Physics 1C - Winter 2017

Midterm Exam #2

READ THIS BEFORE YOU BEGIN

- You are allowed to use only yourself and a writing instrument on this exam.
- If you finish more than 5 minutes before the end of the exam period, please raise your hand and a proctor will collect your exam. Otherwise, please stay in your seat until the end of time is called.
- When the exam is finished, please remain in your seat, pass your exam to the aisle, and the proctor(s) will come around and collect your exam. Once your exam is collected, you may leave the room.
- Show all work. The purpose of this exam is primarily to test how you think; you will get more partial credit for a logical, well-thought-out response, and **you will get little or no credit for an answer without convincing reasoning**. Points will be given specifically for the quality of your reasoning which includes clarity and conciseness.
- Please **box all of your final answers** to computational problems.
- Use the space provided to give detailed, readable answers. **Don't try to cram your answers on the page containing the problem statement!**
- You may use the back of any exam paper as room for extra work.

Name ______

ID # ______

Discussion S

Problem 1. (28 points)

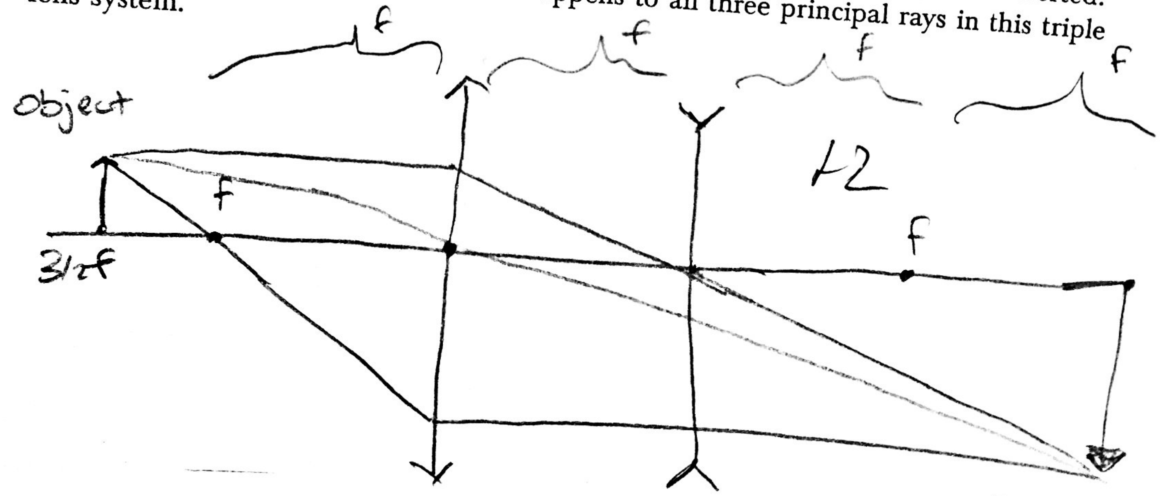
A converging lens with focal length f is placed a distance f to the left of a diverging lens whose focal length has the same magnitude. An object is place a distance $(3/2)f$ to the left of the converging lens.

a. **(8 points)** If the diverging lens weren't there, where would the image of the object form? Would it be upright or inverted? Would it be real or virtual? What would be its lateral magnification? Draw a ray diagram for this system.

b. **(10 points)** Now consider the full scenario including the diverging lens. Determine the location of the final image for this double lens system, and draw a ray diagram showing what happens to all three principal rays emanating from the tip of the object. Make sure to clearly indicate where the rays or their extensions converge to form the final image. That is the total lateral magnification for this system? Is the final image real or virtual? Is it upright or inverted?

c. **(10 points)** Since we like lenses so much, suppose that we now insert a third converging lens with focal length f at a distance f to the right of the diverging lens. Where will the final image form now? Will it be real or virtual? Will it be upright or inverted? Draw a ray diagram that shows what happens to all three principal rays in this triple lens system.

a)



