Physics 1C Spring 2018 Final

Timothy Rediehs

TOTAL POINTS

96 / 106

QUESTION 1

1 1 **10 / 10**

✓ **+ 3 pts** Correct expression for I(\phi,\beta)
✓ **+ 2 pts** Correct expression for \phi
✓ **+ 2 pts** Correct expression for \beta
✓ **+ 3 pts** Correct numerical answer
+ **0 pts** Click here to replace this description.
+ **10 pts** Correct *

QUESTION 2

2 2a **5 / 5**

✓ **+ 2 pts** dsin(\theta) = m \lambda
✓ **+ 2 pts** sin(\theta) = y/L
✓ **+ 1 pts** Correct \lambda
+ **0 pts** Click here to replace this description.

QUESTION 3

3 2b **5 / 5**

✓ **+ 1 pts** Correct expression for max
✓ **+ 1 pts** Correct expression for min.
✓ **+ 1 pts** Let correct distances be equal
✓ **+ 2 pts** Solve for smallest integer values
+ **0 pts** Click here to replace this description.

QUESTION 4

4 3a **2 / 4**

+ **1 pts** x'_1
+ **1 pts** x'_2
✓ **+ 1 pts** t'_1
✓ **+ 1 pts** t'_2
+ **0 pts** Click here to replace this description.

QUESTION 5

5 3b **3 / 6**

+ **1.5 pts** Correct time interval in S'
+ **1.5 pts** Correct time interval in S
✓ **+ 1.5 pts** NOT entirely a result of time dilation
✓ **+ 1.5 pts** Short reason for conclusion (i.e. clocks no longer synchronized/ events took place at different positions in both frames)
+ **0 pts** Click here to replace this description.

QUESTION 6

6 4 **12 / 12**

✓ **+ 3 pts** Correct expression for length in moving frame
✓ **+ 3 pts** Correct \gamma for spaceship B
✓ **+ 3 pts** Let contracted lengths be equal
✓ **+ 3 pts** Solve for correct velocity of spaceship A
+ **0 pts** Click here to replace this description.

QUESTION 7

7 5a **3 / 3**

✓ **+ 2 pts** Write displacement current as a time derivative of electric flux
✓ **+ 1 pts** Correct final expression for displacement current
+ **0 pts** Click here to replace this description.

QUESTION 8

8 5b **3 / 5**

✓ **+ 2 pts** Correct magnitude in terms of displacement current from (a)
+ **2 pts** Correct direction
+ **0 pts** Click here to replace this description.
✓ **+ 1 pts** Ampere's Law

QUESTION 9

9 5c **2 / 2**

✓ **+ 1 pts** B field lines are circles
+ **0 pts** Click here to replace this description.
✓ **+ 1 pts** B field goes in the correct direction

QUESTION 10

10 6 **10 / 10**

✓ **+ 10 pts** **Correct**

+ 2 pts Partial points: Gravity Fg=mg=density*area*length*g

+ 2 pts Partial points: Force due to magnetic field: Fb=J*area*length*B0

+ 2 pts Partial points: Fg=Fb

+ 2 pts Partial points: correct final expression for J. J=density*g/B0

+ 2 pts Partial points: Direction of current: from west to east

+ 0 pts no point

QUESTION 11

11 7a **6 / 6**

✓ **+ 6 pts** **Correct**

+ 2 pts Partial point: length equation

+ 2 pts Partial point: object distance+image distance=D

+ 0 pts no point

QUESTION 12

12 7b **4 / 4**

✓ **+ 4 pts** **Correct**

+ 0 pts no point

QUESTION 13

13 8a **4 / 5**

+ 5 pts Correct

+ 1 pts Partial point: q(t)=Qcos(omega*t)

+ 1 pts Partial point: omega=1/sqrt(LC)

+ 1 pts Partial point: Ec(t)=q(t)^2/2C

+ 1 pts Partial point: Ec(T)=(1/4)*Ec(0)

+ 0 pts no point

+ 4 **Point adjustment**

cos(wT)=1/2

QUESTION 14

14 8b **5 / 5**

✓ **+ 5 pts** **Correct**

+ 4 pts All correct but use wrong value of inductor(should be 20*10^-3 H) or make some mistake when plug in values and calculate.

