Physics 116 B
Spring 2025

116B - MORALES

Midterm 2
May 20th, 2025

Please use the boxes below to clearly print your name and UW NetID.
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I certify that the work I shall submit is my own creation, not copied from any source.

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Clearly fill out this cover page and the top portion of the provided bubble sheet with the necessary information.

Do not open the exam until told to do so.
When prompted, clearly print the information required at the top of each page of this exam booklet.
You can remove the equation sheet(s). Otherwise, keep the exam booklet intact.
You will have 60 minutes to complete the examination.

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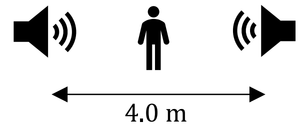
I. Lecture Multiple Choice [60 pts]. **Choose only one answer for each question, circle your answer in this booklet, and fill it out on your bubble sheet.**

1. [5 pts] Two speakers generating an identical signal of frequency 170 Hz are separated by a distance of 4.0 m. You are standing exactly midway between them. The combined sound you hear from them is loud (a maximum). You move a distance x toward one speaker (and away from the other), and the sound becomes quiet. What is the smallest distance x that would achieve that? Assume the speed of sound at that location to be 340 m/s.



   A. 4.0 m

   B. 2.0 m

   C. 1.0 m

   D. 0.50 m

   E. 0.25 m

2. [5 pts] Just before an orchestra performance, the oboe plays the note A (440 Hz). Our violist plays what they think should be the note A, and hears beats at a frequency of about 2 Hz. This means the viola is out of tune. What frequency is the viola actually playing?

   A. 438 Hz

   B. 440 Hz

   C. 442 Hz

   D. 880 Hz

   E. Both A & C could be correct

3. [5 pts] A diffraction grating has 710 lines per millimeter. Monochromatic light of wavelength 506 nm is incident normally on the grating. The largest angle away from the central maximum at which a bright fringe on the screen is observed is 46°. How many bright fringes in total are observed?

   A. 4

   B. 5

   C. 6

   D. 7

   E. 9

4. [5 pts] A student conducts a Young double-slit experiment using a selection of monochromatic lights of various wavelengths λ and masks with double slits of various separation d. The student's task is to maximize the bright fringe separation Δy formed on a screen. The distance of the screen from the mask L is kept fixed. Which of the following combinations would achieve the student's goal?

   A. The smallest λ and smallest d

   B. The largest d and largest λ.

   C. The largest d and smallest λ.

   D. The largest λ and smallest d.

   E. Δy cannot be changed, since the screen distance L is fixed.

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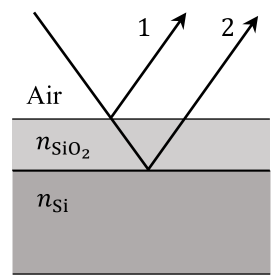
5. [5 pts] The student in the previous question is now given a light source of an unknown wavelength and asked to use a double-slit setup that has a slit separation of 3.0×10^{-5}m to find that wavelength. The student measures the angle to the third-order bright fringe from the central maximum and finds it to be 3.4°. What is the unknown wavelength?

   A. 590 nm
   B. 430 nm
   C. 470 nm
   D. 650 nm
   E. 710 nm

Use the following situation to answer the next two questions:
A solar cell made of silicon ($n_{\mathrm{Si}} = 3.50$) is coated with a thin layer a transparent silicon oxide $\mathrm{SiO_2}$ ($n_{\mathrm{SiO_2}} = 1.45$) meant to minimize energy loss through reflection and thereby maximize transmission to the silicon underneath.



6. [5 pts] The figure at right shows part of the solar cell with the silicon oxide coating. A ray is incident normally (shown incident at angle for illustration). Part of the ray reflects back into air (1) and part transmits and reflects off of the $\mathrm{SiO_2}$- Si interface (2). Which of the following is true of the two reflected rays?

   A. Only ray 1 undergoes inversion.
   B. Only ray 2 undergoes inversion.
   C. Both rays undergo inversion.
   D. Neither ray undergoes inversion.

7. [5 pts] If the incident light has a wavelength of 550 nm, what is the smallest thickness of the $\mathrm{SiO_2}$ coating that would minimize reflection?