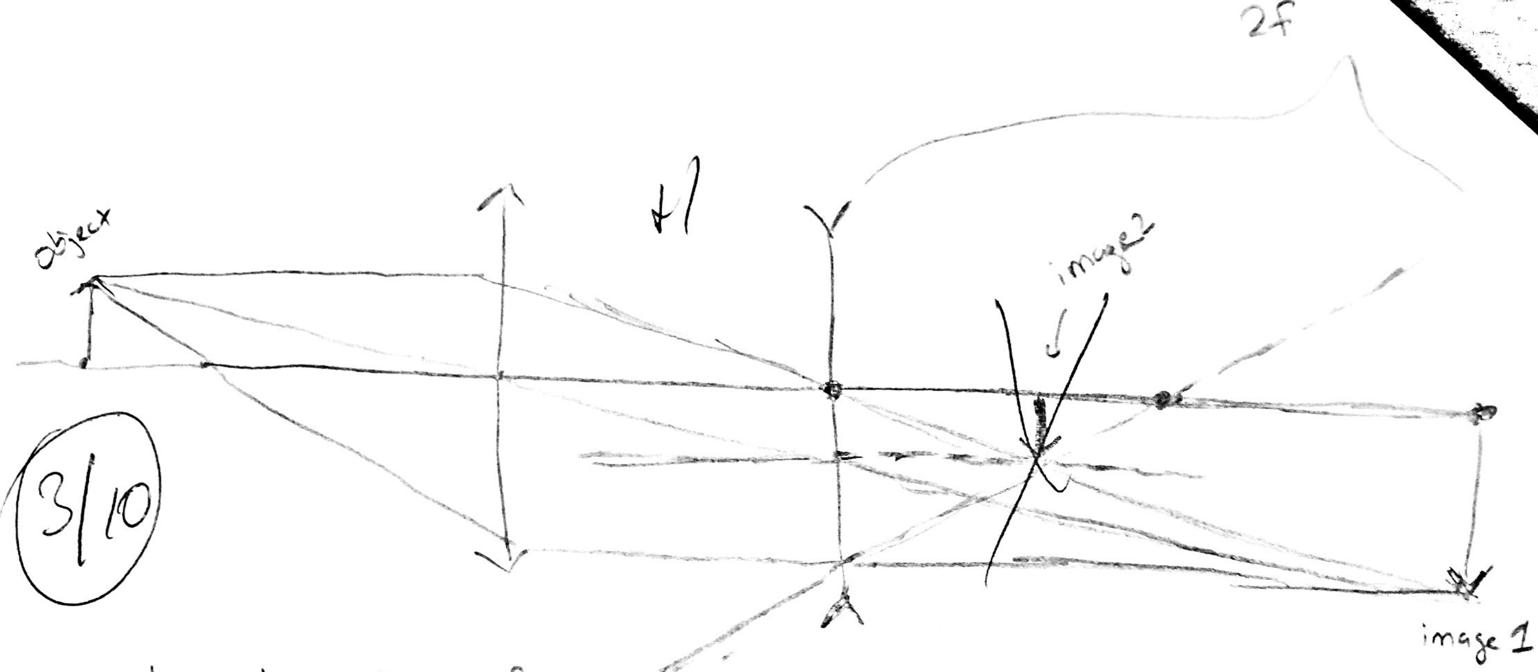
8/8

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \Rightarrow \frac{1}{\frac{3f}{2}} + \frac{1}{s'} = \frac{1}{f} \qquad s' = \frac{s \cdot f}{s - f} = \frac{\frac{3}{2}f \cdot f}{\frac{3}{2}f - f}$$

$$s' = \frac{3/2\, f^2}{1/2\, f} = \frac{3f}{2} \Big/ \frac{1}{2} = 3f \qquad m = \frac{-s'}{s} = \frac{-3f}{3/2\, f} = \frac{-3}{3/2} = -2$$

Real, inverted, -2x magnification

+2 +2 +2



$\frac{1}{s_2} + \frac{1}{s_2'} = \frac{1}{f}$ → f is negative since diverging lens
s_2 is ~~negative since~~ virtual object with respect to lens

