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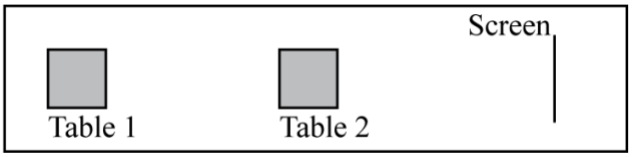
1. [4 pts] A physics instructor is setting up a single-slit interference demonstration. In the equipment room, they have access to a red laser ($\lambda_{red} = 640$ nm), a green laser ($\lambda_{green} = 550$ nm), a grating (grating A) with a single slit of width 0.20 mm and a grating (grating B) with a single slit of width 0.10 mm. The set-up of the room is shown. The instructor can place a laser and grating both on table 1 or both on table 2. Which set of conditions would produce the widest central maximum on the screen?



A. Green laser, grating B, table 1
B. Green laser, grating A, table 2
C. Red laser, grating A, table 2
D. Red laser, grating B and table 1
E. Information on table to screen distance is needed to answer.

2. [4 pts] In a photoelectric-effect experiment, light of wavelength λ_0 is incident on a copper surface. As a result, electrons emerge from the copper surface ($E_{0,\text{copper}} = 4.65$ eV) with a maximum kinetic energy of 1.81 eV. What is the wavelength λ_0? ($hc = 1242$ eV · nm)

A. 192 nm
B. 293 nm
C. 350 nm
D. 410 nm
E. 437 nm

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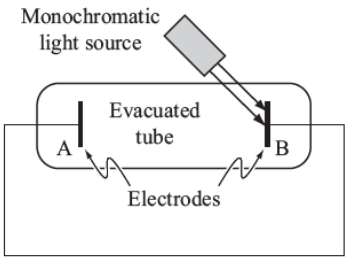
3. [4 pts] Light source 1 with a wavelength λ and a power P_0 is incident on a metal surface. As a result, electrons are emitted from the metal surface. Suppose light source 1 is replaced with light source 2, of power P_0 and wavelength λ', where $\lambda' > \lambda$, but λ' is still less than the threshold wavelength. Which of the following statements are true after light source 1 is replaced with light source 2?



A. More electrons are emitted with greater kinetic energy than those ejected by Light #1
B. More electrons are emitted with the same kinetic energy as those ejected by Light #1.
C. More electrons are emitted with lower kinetic energy than those ejected by Light #1.
D. Less electrons are ejected with greater kinetic energy than those ejected by Light #1.
E. Less electrons are ejected with lower kinetic energy than those ejected by Light #1.

4. [4 pts] An electron moving with a speed *v* has a de Broglie wavelength of 495 nm. Determine the speed of the electron. $m_{electron} = 9.11 \times 10^{-31}$ kg

A. 1.47×10^3 m/s
B. 1.64×10^3 m/s
C. 1.90×10^3 m/s
D. 2.14×10^3 m/s
E. 2.59×10^3 m/s

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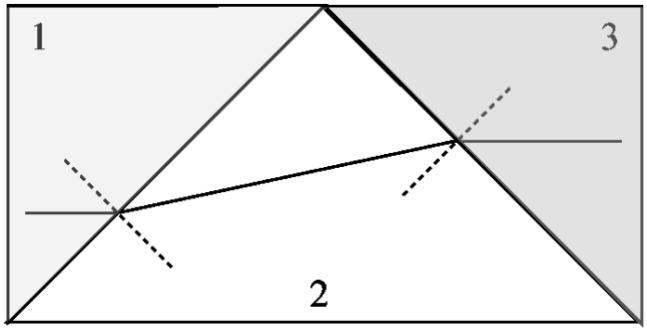
5. [4 pts] Three different transparent materials (1, 2, and 3) are stuck together. A laser beam that originates in material 1 passes through the three materials as shown. Rank the materials according to their index of refraction, from largest to smallest. The light rays in material 1 and material 3 are horizontal.



A. $n_2 > n_1 > n_3$

B. $n_1 = n_3 > n_2$

C. $n_2 > n_1 = n_3$

D. $n_3 > n_2 > n_1$

E. $n_1 > n_2 > n_3$

6. [4 pts] A physics instructor is designing a classroom demonstration where they want to form an image of a light bulb on the wall of the classroom. They would like the image to be upright and enlarged. Which of the following set-ups could they use?

A. A diverging lens and place the object between the focal length and the lens.

B. A converging lens and place the object further than $2f$ from the lens.

C. A converging lens and place the object between f and $2f$ from the lens

D. A converging mirror and place the object between the mirror and the focal point f.

E. None of the above choices will create the desired image.

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7. [4 pts] An 8.00-mm-tall object is placed 9.90 cm to the left of a converging mirror. An image of the object is formed 25.0 cm to the left of the mirror. What is the **radius of curvature** of the mirror?

