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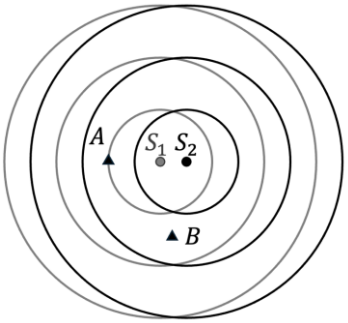
I. Lecture multiple choice (60 points – 12 questions)

1) (5 pts) Surface waves are generated from two coherent sources, S_1 and S_2, separated by a small distance. The figure shows the wave crests from S_1(gray) and S_2(black) at a particular instant. Point A is located at a position of perfect destructive interference, and Point B is located at a position of maximum constructive interference.
Now, the frequency of both sources is doubled. Which of the following statements are correct? **Select all that apply.**



A. Point A remains a position of perfect destructive interference.
B. Point A becomes a position of maximum constructive interference.
C. Point B becomes a position of perfect destructive interference.
D. Point B remains a position of maximum constructive interference.
E. None of the above is correct.

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2) (5 pts) A light wave traveling in air, with frequency f_{air} and wavelength λ_{air}, enters a transparent gem. If the index of refraction of the gem is 2.0, which of these relationships for wavelength, λ_{gem}, and frequency, f_{gem}, in gem are correct? **Select all that apply.**

A. $f_{\text{gem}} = 2f_{\text{air}}$
B. $f_{\text{gem}} = 0.5f_{\text{air}}$
C. $\lambda_{\text{gem}} = 2\lambda_{\text{air}}$
D. $\lambda_{\text{gem}} = 0.5\lambda_{\text{air}}$
E. None of the above is correct.

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3) (5 pts) Light with a wavelength of λ = 400 nm passes through a barrier containing two very narrow slits separated by a distance $d = 6.0 \times 10^{-6}$ m. A interference pattern is observed on a screen located 1.0 m away from the slits. Which of following best describes the nature of light observed at a point on the screen located 0.025 m from the center of the pattern?

A. It is a minimum (completely dark).
B. It is a maximum.
C. It is neither a minimum nor a maximum.
D. Not enough information is given.

4) (5 pts) A commercial diffraction grating has 800 lines per mm. When a student shines a 410 nm laser through this grating, how many bright spots could be seen on a screen behind the grating?

A. 3
B. 4
C. 5
D. 6
E. 7

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5) (5 pts) An antireflective coating is applied to eyeglass lenses to minimize the reflection of stray light. The coating has a minimum thickness of 90 nm and is most effective at reducing reflection for light with a wavelength of 480 nm in air. Assuming the index of refraction of the coating is less than that of the lens material, what is the index of refraction of the coating?

A. 1.3
B. 2.7
C. 4.0
D. 5.3
E. 8.0

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6) (5 pts) Green light with wavelength 532 nm passes through a single narrow slit and produces a diffraction pattern on a distant screen. Which of the following individual changes makes the central maximum on the screen *narrower*? **Select all that apply.**

A. Move the screen closer.
B. Use blue light with wavelength 473 nm instead.
C. Make the slit narrower.
D. None of the above.

7) (5 pts) A monochromatic light illuminates a hole with diameter 4.8×10^{-4} m. If the width of the central maximum on a screen located 5.0 m away is 1.6×10^{-2} m, what is the wavelength of the light?

A. 190 nm
B. 380 nm
C. 630 nm
D. 1300 nm
E. 1500 nm

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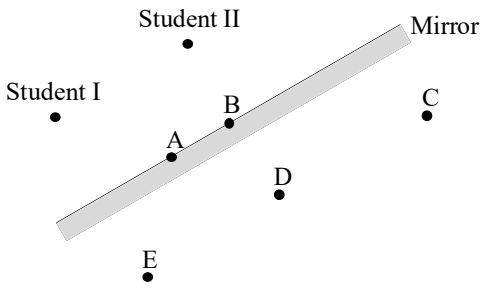
8) (5 pts) An object (not shown) is placed in front of a plane mirror, and Student I observes the image of the object to be located at position E indicated in the figure at right. Where does another student, Student II, observe the image to be located?



A. Location A
B. Location B
C. Location C
D. Location D
E. Location E

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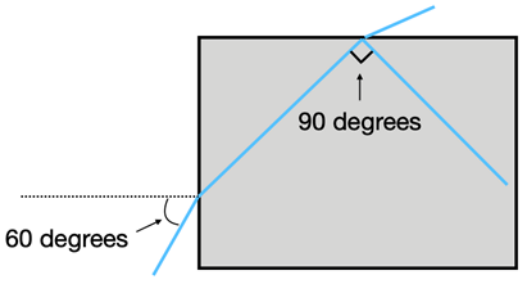
9) (5 pts) A light ray enters a slab of transparent material at an angle of 60 degrees to the normal. At the subsequent internal reflection, the ray bends by 90 degrees as shown. What is the index of refraction of the material?