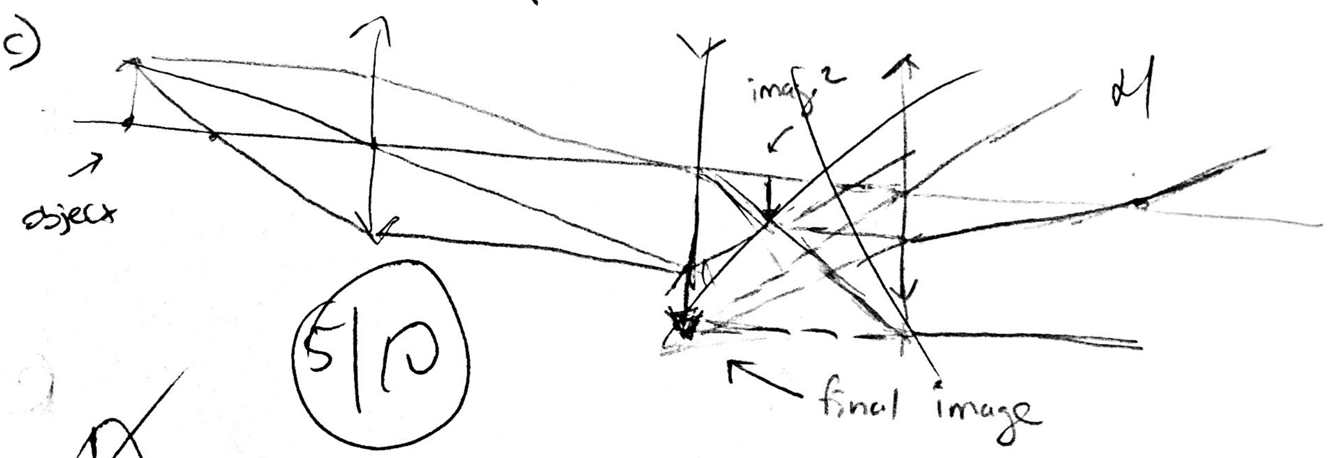
$\frac{1}{-2f} + \frac{1}{s_2'} = \frac{1}{-f}$ → $\frac{1}{s_2'} = \frac{1}{-f} + \frac{1}{2f}$ Yes $s_2' = \frac{2f \cdot -f}{}$ +1

+1 Algebra! $s_2' = -\frac{1}{2}f =$ $\frac{1}{2}f$ to right of the 2nd lens

$s_2' = -2f$

Final image is ~~real~~ and ~~inverted~~ and magnification is $-\frac{1}{2}$

c)



$\frac{1}{\frac{1}{2}f} + \frac{1}{s_3'} = \frac{1}{f}$ → $s_3' = \left(\frac{1}{f} - \frac{1}{\frac{1}{2}f}\right)^{-1} = \frac{f \cdot \frac{1}{2}f}{\frac{1}{2}f - f} = \frac{\frac{1}{2}f^2}{-\frac{1}{2}f} = -f$

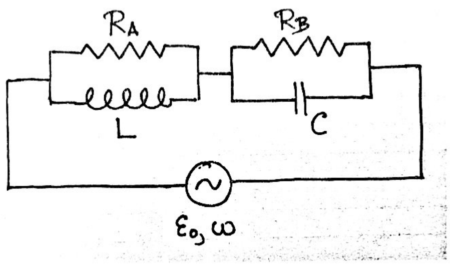
~~$\frac{+f}{\frac{1}{2}f} = 2f$~~ +1

+3

The final image is inverted, has |2x| magnification, and is ~~virtual~~, Located at the diverging lens.

Problem 2. (34 points)

Consider the AC circuit depicted below. Make sure all boxed, mathematical answers are written only in terms of the quantities labeled on the diagram.



a. **(6 points)** What is the phase difference between the voltage in the inductor and the voltage in resistor *A*? What is the phase difference between the current in the inductor and the current in resistor *A*? Draw a phasor diagram containing the voltage and current phasors for these circuit elements.

b. **(6 points)** What is the phase difference between the voltage in the capacitor and the voltage in resistor *B*? What is the phase difference between the current in the capacitor and the current in resistor *B*? Draw a phasor diagram containing the voltage and current phasors for these circuit elements.