   A. 6.12 cm

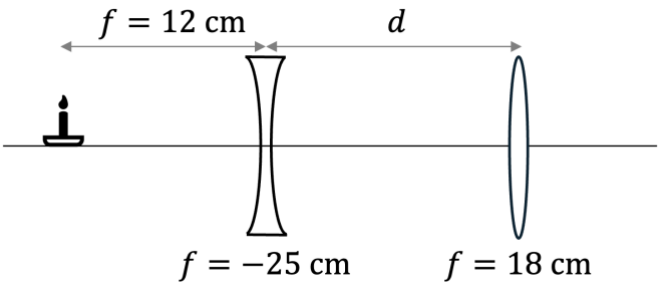
   B. 7.09 cm

   C. 9.84 cm

   D. 12.1 cm

   E. 14.2 cm

8. [5 pts] A candle is placed 12 cm to the left of a diverging lens with a focal length of -25 cm. The diverging lens is placed a distance d from a converging lens with a focal length of 18.0 cm. The final image produced by this two-lens system is formed 27 cm to the right of the converging lens. What is the distance, *d*, between the two lenses? *Diagram not drawn to scale.*



   A. 32 cm

   B. 46 cm

   C. 54 cm

   D. 62 cm

   E. 70 cm

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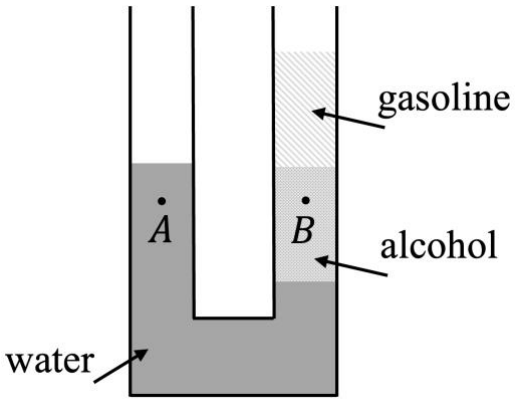
9. [4 pts] You have noticed that one of your grandparents wears bi-focal glasses, which allows them to clearly see objects at 20.0 cm from their eyes and to also see objects at very large distances. The bi-focal lens has focal lengths of +2.8 D and -1.2 D.

   What is the person's uncorrected near point?

   A. 26.3 cm
   B. 45.5 cm
   C. 48.1 cm
   D. 56.2 cm
   E. 61.8 cm

10. [4 pts] A U-tube is filled with water. Alcohol is then carefully poured into the right side of the U-tube, and a volume of gasoline is then poured onto the alcohol. Assume the liquids do not mix and all liquids are at rest. Points A and B are at the same horizontal level and both sides are open to the atmosphere. Is the pressure at point A *greater than, less than,* or *equal to* the pressure at point B? $\rho_{water} > \rho_{alcohol} > \rho_{gasoline}$.



   A. Greater than
   B. Less than
   C. Equal to
   D. Not enough information

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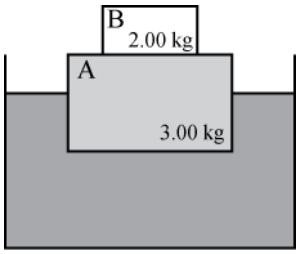
11. [4 pts] A wooden block, block A, with mass 3.00 kg and density 0.4 kg/L is placed in water ($\rho_{water} = 1$ kg/L). A concrete block, block B, with mass of 2.00 kg is then placed on top of block A. Determine the volume of block A that is *above the surface* of the water.



A. 1.5 liters

B. 2.5 liters

C. 3.0 liters

D. 5.0 liters

E. 7.5 liters

12. [4 pts] Water is traveling through the pipe shown at right. At point 1, the water pressure is 60.0 kPa and the water is moving at 0.400 m/s. The pipe has a diameter of 6.00 cm at point 1. Point 2 is a vertical height *y* above point 1. The diameter of the pipe at point 2 is 2.00 cm. The fluid pressure at point 2 is 45.0 kPa. Treat water as an ideal fluid with a density of 1000 kg/m^3. Find the height *y*.

A. 0.878 m

B. 1.39 m

C. 2.10 m

D. 2.33 m

E. 3.15 m

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13. [4 pts] A patient is diagnosed with a narrowing of a particular blood vessel of length L. The pressure across this blood vessel is higher than normal, and denoted P_{high}. The patient undergoes surgery which increases the diameter of this blood vessel by 3%. If the patient's blood flow rate and blood viscosity both remain the same, what is the new pressure (P_{new}) across this blood vessel?

