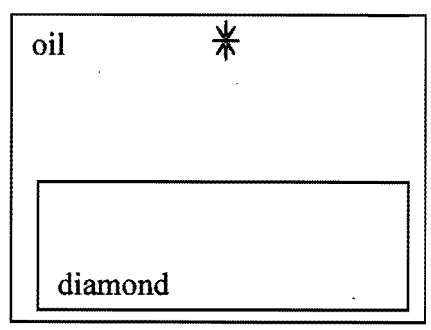
$\frac{E_2}{E_1} = \frac{R_o^2}{9R_o^2} = \frac{1}{9}$

$E_2 = \frac{E_1}{9} = \frac{100 N/C}{9}$

$E_2 = 11.1 N/C$

12. Light from a source immersed in oil of refractive index 1.70 is incident on the plane face of a diamond (n=2.42), also immersed in the oil.

a) Determine the angle of incidence at which maximum polarization occurs upon reflection.
b) For this angle of incidence, what is the angle of refraction into the diamond?
c) Is there an angle where the light from this source will be totally reflected off of the diamond? Explain



a) $\tan\theta_B = \frac{n_t}{n_i}$ $\theta_B = \tan^{-1}\left(\frac{n_t}{n_i}\right) = \tan^{-1}\left(\frac{2.42}{1.70}\right) = 54.9°$

b) $n_i \sin\theta_i = n_t \sin\theta_t$

$\theta_t = \sin^{-1}\left(\frac{n_i}{n_t}\sin\theta_i\right)$

$= \sin^{-1}\left(\frac{1.70}{2.42}\sin 54.9\right)$

$= 35°$

c) No. Total internal reflection only occurs when light goes from a high index to a low index

Also $\sin\theta_c = \frac{n_t}{n_i} = \frac{2.42}{1.7} = 1.42$

But this is greater than 1 and the sine function is undefined

Name_______________________________

Problems: Choose 4 out of 5. Write OMIT on the one you want to skip. (20pts each)

1. The counting rate from a radioactive source is 8000 counts per second at a time t=0. Ten minutes later the rate is 1000 counts per second.

a) What is the half life?

b) What is the decay constant? ← 1 minute

c) What is the count rate after ~~10~~ 1 minute~~s~~?

$$R = R_0 \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

$$\frac{R}{R_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

$$\frac{R}{R_0} = \frac{1000}{8000} = \frac{1}{8}$$

$$\log\left(\frac{R}{R_0}\right) = \log\left(\frac{1}{2}\right)^{t/T_{1/2}}$$

$$= \frac{t}{T_{1/2}} \log\left(\frac{1}{2}\right)$$

$$T_{1/2} = t \frac{\log(1/2)}{\log(R/R_0)} = 3.33 \text{ min}$$

$$R = R_0 e^{-t/\tau}$$

$$\frac{R}{R_0} = e^{-t/\tau}$$

$$\ln\left(\frac{R}{R_0}\right) = -t/\tau$$

$$t/\tau = \ln(R_0/R)$$

$$\tau = \frac{t}{\ln(R_0/R)}$$

$$\tau = \frac{10 \text{ min}}{\ln 8} = 4.8 \text{ min}$$

decay constant=lambda
lambda=1/lifetime=1/tao
=1/(4.8minx60s/min)=3.47×10^{-3} 1/s

check $\tau = \frac{T_{1/2}}{\ln 2} = 4.8 \text{ min}$

c) $R = R_0 (1/2)^{t/T_{1/2}}$

$$= 8000 (1/2)^{1/3.33}$$

$$= 6498 \text{ counts/sec}$$

Name________________________________

2. Luke Skywalker can travel from his home on the planet Tatooine to the capital in 32 minutes as measured from his X-wing star fighter traveling at a speed of 0.95 c.

a) What is γ?

b)What time would be measured on Tatooine?

c) What distance would Luke measure this to be from the reference frame of his X-wing star fighter?

d) What distance would be measured on Tatooine?

e) Which reference frame has proper time and which reference frame has proper length?

a) $\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = 3.20$

b) proper time is the reference frame where the events occur in the same place. The events are travel from home to capital. These occur in the same place on the X-wing star fighter

so $\Delta t_0 = 32$ minutes

$\Delta t = \gamma \Delta t_0 = (3.20)(32 \text{ min}) = 102$ minutes

c) $\text{distance}_{\text{Luke}} = \text{velocity} \times \text{time}_{\text{Luke}} = (0.95)(3\times10^8 \text{ m/s})(32 \text{ min})\frac{60 \text{ s}}{\text{min}} = 5.47\times10^{11} \text{ m}$

d) $\text{distance}_{\text{Tatooine}} = \text{velocity} \times \text{time}_{\text{Tatooine}} = (0.95)(3\times10^8 \text{ m/s})(102 \text{ min})\frac{60 \text{ s}}{\text{min}} = 1.74\times10^{12} \text{ m}$

e) proper time: Luke proper length – distance is at rest: Tatooine

check $L = \frac{L_0}{\gamma}$ $\gamma = \frac{L_0}{L} = \frac{1.74\times10^{12} \text{ m}}{5.47\times10^{11} \text{ m}} = 3.19$ $L_0 = \gamma L$

Name______________________________

3. For a concave mirror of focal length 12 cm and an object 5 cm tall, if the object is 8 cm from the mirror,
   a. Where is the image (which side of the mirror and how far in cm)?
   b. What is the magnification?
   c. Is the image upright or inverted? How do you know?
   d. Is the image enlarged or diminished? How do you know?
   e. Is the image virtual or real? How do you know?