c. **(6 points)** Let I_A, I_L, I_B, I_C be amplitudes of the current in resistor *A*, the inductor, resistor *B*, and the capacitor respectively. Using physical intuition (no math) about how inductors and capacitors behave at low and high frequencies, what would you expect for the ratios I_L/I_A and I_C/I_B is the low and high frequency limits respectively?

d. **(4 points)** Compute the ratios I_L/I_A and I_C/I_B. Do your mathematical results agree with your physical intuition?

e. **(2 points)** Let i_A, i_L, i_B, i_C denote the time-dependent currents in resistor *A*, the inductor, resistor *B*, and the capacitor respectively. What is the relationship between these currents according to the junction rule?

f. **(8 points)** What is the ratio I_A/I_B?

g. **(2 points)** What is the ratio V_A/V_B?

a) ELI the ICE man → Voltage leads current in the inductor → since in parallel,

V inductor is in phase with V Resistor, but I conductor lags I resistor so phase difference = $\Phi = \tan^{-1} \frac{\omega L}{R}$

Phasor diagram:

V_R = resistor voltage in RA

I_R = resistor current in RA

V_L = inductor voltage

I_L = inductor current

+6

b) For Rb, the voltage is still same for both Rb and capacitor since in parallel, so in phase, but the ICE, current leads the voltage:

$\therefore \phi V_{RB} = \phi V_c$, but ϕI_c leads I_{RB} by $\tan^{-1}\left(\frac{\frac{1}{\omega C}}{R}\right)$

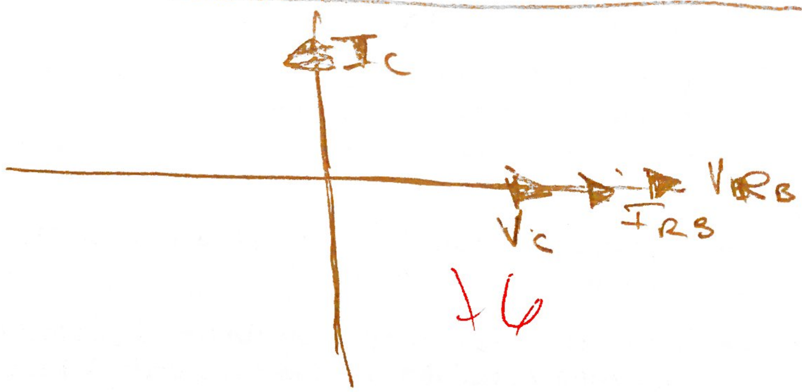
Phase diagram

V_{RB} = Rb voltage

I_{RB} = Rb current

I_c = capacitor current

V_c = capacitor voltage



+6

c) Using just physical intuition, $\frac{I_L}{I_A}$ would be +4

the low frequency limit since an inductor, $X_L = \omega L$, would allow high frequencies to pass, thus it creates the lower band for the frequencies, which would correspond to the current ratio being lower band. Conversely, $X_c = \frac{1}{\omega C}$, allows low frequencies to pass, which means it creates

The upper bound on the frequencies that can pass. Thus the current ratio for I_C/I_B would give the upper boundary for frequency.

d) $\frac{I_L}{I_A}$ => $V = iX$ is V_X -> V is same for both, so

$\frac{X_L}{X_C}$ => $\frac{\omega L}{R} = \frac{I_L}{I_A}$ => as expected, lets high frequencies pass, thus creating lower bound

$\frac{I_C}{I_B}$ -> V same again, so $\frac{V X_C}{V X_R} = \frac{X_C}{X_R} = \frac{\frac{1}{\omega C}}{R} = \frac{1}{\omega C R}$

$\frac{1}{\omega C R}$ lets low frequencies through which creates the upper bound for frequencies passed.

+3

e) The relationship between those currents is that $i_a + i_L = i_B + i_C$ since current going in a junction must equal current coming out of the junction.

+2

f) Ratio of I_A/I_B is -> ~~$I = V/X$~~ ~~RATIO~~ $V = \mathcal{E}_0 \cos(\omega t)$ through circuit

Total impedance is $\sqrt{R_A^2 + (\frac{1}{\omega C})^2) + (R_B^2 + (\omega C)^2}$

+1

g) The ratio V_A/V_B = ~~R_B~~ $\frac{R_A}{R_B}$

why?