A. $P_{new} = 0.71P_{high}$

B. $P_{new} = 0.81P_{high}$

C. $P_{new} = 0.89P_{high}$

D. $P_{new} = 0.94P_{high}$

E. $P_{new} = 0.97P_{high}$

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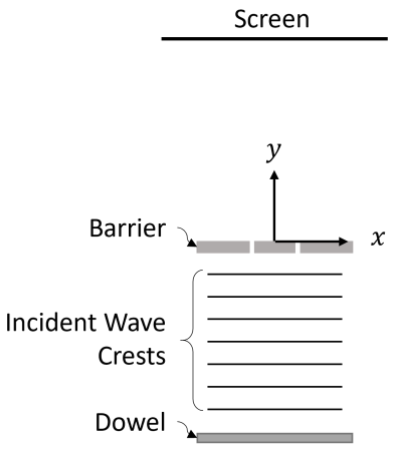
Lab Multiple Choice Questions

14. [4 pts] In lab A3, a group of students explored how modifying the simulation affects wave propagation on a string. Originally, each non-end ball has a force due to the springs on the left and the right, but one modification you could make to the code was to add friction, which depended on the speed v_{ball} of the ball in the form $F_{fric} = -f v_{ball}$. Keeping the initial height above equilibrium, h_i, and the initial width w_i of the pulse the same, the group varies the values of f and measures the new height h_2 after a certain amount of time. Which of the following represents their dependent variable?

A. F_{fric}
B. w_i
C. h_2
D. f
E. h_i

15. [4 pts] A pan of water contains a dowel that moves up and down at a constant rate producing straight wavefronts that propagate towards a barrier. The barrier contains two very narrow slits through which the waves can pass. Consider a coordinate system with the origin at the center of the barrier, as shown in the diagram at the right.



Consider water waves with a wavelength of 0.40 m, and a barrier with slit *L* at (-0.60 m, 0.00 m) and slit *R* at (0.60 m, 0.00 m).

Consider a point P on the screen with (*x,y*) coordinate of (1.475 m, 2.500 m). Will the interference of the two waves from the left and right slit at point be maximum constructive, complete destructive interference or something in between?

A. Maximum constructive interference
B. Complete destructive interference
C. Something in between
D. Not enough information

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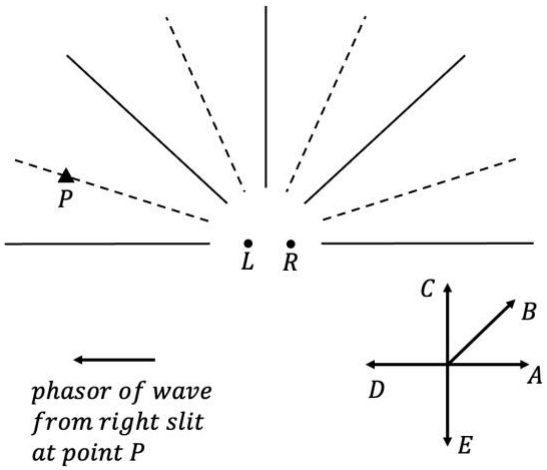
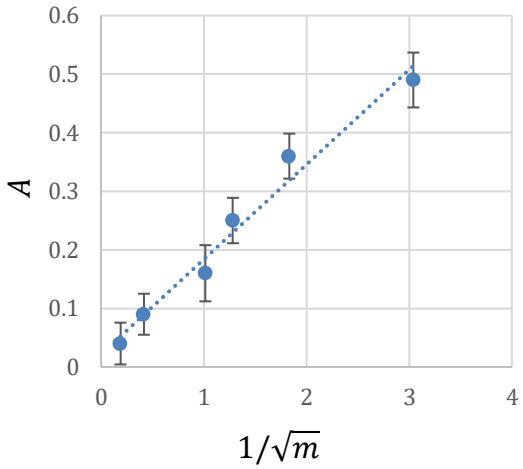
16. [4 pts] Consider two in-phase point-sources of water waves, L and R. The top view diagram at right shows the nodal lines (dashed) and antinodal lines (solid) due to these two sources. Consider point P on the diagram. The phasor of the wave from the right slit at point P is also shown at right. Which of the arrows (A to E) represent the phasor of the wave from the left slit at point P at the same instant?



A. Arrow A
B. Arrow B
C. Arrow C
D. Arrow D
E. Arrow E

17. [4 pts] In lab A3 a group of students altered the mass m of the balls, which is the factor by which balls of the second half of the string was greater than the first half. The graph at right measures A, the amplitude of the transmitted pulse vs. $1/\sqrt{m}$.



