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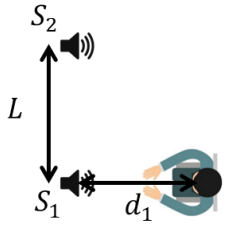
I. Lecture multiple choice (60 points – 12 questions)

1) (5 pts) A pair of in-phase stereo speakers, S_1 and S_2, are separated by a distance $L = 4.00$ m. As shown, you are sitting a distance $d_1 = 3.00$ m directly in front of S_1. If the speakers play a constant note with frequency of 3430 Hz, do the sound waves from the speakers maximally constructively interfere, perfectly destructively interfere, or neither? Assume the speed of sound is 343m/s.



A. Maximally constructively interfere
B. Perfectly destructively interfere
C. Neither
D. Not enough information is given to determine.

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2) (5 pts) A monochromatic light wave travels from water into oil. The wavelength of the light in water is 300 nm, and its wavelength in oil is 280 nm. The index of refraction of water is 1.33. What is the index of refraction of the oil?

A. 0.933
B. 1.07
C. 1.24
D. 1.43
E. 1.93

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3) (5 pts) Monochromatic light of wavelength λ illuminates a mask containing two narrow slits separated by a small distance d. The resulting interference pattern that is observed on a far screen located a distance L from the mask is shown in Figure A. Which of the following changes to the original experiment could produce the interference pattern shown in Figure B? You may assume the small-angle approximation applies.

Figure A

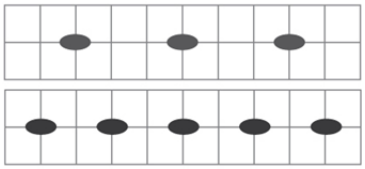

Figure B

A. Half the slit separation to $\frac{d}{2}$ and triple the wavelength to 3λ
B. Double the screen distance to $2L$ and triple the wavelength to 3λ
C. Double the screen distance to $2L$ and triple the slit separation to $3d$
D. Half the slit separation to $\frac{d}{2}$ and double the screen distance $2L$
E. Half the screen distance to $\frac{d}{2}$ and triple the wavelength to 3λ

4) (5 pts) Monochromatic light illuminates a diffraction grating which has 900 lines per mm, producing an interference pattern on a distant screen. The grating is then replaced with another one that has 1800 lines per mm while all the other aspects of the set up remain unchanged. How would the positions of the bright and dark fringes on the screen change?

A. They would be farther apart from each other.
B. They would be closer together.
C. They would remain the same.
D. The locations of the bright fringes would swap with the locations of the dark fringes.
E. The answer depends on the wavelength.

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5) (5 pts) An antireflective coating is applied to eyeglass lenses to minimize the reflection of stray light. The coating effectively reduces the reflection of light with a wavelength of 600 nm in air. The index of refraction of the coating is 1.50, and that of the lenses is 1.40. What is the minimum thickness of the coating?

A. 100 nm
B. 107 nm
C. 200 nm
D. 214 nm
E. 400 nm

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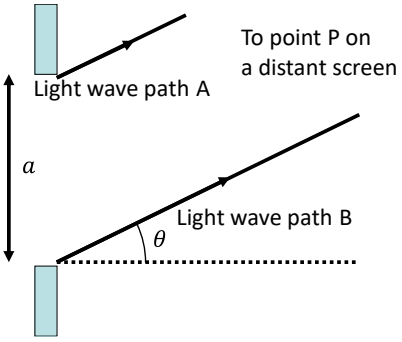
6) (5 pts) Monochromatic light of wavelength λ illuminates a mask with narrow slit of width a and produces a diffraction pattern on a distant screen. Consider the two light wave paths, A and B, that originate from the edges of the slit and arrive at the same point on the screen, point P. If the path length difference of Path A and Path B is λ, is point P a bright fringe, dark fringe, or somewhere in between?



A. Bright fringe
B. Dark fringe
C. Somewhere in between
D. The answer depends on whether $\frac{a}{\lambda}$ is an integer or a half-integer.
E. The depends on whether $\frac{\lambda}{a}$ is an integer or a half-integer.

7) (5 pts) Two light bulbs are 2.0 m apart. From what distance can these lightbulbs be marginally resolved by a small telescope with a 4.0-cm-diameter objective lens? Assume that the lens is limited only by diffraction, and the wavelength of the light from the light bulbs is 600 nm.

