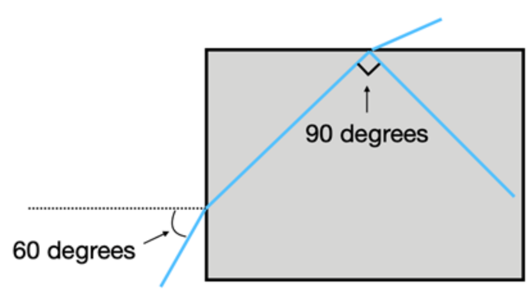
I. [45 points total] Lecture Multiple Choice Questions

1. [5 points] A mask consisting of two small holes separated vertically is placed between a light source and a screen. The light source is composed of two-point sources separated vertically (blue above red). What could be projected on the screen? **Select all that apply.**
   A. 4 bright spots separated vertically; blue, blue, red, red from top to bottom
   B. 4 bright spots separated vertically; red, red, blue, blue from top to bottom
   C. 4 bright spots separated vertically; blue, red, blue, red from top to bottom
   D. 4 bright spots separated vertically; red, blue, red, blue from top to bottom
   E. 2 bright spots separated vertically, red then blue from top to bottom

2. [5 points] A laser beam hits a corner reflector (composed of 3 mirrors at right angles, as demonstrated in class) and goes back in the direction from which it came. What are all the possibilities for how many individual reflections the laser beam undergoes?
   A. exactly 3 reflections
   B. 2 or 3 reflections
   C. 1, 2, or 3 reflections
   D. exactly 1 reflection
   E. exactly 2 reflections

3. [5 points] A ray enters a slab of material at an angle of 60 degrees to the normal. After the subsequent internal reflection, the ray turns 90 degrees. What is the index of refraction of the material?
   A. 0.92
   B. 1.02
   C. 1.12
   D. 1.22
   E. 1.32



4. [5 points] In class we showed a spherical concave mirror with radius of curvature R, and an object that was placed a distance R in front of the mirror. The resulting image was the same size as the object but inverted. What would happen to the image if the mirror were replaced by a convex spherical mirror with the same radius of curvature?
   A. upright image, image distance $i = -3R$
   B. upright image, image distance $i = -R/3$
   C. inverted image, image distance $i = -3R$
   D. inverted image, image distance $i = -R/3$
   E. none of the above

5. [5 points] Monochromatic light of wavelength 600 nm is incident on a mask with two slits separated by 18000 nm. The resulting interference pattern is observed on a screen 5 m from the mask. How far off center is the second (n = 2) dark fringe?
   A. 2.5 cm
   B. 1 cm
   C. 4 cm
   D. 25 cm
   E. 50 cm

6. [5 points] A crystalline material has a spacing of 4 nm between atomic layers. What's the largest value of wavelength for which monochromatic light with that wavelength has a Bragg peak at a Bragg angle of 45 degrees?
   A. 1.66 nm
   B. 2.66 nm
   C. 3.66 nm
   D. 4.66 nm
   E. 5.66 nm

7. [5 points] A spy camera has an aperture of diameter 7.32 mm. Assuming a light of wavelength 600 nm, what's the maximum distance at which the camera can resolve two objects 1 meter apart from each other?
   A. 100 m
   B. 1 km
   C. 10 km
   D. 100 km
   E. 1000 km

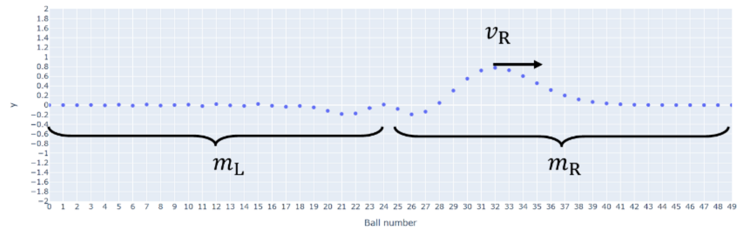
8. [5 points] A matter wave composed of one million electrons goes through a double slit, with the separation between the slits being 100 nm. The total momentum in the matter wave is 3.32×10^{-19} kg m/s. What is the angle θ of the first bright fringe in the corresponding diffraction pattern?
   A. 0.02 rad
   B. 0.2 rad
   C. 2 rad
   D. 1 rad
   E. 0.1 rad