+ 1 pts nice try

+ 0 pts no point

QUESTION 15

15 9a **4 / 4**

✓ **+ 4 pts** **Correct**

+ 2 pts reason is not so correct. Key point is that first coil needs AC or time-varying current to produce emf.

+ 0 pts no point

QUESTION 16

16 9b **5 / 5**

✓ **+ 5 pts** **above and correct reason. (derive from VL>VC)**

+ 2 pts driven above resonant but reason is not correct.

+ 0 pts no point

QUESTION 17

17 9c **4 / 4**

✓ **+ 2 pts** **Yes**

✓ **+ 2 pts** **correct direction. (CCW if look from above)**

+ 0 pts no points

QUESTION 18

18 9d **4 / 5**

✓ **+ 2.5 pts** **Speed of light is measured to be the same for all inertial abservers**

✓ **+ 2.5 pts** **The laws of physics are the same for all inertial abservers**

✓ **- 1 pts** **Do not mention inertial observers when saying the laws of physics are the same.**

+ 0 pts no point

QUESTION 19

19 extra **5 / 6**

+ 6 pts correct

+ 2 pts Partial points: Length contraction for x direction(direction of velocity)

+ **2 pts** Partial points: length does not change in y direction

+ **0 pts** no point

+ **5** **Point adjustment**

x'=x/gama not x*gama

Physics 1C – Spring 2018: Final Exam

Name Timothy Redlehs [redacted]

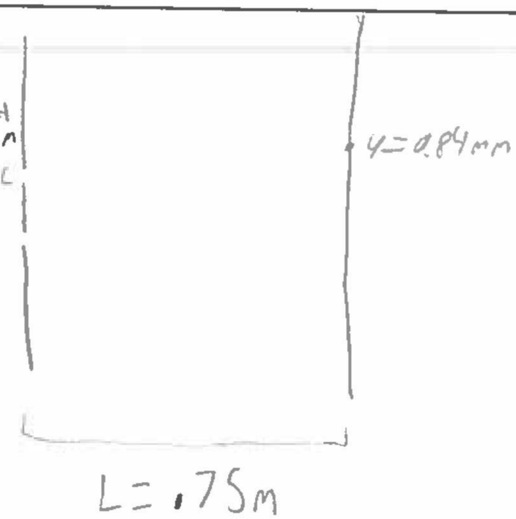
This exam is closed book and closed notes. Electronics are not permitted, except for one calculator. Please show your full solution in the boxes provided (where the scanners can pick them up). Answers recorded outside of boxes will not be graded. Your solutions will be graded on correctness and coherence; results given with no details will receive zero credit. There is additional scratch paper attached so you can collect your thoughts first. Academic dishonesty is reported to the Office of the Dean of Students. Good Luck!

Problem 1. Parallel rays of monochromatic light with wavelength 568 nm illuminate two identical slits and produce an interference pattern on a screen that is 75.0 cm from the slits. The centers of the slits are 0.640 mm apart and the width of each slit is 0.434 mm. If the intensity at the center of the central maximum is 3.20×10^4 W/m^2, what is the intensity at a point on the screen that is 0.840 mm from the center of the central maximum? (10 pts)

$\lambda = 568 \cdot 10^{-9}$ m

$a = 4.34 \cdot 10^{-4}$ m

$d = 6.4 \cdot 10^{-4}$ m



$$I = I_0 \left(\frac{\sin(\beta)}{\beta}\right)^2 \cdot \cos\left(\frac{\phi}{2}\right)^2$$

$$\beta = \frac{\pi a (\sin\theta)}{\lambda}$$

$\sin\theta \approx \tan\theta \approx \frac{y}{L} = .00112 \approx \sin\theta$

(B) $\beta = 2.68844\ldots$

$$\phi = \frac{2\pi}{\lambda}(r_2 - r_1) \approx \frac{2\pi}{\lambda} d \sin\theta = \frac{2\pi}{568 \cdot 10^{-9}} \cdot 6.4 \cdot 10^{-4} \cdot 0.0112 = 7.929\ldots \text{ rad} \quad (\phi)$$

$$I = I_0 \left(\frac{\sin(\beta)}{\beta}\right)^2 \cos\left(\frac{\phi}{2}\right)^2 = \boxed{392 \frac{W}{m^2}}$$