A. 55 km
B. 67 km
C. 110 km
D. 130 km
E. 2700 km

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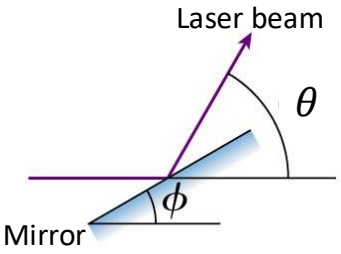
8) (5 pts) A plane mirror is tilted from horizontal by an angle ϕ. A horizontal laser beam is deflected by the mirror by $\theta = 50°$. What is the angle ϕ?



A. $17°$
B. $20°$
C. $25°$
D. $30°$
E. $65°$

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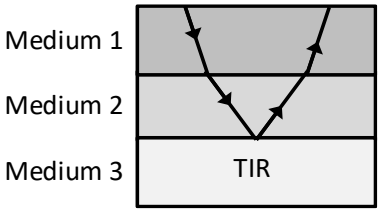
9) (5 pts) A laser beam refracts at the interface between media 1 and 2, and total internal reflection at the interface between media 2 and 3 as shown. Rank the speeds of light in media 1, 2, and 3 (v_1, v_2, and v_3, respectively).



A. $v_1 < v_2 < v_3$
B. $v_3 < v_1 < v_2$
C. $v_1 < v_3 < v_2$
D. $v_2 < v_3 < v_1$
E. $v_3 < v_2 < v_1$

Use the following scenario for the next two questions.

An object is placed 3.0 m in front of a spherical mirror, and the image of the object is formed 1.2 m **behind** the mirror.

10) (5 pts) What is the focal length of the mirror?

A. -2.0 m
B. -0.83 m
C. -0.50 m
D. +1.2 m
E. +1.8 m

11) (5 pts) Which of the following statements about the image is/are correct? **Select all that apply.**

A. It is real.
B. It is enlarged.
C. It is inverted.
D. None of the above choices are correct.

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12) (5 pts) Two microscopes, A and B, have identical eyepieces and tube length, but the focal length of the objective lens of microscope A is twice as long as that of microscope B. Which microscope has a greater absolute value of angular magnification?

A. Microscope A
B. Microscope B
C. Both microscopes have the same angular magnification.
D. Not enough information is given to determine.

Continue on the next page.

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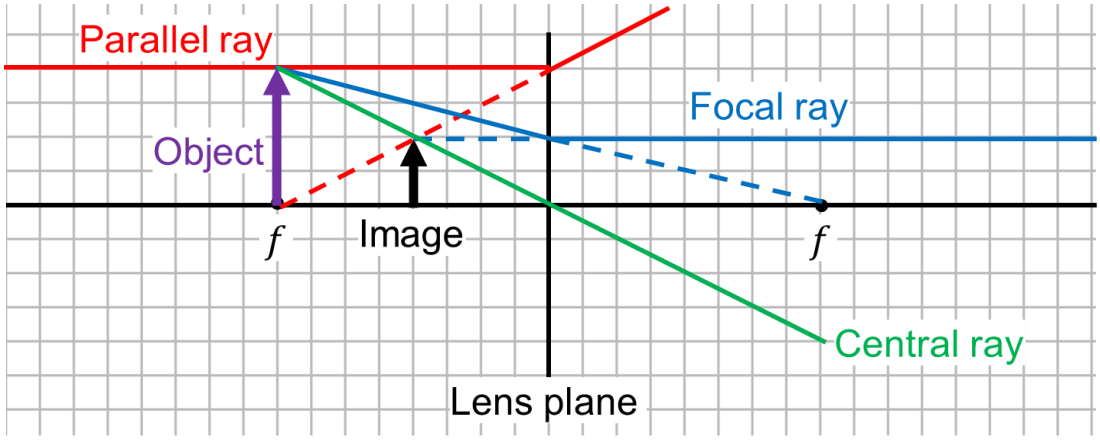
II. Lecture free response (20 points)

Use the following scenario for the next two questions.

An object (not shown) is placed on the left side of a diverging lens, and the image of the object is formed as shown below.