9. [5 points] With the usual photoelectric effect setup, ultraviolet light of wavelength 200 nm shining on the target leads to a stopping voltage of 1.40 V. Suppose the light wavelength is reduced to 150 nm. What is the new stopping voltage? The electron charge is 1.60×10^{-19} C.
   A. 3.47 V
   B. 2.47 V
   C. 1.40 V
   D. 1.47 V
   E. 0.47 V

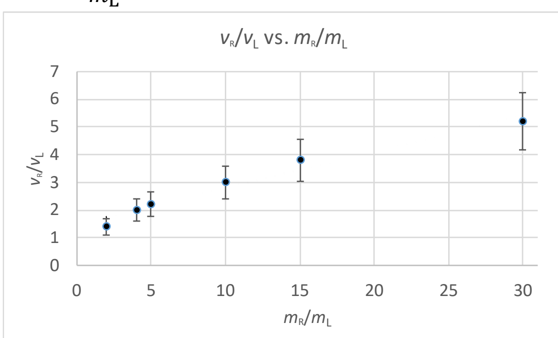
II. [15 points total] Lab Multiple-Choice Questions

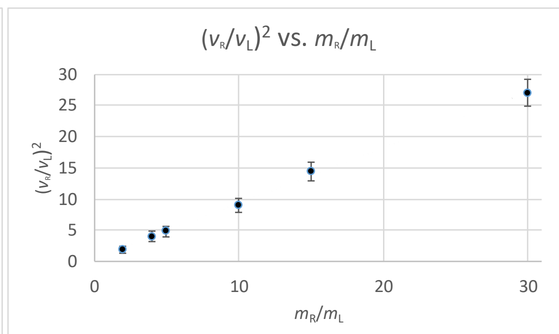
Use the following scenario for the next two questions.

In Lab A3, a lab team chose to alter the mass of the balls in the right half, m_{R}, in the simulation, keeping the mass of the left half, m_{L}, constant. They measured the ratio of the speed of the pulse on the right side to that on the left side of the boundary, $\frac{v_{\mathrm{R}}}{v_{\mathrm{L}}}$.



10. [5 points] The left graph below shows, $\frac{v_{\mathrm{R}}}{v_{\mathrm{L}}}$ vs. $\frac{m_{\mathrm{R}}}{m_{\mathrm{L}}}$. The right graph below shows $\left(\frac{v_{\mathrm{R}}}{v_{\mathrm{L}}}\right)^2$ vs. $\frac{m_{\mathrm{R}}}{m_{\mathrm{L}}}$. Each graph includes a linear best-fit line.





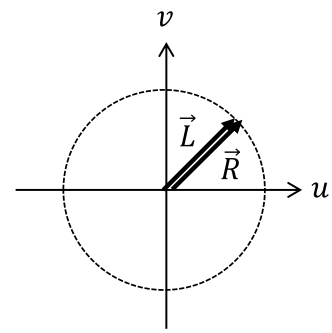
Which of the following statements are consistent with the measurements? In the equations below, A and B are different constants. Select all that apply.

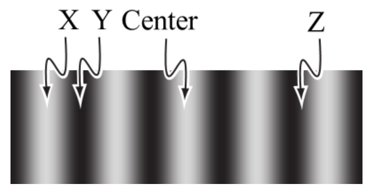
A. The best-fit line in the left graph is a good fit.
B. The best-fit line in the right graph is a good fit.
C. $\frac{v_{\mathrm{R}}}{v_{\mathrm{L}}} = A\frac{m_{\mathrm{R}}}{m_{\mathrm{L}}} + B$
D. $\left(\frac{v_{\mathrm{R}}}{v_{\mathrm{L}}}\right)^2 = A\frac{m_{\mathrm{R}}}{m_{\mathrm{L}}} + B$
E. None of the above models is consistent with the measurements.