$I_0 = 3.2 \cdot 10^4$

Problem 2. Consider Young's double slit experiment.

a. Light passes through two slits separated by a distance d=0.8mm, and the observing plane is 1.6m away from the two slits. If the distance between the two consecutive maxima is 5mm, what is the wavelength of the light? (5 pts)

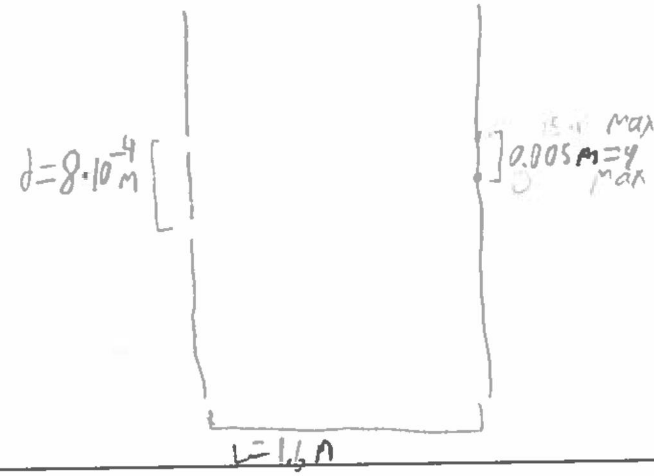
$d\sin(\theta) = m\lambda$

$d\cdot\frac{y}{L} = \lambda$ $\quad d = 8\cdot10^{-4}$

$y = 5\cdot10^{-3}$

$L = 1.6$

$\boxed{\lambda = 2.5\ NM}$



b. Now consider the same setup, but instead of sending through light of the wavelength calculated above, you send in light containing two wavelengths, 450nm and 600nm. What is the least order at which a maximum of one wavelength will fall exactly on a minimum of the other? (You should state the order for both wavelengths that lead to this condition.) (5 pts)

$\lambda_1 = 450\cdot10^{-9} m \quad \lambda_2 = 600\cdot10^{-9} m \quad d = 8\cdot10^{-4} m \quad L = 1.6 m$

$d\sin(\theta_1) = m_1\lambda_1 \quad d\sin(\theta_2) = (m_2+\frac{1}{2})\lambda_2$

$d\frac{y_1}{L} = m_1\lambda_1 \quad d\frac{y_2}{L} = (m_2+\frac{1}{2})\lambda_2$

$y_1 = \frac{m_1\lambda_1 L}{d} \quad y_2 = \frac{(m_2+\frac{1}{2})\lambda_2 L}{d}$

$y_1 = y_2$

$\frac{m_1\lambda_1\cancel{L}}{\cancel{d}} = \frac{(m_2+\frac{1}{2})\lambda_2\cancel{L}}{\cancel{d}}$

$\frac{m_1}{m_2+\frac{1}{2}} = \frac{\lambda_2}{\lambda_1} = \frac{600}{450} = \frac{4}{3}$

$m_1 = 2 \quad m_2 = 1$ ← answer

$d\sin(\theta_1) = (m_1+\frac{1}{2})\lambda_1 \quad d\sin(\theta_2) = m_2\lambda_2$

$\frac{(m_1+\frac{1}{2})\lambda_1 L}{d} = \frac{m_2\lambda_2 L}{d}$

$\frac{m_1+\frac{1}{2}}{m_2} = \frac{\lambda_2}{\lambda_1} = \frac{4}{3}$

$\boxed{\text{Nope}}$

Problem 3. A reference frame S' passes a second reference frame S with a velocity of 0.6c in the X direction. Clocks are adjusted in the two frames so that when t = t'= 0 the origins of the two reference frames coincide.