A. 0.0
B. 0.50
C. 0.82
D. 1.2
E. 1.6

10) (5 pts) A thin glass rod is submerged in water. What is the critical angle for light traveling inside the rod? The index of refraction of water is 1.33, and the index of refraction of the glass rod is 1.50.

A. 27.5°
B. 41.8°
C. 45.0°
D. 48.8°
E. 62.5°

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11) (5 pts) Consider a **converging** mirror with a focal length of 1.0 m. If an object is placed 0.5 m in front of the mirror, which of the following statements about the image formed are correct? **Select all that apply.**

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

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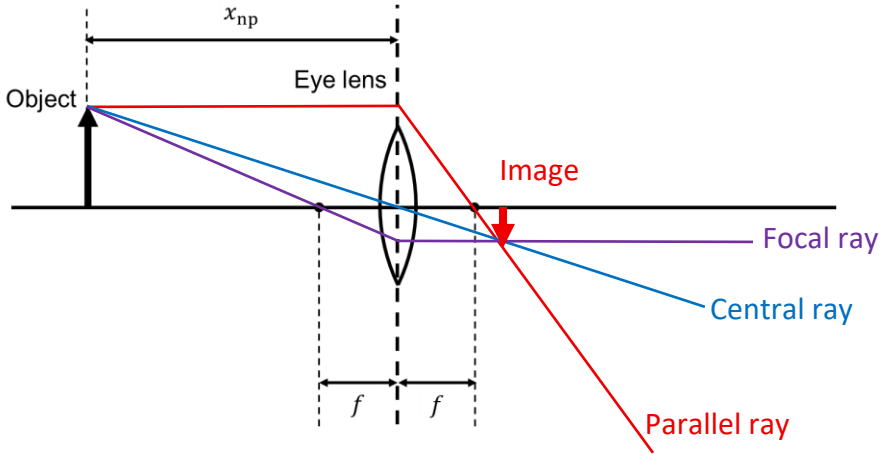
12) (5 pts) Two telescopes have identical objectives, but the focal length of the eyepiece of telescope A is twice as long as that of telescope B. Which telescope has a greater absolute value of angular magnification?

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

II. Lecture free response (20 points)

Use the following scenario for the next four questions.
Approximate an eye as a single thin converging lens placed in front of the retina. An object is placed at your near point, x_{np}, in front of your eye lens, and the eye adjusts the lens's focal length to f so that the image of the object is focused on the retina.



14) (7 pts) On the diagram above, draw the <u>three</u> "special" rays in ray tracing to determine the location of the imaged formed by the lens. <u>Clearly indicate where the image is formed</u>.
[2 points each] correct parallel ray, focal ray, and central ray
[1 point] Image is indicated at the intersections of the special rays

15) (5 pts) What is the distance between the eye lens and the retina in terms of x_{np} and f?
$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$, so $\frac{1}{x_{\text{np}}}+\frac{1}{s'}=\frac{1}{f}$
$s'=\left(\frac{1}{f}-\frac{1}{x_{\text{np}}}\right)^{-1}$
[2 points] using the thin-lens equation
[2 points] the object distance $s=x_{\text{np}}$
[1 point] solving for the image distance s' correctly $\left(\frac{1}{f}-\frac{1}{x_{\text{np}}}\right)^{-1}$

Suppose that your near point, x_{np}, is greater than the distance of the normal near point, $x_{\text{np,normal}}$, and you wish to use a corrective lens so that your vision for seeing nearby objects is normal. Assume that the distance between the corrective lens and the eye lens is negligible.

16) (3 pts) Should the corrective lens be converging or diverging? Explain.
A converging lens is needed. When an object is very far away, the rays from it would be parallel. As the object is brought closer, the rays become more and more diverging. When a person's NP is greater than the normal NP, the person's eye cannot converge rays from the nearby object enough to focus on the retina. So, you need to have a converging lens to bring the object closer and still focus on it.
[1 point] converging lens
[2 points] any correct explanation

17) (5 pts) What is the expression for the refractive power of the corrective lens in terms of x_{np} and $x_{\text{np,normal}}$?

The corrective lens brings the image of the object placed at a normal near point to your near point so that you can focus. Its image is virtual, so its image distance is a negative value.