11. [5 points] Instead of choosing $\frac{v_{\mathrm{R}}}{v_{\mathrm{L}}}$, which of the following could the lab team have chosen as their dependent variable to explore the simulation if their modification to the simulation code is still the same (altering m_{R})? Select all that apply.

A. The ratio of the width of the pulse on the left side to that on the right side.
B. The ratio of the height of the pulse on the left side to that on the right side.
C. The height of the pulse on the left side.
D. Duration of the pulse creation
E. The spring constant of the springs.

12. [5 points] Monochromatic light is normally incident on a mask containing two very narrow identical slits. The interference pattern is viewed on a distant screen. The diagram at right illustrates two phasors that represent the light from the left slit, $\vec{L}$, and the right slit, $\vec{R}$, arriving at a point on the screen. Which of the following points could these phasors represent? Choose all that apply.

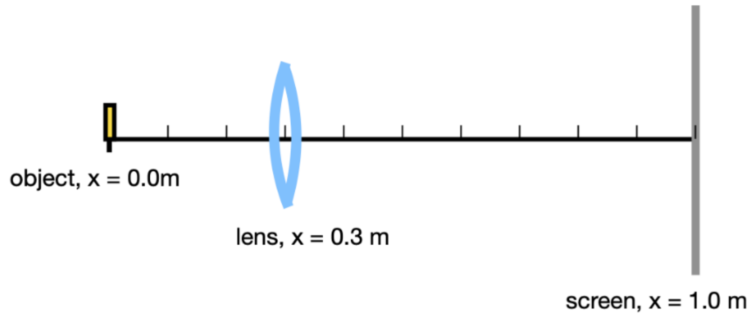




A. Center of the central bright fringe
B. X: center of a bright fringe (other than the central bright fringe)
C. Y: center of a dark fringe
D. Z: somewhere between the centers of a bright and dark fringes
E. None of the above

III. [25 points total] Lecture Free Response Questions
You must show your work to get the full credit.

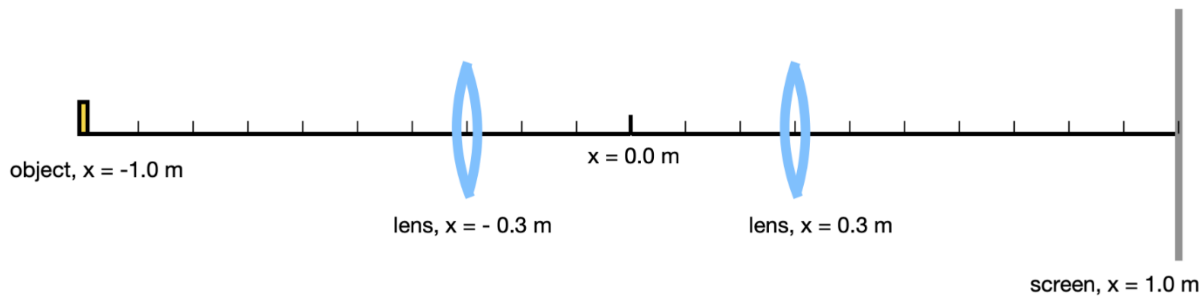
Consider the following scenario for the next 3 questions.



In class we had a demonstration where a converging lens was placed between an illuminated object and a screen. The object was at x = 0.0 m, the lens was at x = 0.3 m, and the screen was at x = 1.0 m, as shown. Assume the object is 2.1 cm tall, and that the image on the screen is sharp and in focus.

13. [3 points] Compute the focal length of the lens, and the height of the image.

14. [5 points] The lens is then moved towards the screen (the object and screen are held fixed). We noticed that the image became blurry, but then became sharply focused again when the distance between the object and lens reached a new value. What is this new value? Is the new image upright or inverted? How tall is the new image?