a. An event occurs in S with space-time coordinates $x_1 = 50\text{m}$, $t_1 = 2.0 \times 10^{-7}s$. A second event occurs at $x_2 = 10\text{m}$, $t_2 = 3.0 \times 10^{7}\text{s}$. What are the coordinates of these two events in S'? (I.e., x'_1, t'_1, x'_2, t'_2). (4 pts)

S

S' $\xrightarrow{.6c}$

$x_1 = 50m$ $t_1 = 2\cdot10^{-7}$, $x_2 = 10m$ $t_2 = 3\cdot10^{-7}$ $V = 0.6c$ $\beta = 0.6$

$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = 1.25$

$x' = \gamma(x - vt)$

$x_1' = 1.25\cdot(50 - .6\cdot3\cdot10^8\cdot2\cdot10^{-7}) = 47.5m$

$x_2' = 1.25\cdot(10 - .6\cdot10^8\cdot3\cdot10^{-7}) = -10m$

$t' = \gamma(t - \frac{vx}{c^2}) = \gamma(t - \frac{\beta}{c}x)$

$t_1' = 1.25(2\cdot10^{-7} - \frac{0.6}{3\cdot10^8}\cdot50) =$

$t_1' = 1.25\cdot10^{-7}$

$t_2' = 1.25(3\cdot10^{-7} - \frac{0.6}{3\cdot10^8}\cdot10)$

$t_2' = 3.5\cdot10^{-7}$

b. What is the time interval between the events as measured in S (Δt) and S'($\Delta t'$)? Is this difference an example solely of time dilation (I.e., are the two time intervals related by a factor of γ)? Give a short reason for your conclusion. (6 pts)

Check if $t_1' \overset{?}{=} \gamma t_1 \overset{?}{=} 2.5\cdot10^{-7}$ NO

No, if you look at the lorentz transformation, $\frac{Vx}{c^2} \neq 0$, so $t' \neq \gamma t$ since $t' = \gamma(t - \frac{Vx}{c^2})$ and $\frac{Vx}{c^2} \neq 0$.

Problem 4. Suppose we have two spaceships A and B, and the rest length L_A of A is twice the rest length L_B of B. If B is moving at $v_B = c/2$ relative to an observer at rest and A is moving at a speed v_A that makes A appear the same length as B to the same observer at rest, how fast is A moving? (12 pts)

$L_A = 2L_B$

$\frac{(c/2)^2}{c^2} = \frac{1}{4}$

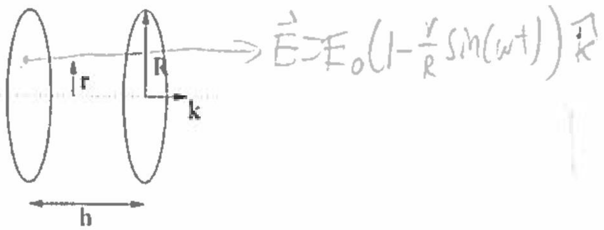
$$L = L_A \cdot \sqrt{1 - \frac{v_A^2}{c^2}} = L_B \cdot \sqrt{1 - \frac{1}{4}}$$

$$\frac{2L_B}{L_B} = \frac{\sqrt{3/4}}{\sqrt{1 - \frac{v_A^2}{c^2}}}$$

$$\sqrt{1 - \frac{v_A^2}{c^2}} = \frac{1}{2}\sqrt{3/4} = \sqrt{\frac{1}{4} \cdot \frac{3}{4}} = \sqrt{3/16} = \sqrt{1 - 13/16}$$

$$\frac{v_A^2}{c^2} = \frac{13}{16} \Rightarrow \frac{v_A}{c} = \frac{\sqrt{13}}{4} \Rightarrow v_A = \frac{\sqrt{13}}{4} c$$

Problem 5. A cylindrical region of space of radius R and length h contains a non-uniform time-varying electric field $\vec{E}$ give by $\vec{E} = E_0(1 - \frac{r}{R} sin(\omega t))\hat{k}$ where $\hat{k}$ is the unit vector along the axis of the cylinder, E_0 is a positive constant and r is the radial distance from the axis of the cylindrical region.