   A. 190 nm
   B. 95 nm
   C. 39 nm
   D. 78 nm
   E. 140 nm

8. [5 pts] Red laser light (λ = 650 nm) is sent through a single vertical slit of width 650 μm and projected onto a wall 10 meters away. Which of the following accurately describes what you see?
[Hint, $1\ \mu\mathrm{m} = 1 \times 10^{-6}$ m]

   A. The light is spread horizontally with evenly spaced dark fringes every 1 cm
   B. The light is spread horizontally with the central bright spot flanked by dark fringes 2 cm apart, with subsequent dark fringes 1 cm apart
   C. The light is spread vertically with evenly spaced dark fringes every 1 cm
   D. The light is spread vertically with evenly spaced dark fringes every 1.5 cm

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9. [5 pts] You have a small telescope with a lens 10 cm in diameter and a tube length of 100 cm. When looking at a star, what do you see? [Assume a wavelength of 500 nm, which is nominally green at the center of the visible spectrum]

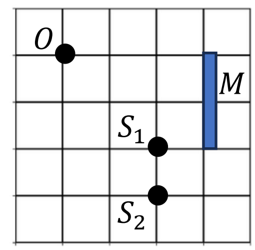
   A. A perfect point because stars are so far away

   B. Concentric circles with the central dot 1 micro rad in diameter

   C. Concentric circles with the central dot 12 micro rad in diameter

   D. A single circle with an angular diameter of 0.1 radians

10. [5 pts] Two sources of light, S_1 and S_2 are next to a mirror M. An observer is located at point O. The image at right shows a top view of scene. When looking at the mirror, what can the observer see?



   A. S_1 only.

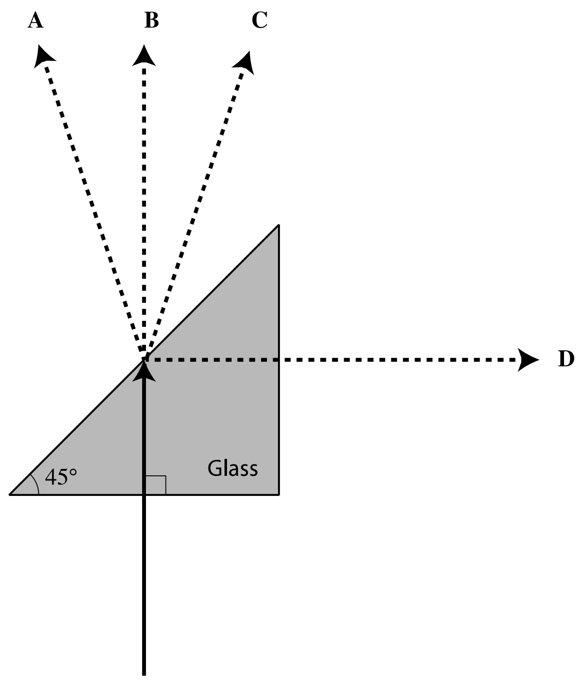
   B. S_2 only.

   C. Both S_1 and S_2.

   D. Neither S_1 nor S_2.

   E. Information provided is not enough to answer.

For the next two problems we consider a beam of light entering a glass prism ($n = 1.5$) as shown by the solid line in the diagram at right. The beam enters the first glass face at normal incidence. The dashed lines A-D show possible exit paths.



11. [5 pts] If the prism is in air ($n = 1$), what path does the light take?

   A. A

   B. B

   C. C

   D. D

12. [5 pts] If the prism is now fully immersed in water ($n = 1.33$), what path does the light take?

   A. A

   B. B

   C. C

   D. D

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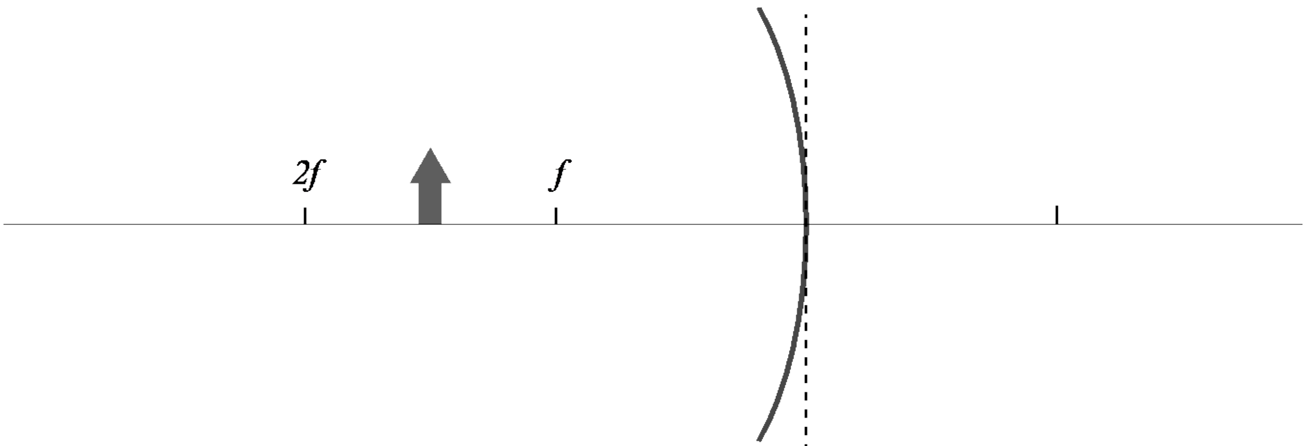
II. Lecture Free Response [20 pts] **Show your work for full credit.**
For questions 13 & 14 an object is placed at 1.5 times the focal length of a concave mirror with focal length of 1 meter.