13) (8 pts) On the diagram above, draw the <u>three</u> "special" rays to determine the location of the object. <u>Clearly indicate the object as an arrow that indicates its orientation, size, and location</u>.
[2 points each] correct parallel ray, focal ray, and central ray
[1 point] The location of the object arrow is at the intersections of the special rays
[0.5 points] The object arrow has the correct orientation
[0.5 points] The object arrow has the correct size

14) (4 pts) Is this image a real image or a virtual image? Explain.
The image is virtual. The image is formed on the incident light side, so the light rays do not actually go to where the image is.
[2 points] correct answer (virtual)
[2 points] correct explanation

<u>Continue on the next page.</u>

Use the following scenario for the next two questions.

Suppose that when your eye is relaxed while trying to view distant objects, the focal length of your eye's lens f_{eye} is **shorter** than the distance between the eye lens and the retina, d.

15) (3 pts) To correct your distance vision so that far-away objects appear in focus on the retina, should the corrective lens you use be converging or diverging? Explain your reasoning.

A diverging lens is needed. When an object is very far away, the rays from it would be parallel, and its image is formed at the lens' focal length from the lens. Since the focal length of the eye lens is shorter than the distance between the lens and the retina, the image is formed too close to the lens. With a diverging lens, the rays from the far away object are now diverging when entering the eye lens, so they converge farther from the lens.

[1 point] diverging lens

[2 points] any correct explanation

16) (5 pts) What is the expression for your far point in terms of f_{eye} and d?

Thin lens equation: $\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$

Far point is the farthest object distance that your eye can focus, i.e., the image is formed on the retina.

$\frac{1}{\text{FP}}+\frac{1}{d}=\frac{1}{f_{\text{eye}}}$

Therefore, $\text{FP}=\left(\frac{1}{f_{\text{eye}}}-\frac{1}{d}\right)^{-1}$

[5 points] for correct answer

OR

[1 point] using thin lens equation

[1 point] Getting the idea that $f=f_{\text{eye}}$

[1 point] Getting the idea that $s=\text{FP}$

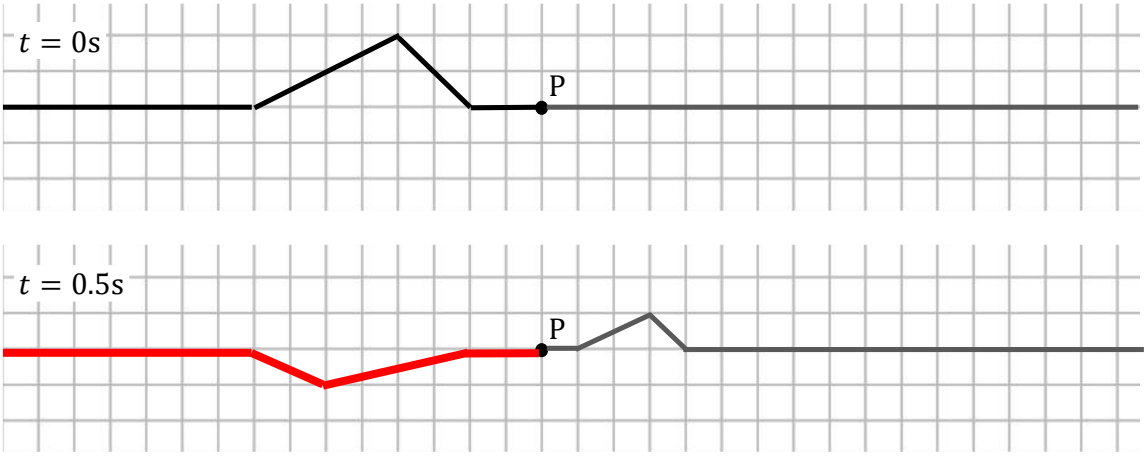
[1 point] Getting the idea that $s'=d$

[1 point] Solving for FP

Continue on the next page.

III. Tutorial free response (20 points)

17) (7 pts) Two horizontal springs with different linear mass densities are connected at point P. A pulse is sent from the left end of the left spring toward point P. The top figure below shows the incident pulse before it reaches point P at $t = 0$s. The bottom figure below shows the transmitted pulse at $t = 0.5$s. Draw the corresponding reflected pulse at $t = 0.5$s in the bottom figure. You do not need to worry about the heights of the pulses.