a. Find the displacement current, i_d in the cylindrical region (r<R). (3 pts)

$$i_d = \varepsilon_0 \frac{d\Phi_E}{dt} = \varepsilon_0 \frac{d}{dt}\left(\int_0^r 2\pi r \cdot \left(E_0\left(1-\frac{r}{R}\sin(\omega t)\right)\right) \cdot dr\right)$$

$$= \varepsilon_0 \frac{d}{dt}\int_0^r 2\pi r E_0 - \frac{2\pi r^2 E_0}{R}\sin(\omega t)\, dr = \varepsilon_0 \cdot \frac{d}{dt}\left(\pi r^2 E_0 - \frac{\frac{2}{3}\pi r^3 E_0}{R}\sin(\omega t)\right)\Big|_0^r$$

$$= \varepsilon_0 \frac{d}{dt}\left(\pi r^2 E_0 - \frac{2\pi r^3 E_0}{3R}\sin(\omega t)\right) = \varepsilon_0 \cdot \frac{-2\pi r^3 E_0}{3R} \cdot \omega\cos(\omega t)$$

$$\boxed{i_d = \frac{-2\varepsilon_0 \pi r^3 E_0}{3R}\omega\cos(\omega t)}$$

b. Find the magnetic field associated with the electric field in the cylindrical region. (Hint: choose coordinates which make your life easier.) (5 pts)

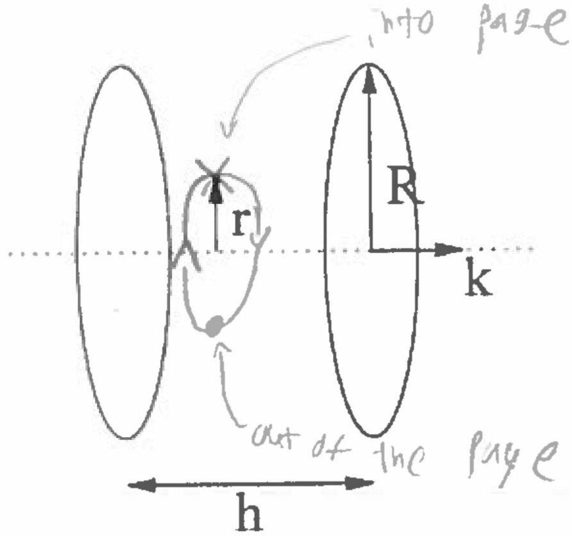
$i_c = 0$

$$\oint B \cdot d\vec{l} = \mu_0 i_{d\,enc}$$

$$\cancel{2\pi r} B = \mu_0 \cdot \frac{-\cancel{2}\varepsilon_0 \cancel{\pi} r^{\cancel{3}\,2} E_0}{3R}\omega\cos(\omega t)$$

$$\boxed{B(r,t) = \mu_0 \frac{-\varepsilon_0 r^2 E_0}{3R}\omega\cos(\omega t)}$$

c. Indicate/sketch the direction of $\vec{B}$ at the radial distance r at t=0 in the figure. (2 pts)

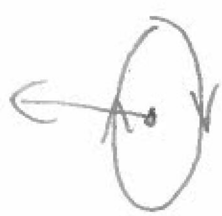


$$B(r,t) = \mu_0 \cdot \frac{-\varepsilon_0 r^2 E_0}{3R}\, \omega \cos(\omega t)$$