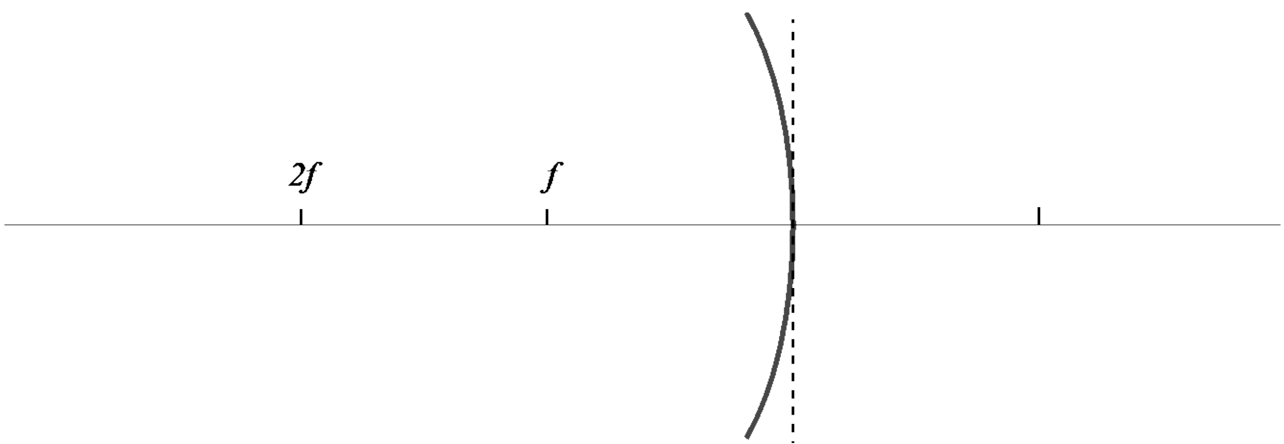
13. [5 pts] Carefully draw a ray diagram with at least 3 principal rays, and indicate the position and orientation of the resulting image. [Hint: as we are using a thin-mirror approximation draw your reflections at the position of the dashed vertical line for higher accuracy.]



14. [5 pts] Mathematically determine the position and magnification of the image. In words describe whether the image is real/virtual and upright/inverted, and connect that to the calculated values. [Hint: be careful with signs.]

15. [5 pts] We are going to use the same mirror with a focal length of 1 meter, but this time we want to move the object so that the image is upright and magnified by 2. Calculate the position of both the object and the image, and describe whether the image is real or virtual.

16. [5 pts] On the diagram below place and label the image and object from your answer to 15, and draw at least three principal rays.



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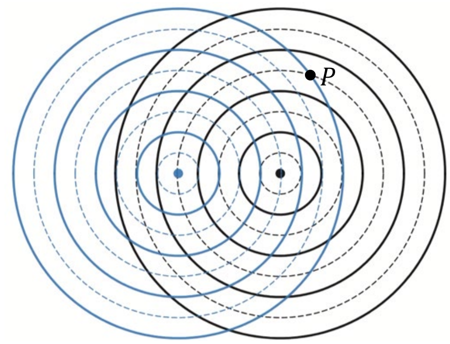
III. Tutorial Free-Response [20 pts]. **Explain your reasoning where stated to get full credit.**

Two in-phase sources produce waves in a ripple tank with the same frequency. At the instant shown at right, the solid lines represent crests and the dashed ones represents troughs.