Repeat for a convex mirror with the same focal length.

a) concave $\Rightarrow f = +12\text{ cm}$ $R = 24\text{cm}$ $h = 5\text{ cm}$ $p = +8\text{cm}$

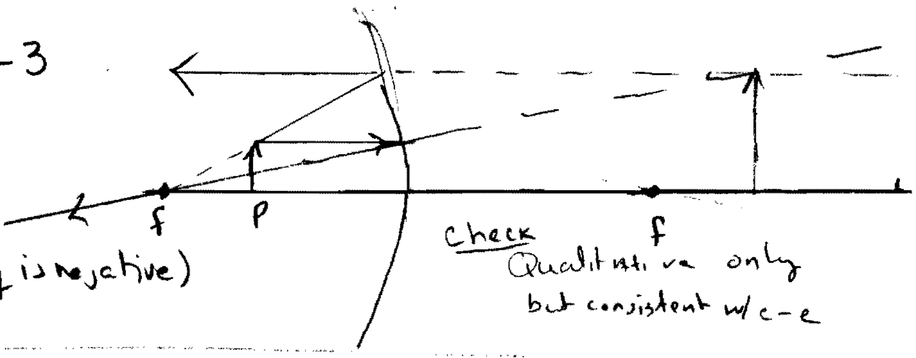
$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \Rightarrow \frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{p-f}{fp} \Rightarrow q = \frac{fp}{p-f} = \frac{(12)(8)}{8-12} = \frac{96\text{cm}}{-4} = -24\text{ cm}$ ↑ behind mirror

b) $m = -\frac{q}{p} = -\frac{(-24\text{cm})}{8\text{ cm}} = +3$

c) m is ⊕ so upright

d) m is > 1 so enlarged

e) image is virtual (q is negative)



a) convex $f \Rightarrow -12\text{ cm}$ $p = 8\text{cm}$

$q = \frac{fp}{p-f} = \frac{(-12)(8)}{8-(-12)} = \frac{-96\text{cm}}{20} = -4.8\text{ cm}$ ← behind mirror

negative q → virtual

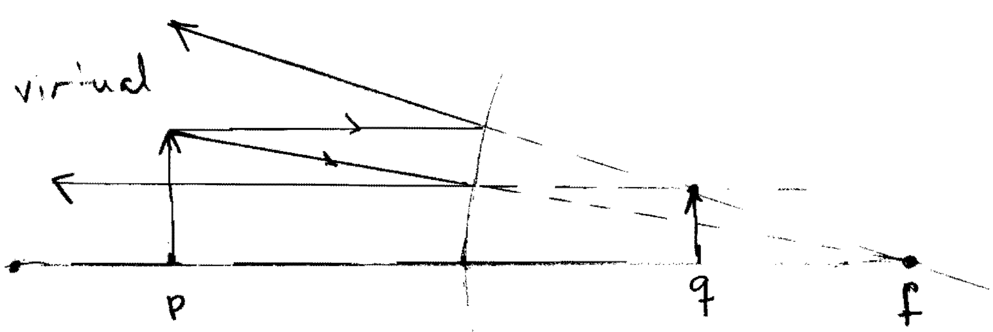
b) $m = -\frac{q}{p} = \frac{-(-4.8\text{cm})}{8\text{cm}} = +0.6$

c) ⊕m ⇒ upright

d) m < 1 diminished

e) q is negative so virtual

Check with sketch



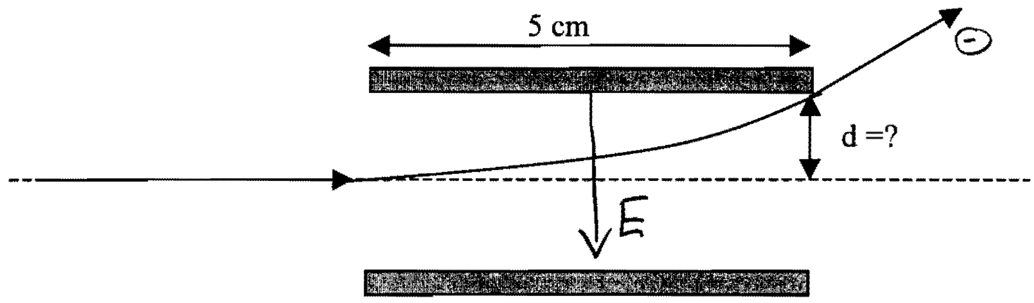
Name________________________________

4. An electron is accelerated through a horizontal potential difference of 5000 V before it enters the center of the space between two charged parallel plates moving in a horizontal direction. The plates are 5.0 cm long.