[1.5 points] The reflected pulse has the correct left-right orientation.
[1.5 points] The reflected pulse has the correct up-down orientation.
[2 points] The reflected pulse has the correct location (either the left end, the peak, or the right end)
[1 point] The reflected pulse has the correct total width.
[1 point] The relative widths of the parts of the pulse that have negative and positive slopes are correct.

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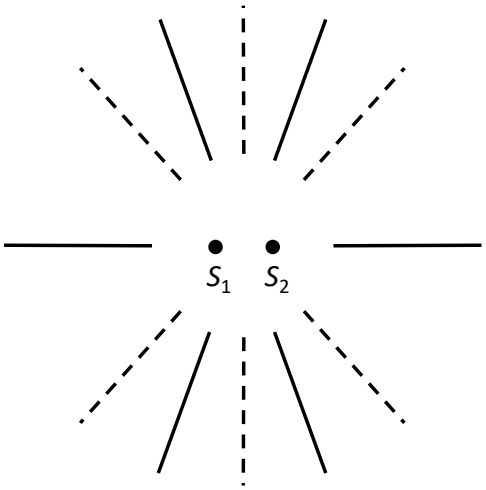
Use the following scenario for the next two questions.

Two point-sources (S_1 and S_2) generate periodic waves of wavelength λ_o in a body of 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.

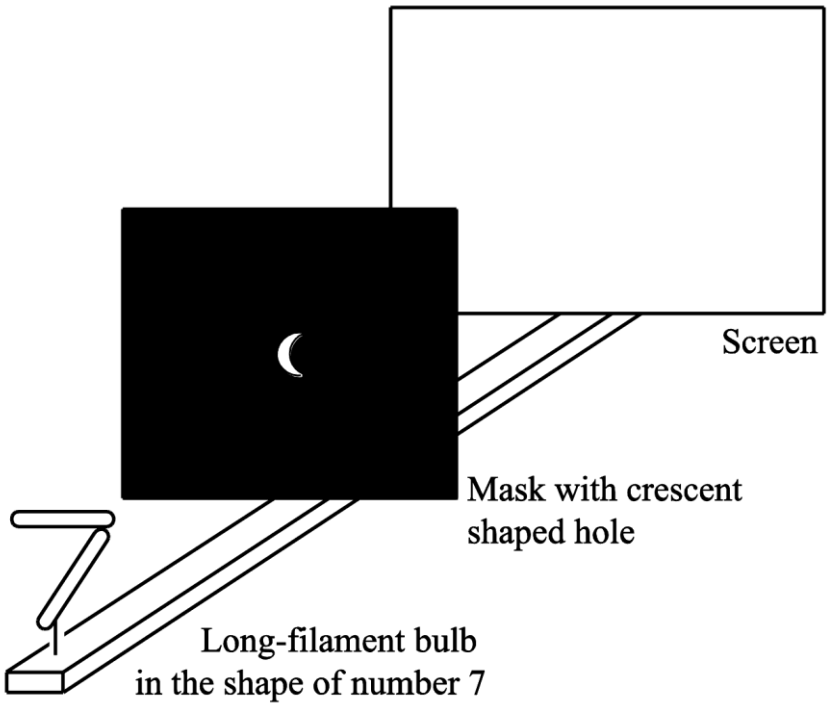


18) (3 pts) Label each nodal and antinodal line in the figure with path length difference, Δr, from the sources, expressed in terms of λ.
[1 point] Both vertical lines are $\Delta r = 0$
[1 point] Each line away from the vertical lines have Δr increasing by $\lambda/2$.
[1 point] the horizontal lines are $\Delta r = 3\lambda/2$

19) (3 pts) Are the sources S_1 and S_2 in phase or out of phase? Explain.
[1 point] Correct answer (out of phase)
[2 points] Correct explanation: The vertical lines that correspond to $\Delta r = 0$ are nodal lines. If the waves travel the same distance yet destructively interfere, the waves must be produced out of phase.

Continue on the next page.

20) (7 pts) A mask with a small crescent-shaped hole is placed between a bulb in the shape of the number 7 and a screen, as shown below. (Assume that the room is dark before the bulb is turned on and ignore any interference or diffraction effects.) Sketch what you will see on the screen in the figure below or describe the image when the bulb is lit.



[1.5 points] The image is a collection of crescents.
[1.5 points] The image has a general shape of "7"
[2 points] The "7" has the correct left right orientation
[2 points] The '7" has the correct up-down orientation