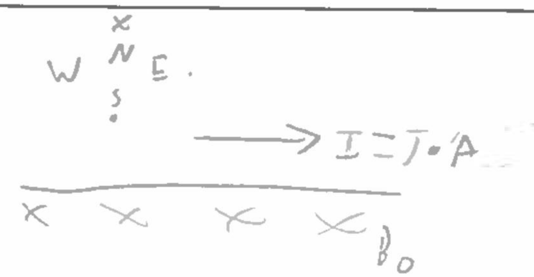
when $t=0$

$\cos(\omega t) = 1$

$B(r,t) < 0$



Problem 6. A copper wire of diameter d carries a current density **J** at the earths equator where the earths magnetic field is horizontal, points north, and has magnitude B_0. The wire lies in a plane that is parallel to the surface of the earth and is oriented in the east-west direction. The density of copper is ρ_{cu}. Find an expression for the magnitude of **J** and the direction it must flow in order to levitate the wire. (10 pts)



$$F_B = I L B_0 =$$
$$F_B = J A \cdot L B_0 = J \cdot V B_0$$
$$F_G = mg = \rho_{cu} \cdot V \cdot g$$

$$F_B = F_g$$

$$J \cdot V \cdot B_0 = \rho_{cu} \cdot V \cdot g$$

$$J \cdot B_0 = \rho_{cu} \cdot g$$

$$J = \frac{\rho_{cu} \cdot g}{B_0}$$

let $g \approx 9.8$ m/s/s and be the accelaration due to gravity on Earth

Problem 7. A converging lens with focal length f is placed between a light source and a screen. The distance between the light source and the screen is D.

a. Find the two locations of the converging lens such that the image is formed at the screen. Give answers in terms of D. (6 pts)

$$d_o + d_i = D$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$\frac{1}{d_o} + \frac{1}{D-d_o} = \frac{1}{f}$$

$$(D-d_o)f + d_o f = d_o(D-d_o)$$

$$Df - d_o f + d_o f = d_o D - d_o^2$$

$$D \cdot f = d_o D - d_o^2$$

$$d_o^2 - D d_o + Df = 0$$

$$\boxed{d_o = \frac{D \pm \sqrt{D^2 - 4Df}}{2}}$$

(d_o is the distance of lens from light)

b. What happens if D < 4f ? Can you still get an image on the screen? (4 pts)

I don't think so, because $\sqrt{D^2-4Df}$ is not real when $D<4f$

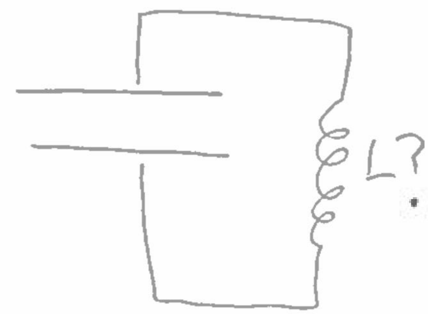
NO

Problem 8.

1. Initially, the capacitor in a series LC circuit is charged. A switch is closed, allowing the capacitor to discharge, and after time T the energy stored in the capacitor is one fourth its initial value. Determine L if C and T are known (in terms of C and T). (5 pts)

$E_C = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$ $\quad C = \frac{Q}{V}$

if $E_C' = \frac{1}{4}E_0$, then $Q' = \frac{1}{2}Q$



$q = Q\cos(\omega t) = Q\cos\left(\frac{1}{\sqrt{LC}}T\right)$

$\frac{1}{4} = \cos\left(\frac{T}{\sqrt{LC}}\right)$

$\cos^{-1}\left(\frac{1}{4}\right) = \frac{T}{\sqrt{LC}} \Rightarrow \left(\cos^{-1}\left(\frac{1}{4}\right)\right)^2 = \frac{T^2}{LC} \Rightarrow \boxed{L = \frac{T^2}{C\left(\cos^{-1}\left(\frac{1}{4}\right)\right)^2}}$

2. An LC circuit consists of a 20.0-mH inductor and a 0.500-F capacitor. If the maximum instantaneous current is 0.100 A, what is the greatest potential difference across the capacitor? (5 pts)

$C = \frac{Q}{V}$ $\quad V = \frac{Q}{C}$ $\qquad L = 0.02H \quad C = .5F$

$I = .1A$

$\frac{1}{2}LI^2 = \frac{Q^2}{2C}$

$Q^2 = \frac{1}{2}\cdot\frac{LI^2}{2C} \Rightarrow Q = \sqrt{\frac{1}{2}\cdot\frac{LI^2}{4C}} = 0.01$