a) Show that the speed of the electron as it enters the plates is $v_o = 4.2 \times 10^7$ m/s (hint: energy)

b) If the Electric field has a magnitude of 3.0×10^4 N/C, what is the vertical deflection, d, of the electrons as they leave the plates?

c) What is the direction of the electric field? (draw it in the picture below)



a) $KE = \frac{1}{2}mv^2 = eV_o$ $v^2 = \frac{2eV_o}{m}$ $v = \sqrt{\frac{2eV_o}{m}} = \sqrt{\frac{2(1.6\times10^{-19}C)(5000V)}{9.11\times10^{-31}kg}} = 4.2\times10^{+7}\frac{m}{s}$

b) $E = 3.0\times10^4 N/C$ $F = qE = ma$

$a = \frac{qE}{m} = \frac{(1.6\times10^{-19}C)(3.0\times10^4 N/C)}{9.11\times10^{-31}kg} = 5.27\times10^{15} m/s^2$

$y = v_{oy}t + \frac{1}{2}a_y t^2$ don't know t ...

but $x = v_{ox}t$ since $a_x = 0$

$t = \frac{x}{v_{ox}} = \frac{0.05m}{4.2\times10^7 m/s} = 1.19\times10^{-9}s$

$y = d = 0 + \frac{1}{2}(5.27\times10^{15} m/s^2)(1.19\times10^{-9}s)^2$

$= 3.73\times10^{-3}m$

$= 3.73mm$

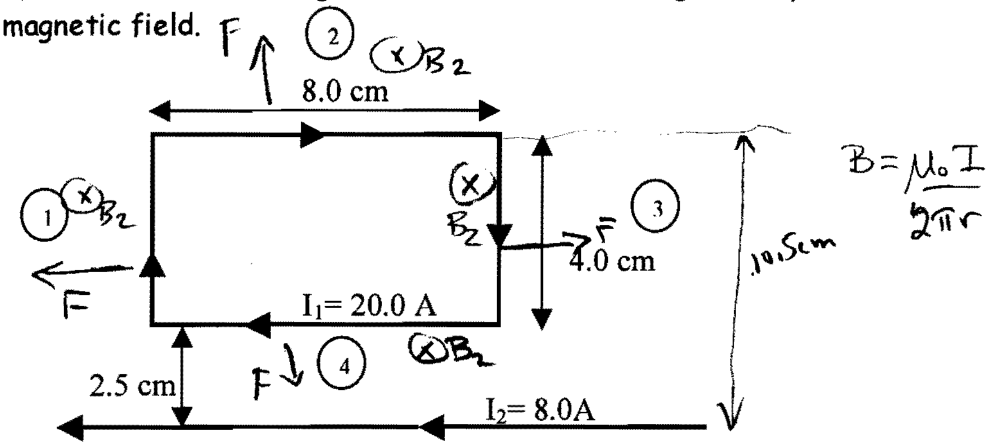
c) E points in the direction a + charge would go so it points opposite the direction the negative charge goes.

Name________________________________

5. A rectangular loop of wire carrying a current $I_1 = 20.0$ A is next to a very long wire carrying a current $I_2 = 8.00$ A to the left.

a) What is the direction of the magnetic force on each of the four sides (labeled in the circles) of the rectangle due to the long wire's magnetic field? Sketch them on the diagram below.

b) Calculate the net magnetic force on the rectangular loop due to the long wire's magnetic field.



a) The magnetic field due to wire 2 points into the page everywhere above the wire

① ↑I ⊗B ← F — Using the right hand rule, point your fingers along I with your palm in the direction of B. Your thumb points along F

F is outward on each side of the square loop.

b) By symmetry we can note that F_1 cancels F_3 Because they are the same distance from I_2 They experience the same B_2. They have the same I_1 and F's in opposite directions

on segment ②

$$F_{②} = L_1 I_1 B_2 \sin\theta = L_1 I_1 \frac{\mu_0 I_2}{2\pi r} = \frac{(8\times10^{-2}\text{m})(20.0\text{A})(4\pi\times10^{-7}\frac{\text{Tm}}{\text{A}})(8.00\text{A})}{2\pi(0.065\text{m})}$$

$$= 3.94\times10^{-5}\text{ N up}$$

r changes

$$F_4 = L_1 I_1 B_2 = L_1 I_1 \frac{\mu_0 I_2}{2\pi r} = \frac{(8\text{cm})(20.0\text{A})(4\pi\times10^{-7}\text{Tm/A})(8.00\text{A})}{2\pi\ (2.5\text{cm})}$$

$$= 10.2\times10^{-5}\text{ N Down}$$

$$F_{net} = F_2 + F_4 = 3.94\times10^{-5}\text{N} - 10.2\times10^{-5}\text{N} = -6.26\times10^{-5}\text{ N}$$

$F_{net} = 6.26\times10^{-5}$N downward