$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}=P$, so

$P=\frac{1}{x_{\text{np,normal}}}+\frac{1}{-x_{\text{np}}}=\frac{1}{x_{\text{np,normal}}}-\frac{1}{x_{\text{np}}}$

[1 point] correct answer: $\frac{1}{x_{\text{np,normal}}}-\frac{1}{x_{\text{np}}}$

[1 point] Using $\frac{1}{f}=P$

[1 point] using the thin-lens equation

[1 point] The object distance is $s=x_{\text{np,normal}}$

[1 point] the image distance is $s'=-x_{\text{np}}$

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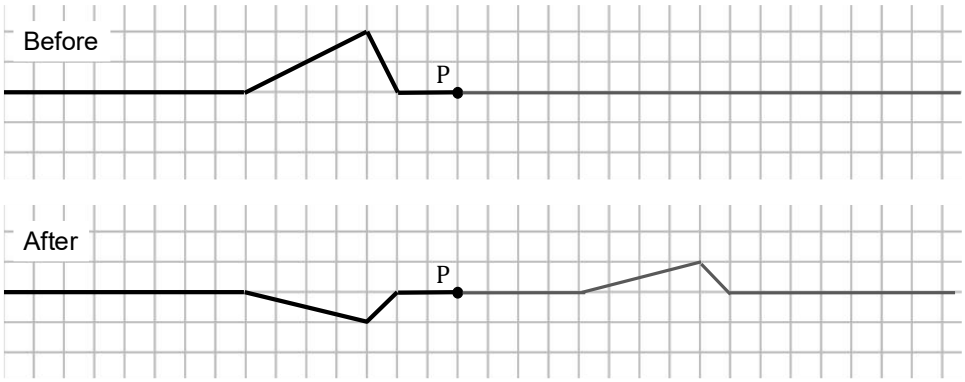
III. Tutorial free response (20 points)

18) (7 pts) Two horizontal springs are connected 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 left spring toward point P. The upper figure below shows the incident pulse before it reaches point P. The lower figure below shows the transmitted and reflected pulses after the incident pulse reaches point P. However, this figure contains several flaws. Identify the flaws and describe how you can correct them.

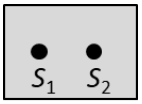


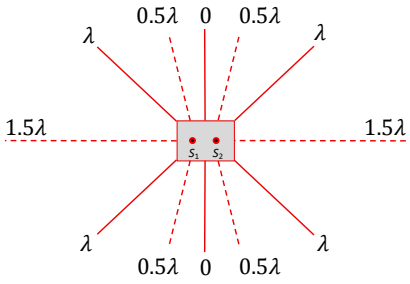
[2 points] The reflected pulse (on the left spring) should be left-right reflected.
[2 points] The reflected pulse (on the left spring) should be up-down reflected.
[2 points] The transmitted pulse (on the right spring) should be twice the width of the incident pulse
[1 point] The position of the transmitted pulse (on the right spring) needs to be corrected relative to the reflected pulse. One way to do this: the right end of the pulse is 5 squares to the right with the left end being at the same position.

Continue on the next page.

19) (6 pts) Two point sources, S_1 and S_2, are oscillating in phase in water, each producing periodic circular waves with wavelength λ. The sources are separated by a distance of 1.5λ. A top-view diagram of the sources is shown below. In the space provided below, draw qualitatively accurate nodal lines (use dashed lines) and antinodal lines (use solid lines) resulting from the interference of the waves. You do not need to draw any lines inside the gray box near the sources. Label each line with path length difference, δs, expressed in terms of λ.

[1 point] alternating nodal and antinodal lines
[1 point] correct number of lines.
[1 points] Both horizontal lines are labeled 1.5λ.
[1 points] Both horizontal lines are nodal
[1 points] both vertical lines are labeled 0.
[1 points] Both vertical lines are antinodal





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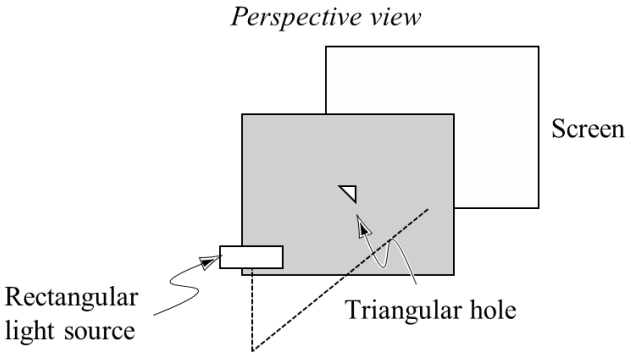
20) (7 pts) A mask with a triangular hole is placed between a rectangular light source and a screen as shown in the diagram. In the space below, draw and/or describe the features of the image pattern observed on the screen.
[2 points] The image is a collection of triangles
[2 points] The general shape is a rectangle
[2 points] The height to width ratio of the rectangle is the same as the light source.
[1 point] lower left corner is missing



Top of screen