$V = \frac{Q}{C} = \frac{1}{C}\sqrt{\frac{LI^2}{4C}} = \frac{I}{2C}\sqrt{\frac{L}{C}} = \boxed{0.02V}$

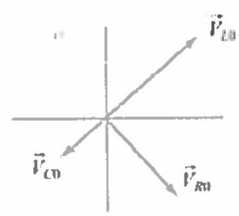
Problem 9. Short conceptual problems

a. Can a battery be used as the primary voltage source for a transformer? Explain using a sentence or two. (4 pts)

~~Yes a transformer simply changes the voltage of a system. You can still do that~~

NO, transformers work by inducing a current in a second solinoid using the current of the first. DC produces a constant B-field which won't induce a current in the other solinoid.

b. Consider the phasor diagram shown below for a driven RLC circuit. Is the driving frequency above or below the resonant frequency? Briefly explain. (5 pts)



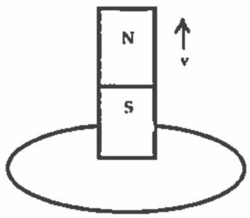
~~$V_L = L\frac{di}{dt}$ $V_C = \frac{q}{C}$ $X_L > X_C$ $\omega L > \frac{1}{\omega C}$ $\omega^2 > \frac{1}{LC}$ $\omega > \frac{1}{\sqrt{LC}}$~~

~~$|V_L|$ is greater than $|V_c|$ so L and C must tend towards being higher~~

It is greater because $X_L = \omega L > \frac{1}{\omega C} = X_C$

$\omega > \frac{1}{\sqrt{LC}}$ = resonance frequency

c. Consider a bar magnet moving with respect to a circular loop of wire as shown below. Will a current be induced in the wire? If so, in which direction as viewed from above? (4 pts)



Yes it will be a counter clock-wise curent

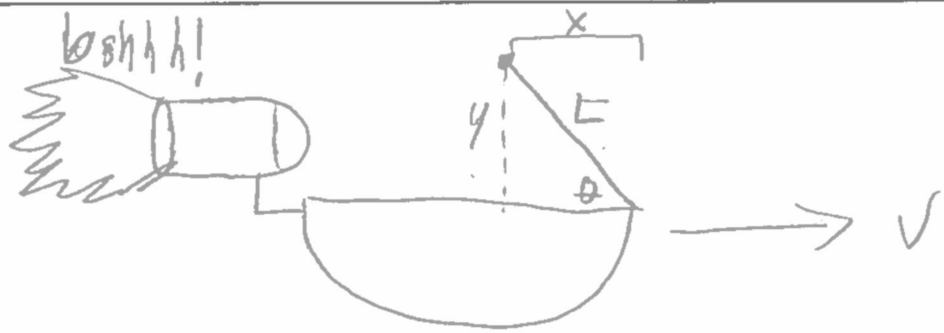
d. State the two postulates Einstein used to formulate the special theory of relativity. (It is possible to state these concisely in only one sentence. This is not how we did it in class, and if you choose to do so, be careful.) (6 pts)

1. Laws of physics are the same in all frames of reference.

2. The speed of light doesn't change regardless of your frame of reference

Extra Credit (6 pts)

Suppose a sailboat moves at speed v relative to an observer on the shore. The sailboat has a mast of length L that is anchored near the front of the boat and makes an angle (when the boat is at rest) of θ with the deck of the boat. What angle will the observer on the shore see?



$$y = L\sin\theta$$
$$x = L\cos(\theta)$$

$$x' = \frac{x}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{L\cos(\theta)}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$y' = y = L\sin\theta$$

$$\tan(\theta') = \frac{y'}{x'} = \frac{L\sin(\theta)}{L\cos(\theta)}\cdot\sqrt{1-\frac{v^2}{c^2}} = \tan(\theta)\cdot\sqrt{1-\frac{v^2}{c^2}}$$

$$\boxed{\theta' = \tan^{-1}\left(\tan(\theta)\cdot\sqrt{1-\frac{v^2}{c^2}}\right)}$$

Scratch paper