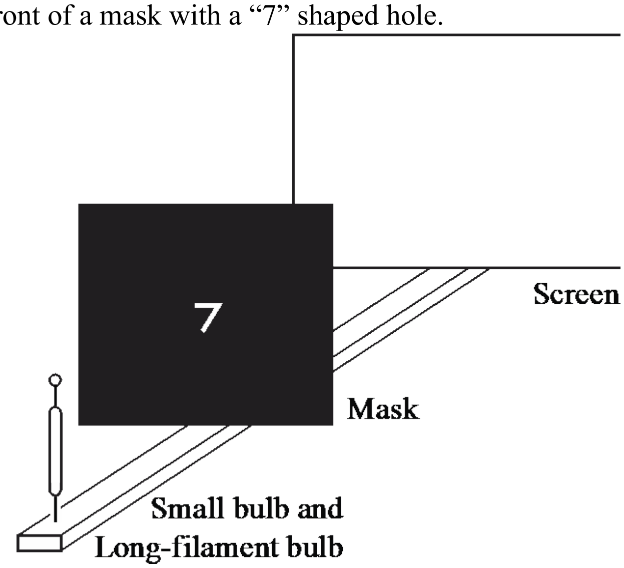


17. [4 pts] Is the displacement of the water surface at point P *zero* (i.e., at its equilibrium level) or *greatest above equilibrium* or *greatest below equilibrium*? No explanation needed.

18. [6 pts] If the frequency of the two sources is doubled, how does your answer to the previous question change? Explain briefly.

A small bulb and a long-filament bulb are placed in front of a mask with a "7" shaped hole.

19. [5 pts] On the diagram, sketch what you would see on the screen when the bulbs are lit. (Assume the room is dark before the bulbs are turned on). Briefly explain the reasoning you used to answer.



20. [5 pts] Suppose the size of the hole in the mask were doubled, but the overall shape was not changed. How, if at all, would this change what you would see on the screen? Sketch your answer in the space at right, and briefly explain your reasoning.

Screen with doubled hole

Phys 116, Equation Sheet, Midterm 2

Constants

Free-fall acceleration $g = 9.80\ m/s^2$

Newton $1\ \mathrm{N} = 1\ \mathrm{kg\ m/s^2}$

Speed of light $c = 3.00 \times 10^8 \mathrm{m/s}$

Mathematics

Components of a 2D vector $\vec{A}$: $A_x = A\cos\theta,\ \ A_y = A\sin\theta$

Magnitude and direction of $\vec{A}$ relative to x-axis: $A = \sqrt{A_x^2 + A_y^2},\quad \theta = \tan^{-1}(A_y/A_x)$

Volume & surface area of a sphere: $V = \frac{4}{3}\pi r^3,\quad A = 4\pi r^2$

Equations from 114 and 115

Kinematics (const. accel. a):

$$(v_x)_\mathrm{f} = (v_x)_\mathrm{i} + a_x t$$
$$x_\mathrm{f} = x_\mathrm{i} + (v_x)_\mathrm{i} t + \tfrac{1}{2} a t^2$$
$$(v_x)_\mathrm{f}^2 = (v_x)_\mathrm{i}^2 + 2 a_x \Delta x$$

Newton's Laws: $\sum\vec{F} = m\vec{a},\quad \vec{F}_{12} = -\vec{F}_{21}$

Weight: $w = mg$

Work due to a constant force: $W = F_\parallel d = Fd\cos\theta$

Conservation of energy: $\Delta E = W$

Power: $P = \dfrac{\Delta E}{\Delta t} = \dfrac{W}{t} = Fv$

Kinetic energy: $K = \frac{1}{2} m v^2$

Elastic potential energy: $\Delta U_\mathrm{s} = \frac{1}{2} k (x_\mathrm{f}^2 - x_\mathrm{i}^2)$

Gravitational potential energy: $\Delta U_\mathrm{g} = mg\Delta y$

Momentum: $\vec{p} = m\vec{v}$

Torque: $\tau = rF\sin\phi$

Pressure: $p = \dfrac{F}{A}$

Hooke's Law: $(F_\mathrm{spring})_x = -kx$

Waves and Sound

Speed of sinusoidal waves: $v = \lambda f$

Speed of a wave on a string: $v_\mathrm{string} = \sqrt{T_s/\mu}$

Linear mass density: $\mu = m/L$

Standing waves and Interference

On a string:

$$f_m = m\left(\frac{v}{2L}\right) = m f_1$$
$$\lambda_m = \frac{\lambda_1}{m} = \frac{2L}{m},\quad m = 1,2,3,\ldots$$