15. [7 points] Now consider a new setup in which the object is moved to x = -1.0 m, and another identical converging lens is placed at x = -0.3 m (the original lens is still at x = 0.3 m, and the screen is still at x = 1.0 m). What is the height of the image projected on the screen? Is it inverted or upright?

Use the following scenario for the next 2 questions.

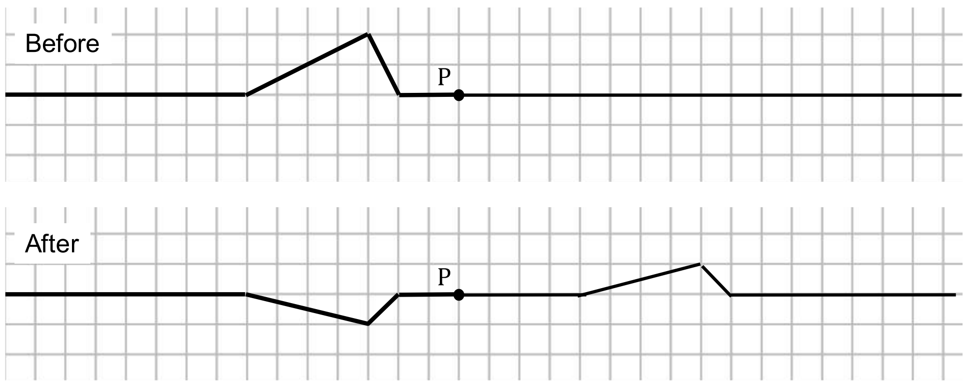
A thin film of oil (index of refraction n = 1.5), of thickness d = 600 nm, sits on top of water (index of refraction n = 1.33). Light of frequency 6.0×10^{14} Hz is normally incident from above. For the speed of light in air use $c = 3.0 \times 10^{8}$ m/s.

16. [7 points] What is the minimum amount by which the thickness d = 600 nm has to be increased to obtain complete destructive interference in the reflected light?

17. [3 points] With the same setup as above, suppose now that we decrease the thickness of the oil, starting from 600 nm. How many different values for the thickness are there, less than 600 nm, which give rise to complete constructive interference in the reflected light?

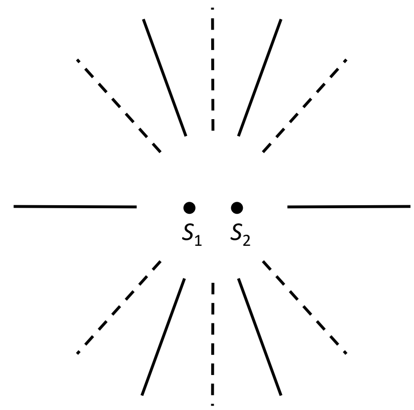
IV. [15 points total] Tutorial Free Response Questions

18. [6 points] Two horizontal springs are connected together at point P. The pulse speed in the right spring is **twice** that in the left spring. A pulse is sent from the left end of the spring towards point P. The upper figure below shows the pulse before it reaches point P. The lower figure below shows the transmitted and reflected pulse after the incident pulse reaches point P. However, this figure has several flaws. Identify them and describe how you can correct them.



Use the following scenario for the next two questions.

Two point-sources (S_1 and S_2) separated by a distance d generate periodic waves of wavelength λ_o by tapping the surface of the water. The diagram at right shows the interference pattern created far away from the sources: antinodal lines are represented by solid lines, and nodal lines are represented by dashed lines.



19. [3 points] Are the two sources in phase or out of phase? Explain your reasoning.

20. [2 points] What is the separation of the two sources in terms of λ_o? Explain your reasoning.

21. [4 points] Consider the interference pattern seen on a screen from a double-slit experiment. The graph with dotted line below shows the intensity versus θ. Suppose now that the distance between the centers of the slits is decreased (without changing the width of the slits). How would this graph be different from the original graph? Draw a qualitatively correct new graph below. Ignore possible changes in the maximum intensity.