Open-open or closed-closed pipe:

$$f_m = m\left(\frac{v}{2L}\right) = m f_1$$
$$\lambda_m = \frac{\lambda_1}{m} = \frac{2L}{m},\qquad m = 1,2,3,..$$

Open-closed pipe:

$$f_m = m\left(\frac{v}{4L}\right) = m f_1$$
$$\lambda_m = \frac{\lambda_1}{m} = \frac{4L}{m},\quad m = 1,3,5,\ldots$$

Path length difference (constructive): $\Delta d = m\lambda$

Path length difference (destructive): $\Delta d = \left(m + \dfrac{1}{2}\right)\lambda$

Beat frequency: $f_\mathrm{beat} = |f_1 - f_2|$

Oscillation frequency: $f_\mathrm{osc} = \dfrac{1}{2}(f_1 + f_2)$

Wave optics

Index of refraction: $v = \dfrac{c}{n}$

Wavelength in material: $\lambda_\mathrm{mat} = \dfrac{\lambda_\mathrm{vac}}{n}$

Double-slit interference:

Small angle approximation: $\sin(\theta) \approx \theta$

Double-slit/diffraction grating:

Bright fringe: $d\sin\theta_m = m\lambda \quad m = 0,1,2,\ldots$

Dark fringe: $d\sin\theta_m = \left(m + \frac{1}{2}\right)\lambda \quad m = 0,1,2,\ldots$

Phys 116, Equation Sheet, Midterm 2

Position of bright fringe (2-slit for small angle) $$y_m = \frac{m\lambda L}{d}$$

Position of dark fringe (2-slit for small angle) $$y_m = \left(m + \frac{1}{2}\right)\frac{\lambda L}{d}$$

Spacing between adjacent bright fringes (2-slit, small angle) $$\Delta y = \frac{\lambda L}{d}$$

Position of bright fringes (2-slit & grating) $$y_m = L \tan\theta_m$$

Index of refraction $$n = \frac{c}{v}$$

Wavelength in material with refractive index n $$\lambda_{\mathrm{mat}} = \frac{\lambda_{\mathrm{vac}}}{n}$$

Thin film phase shift due to reflection:

Number of phase changes:	None or 2	One
Constructive:	$2t = m\frac{\lambda}{n}$	$2t = \left(m + \frac{1}{2}\right)\frac{\lambda}{n}$
Destructive:	$2t = \left(m + \frac{1}{2}\right)\frac{\lambda}{n}$	$2t = m\frac{\lambda}{n}$

Single-slit diffraction

Dark fringes $$a\sin\theta_p = p\lambda \qquad p = 1,2,3, \ldots$$

Small angle approx. $$\theta_p \approx p\lambda/a$$

Position of dark fringe $$y_p = \frac{p\lambda L}{a}$$

Central maximum width $$w = \frac{2\lambda L}{a} \quad \text{for } \frac{\lambda}{a} \ll 1$$

Circular aperture

Central maximum diameter $$w = \frac{2.44\lambda L}{D}$$

First dark fringe $$\theta_1 = \frac{1.22\lambda}{D}$$ $$y_1 = \frac{1.22\lambda L}{D}$$

Geometrical (Ray) optics

Law of reflection $$\theta_{\mathrm{r}} = \theta_{\mathrm{i}}$$

Image by plane mirror

Image distance $$s = s'$$

Image height $$h = h'$$

Snell's law $$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Critical angle $$\theta_{\mathrm{c}} = \sin^{-1}\left(\frac{n_2}{n_1}\right), \quad n_1 > n_2$$

Image by refraction $$s' = \frac{n_2}{n_1}s$$

Magnification of lens or mirror $$m = -\frac{s'}{s} = \frac{h'}{h}$$

Thin lenses & curved mirrors:

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

Sign conventions:

Object $s > 0$ always

Image $s' > 0$, for real image; $s' < 0$, for virtual image

Focal length $f > 0$, convex lens or concave mirror; $f < 0$, concave lens or convex mirror

Magnification $m > 0$ for upright image

Focal Length of mirrors

Convex mirror $$f = -\frac{1}{2}R$$

Concave mirror $$f = \frac{1}{2}R$$

Refractive Power $$P = \frac{1}{f}$$

Combined Power $$P_{\mathrm{total}} = P_1 + P_2$$

Combined magnification $$m_{\mathrm{total}} = m_1 m_2$$