Based on the graph, which of the following best matches conclusions the students could reach from their data?

A. The trend line not a good fit, as it does not go through all the uncertainty bars.
B. The trend line not a good fit, as it does not go through 2/3rds of the uncertainty bars.
C. The trend line is a good fit, as it goes through 2/3rds of the uncertainty bars.
D. The trend line not a good fit, as it goes through less than 2/3rds of the uncertainty bars.
E. The trend line is a good fit, as goes through less than 2/3rds of the uncertainty bars.

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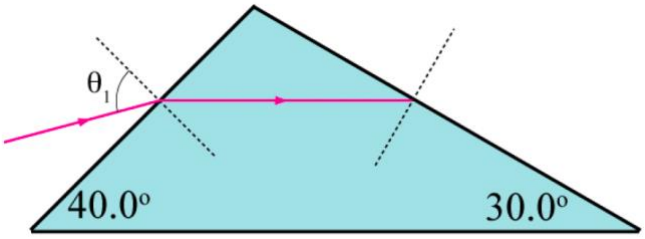
Lecture Free Response [16 pts total]

18. [4 pts] A light ray moving in air (n_{air} = 1.00) is incident at an angle θ_1 to a prism as shown. Upon entering the prism, the light ray refracts and travels *horizontally* as shown. If the index of refraction of the prism is 1.30, what is the angle θ_1? Show your work.



19. [4 pts] Now consider the interaction of the light ray with the right slanted side of the prism. What is the angle of refraction as the light ray exits the prism? If the ray is totally internally reflected, state so explicitly. Show your work.

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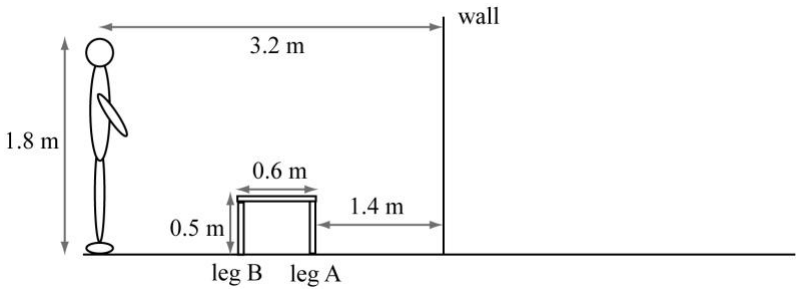
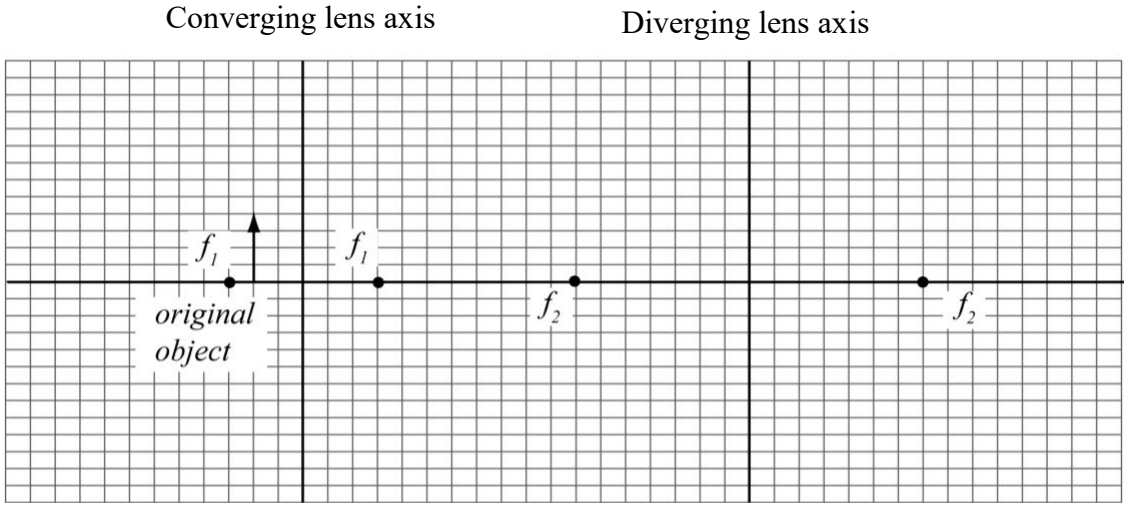
20. [4 pts] A person who is 1.8 m tall stands 3.2 m from a wall. On the wall there is a plane mirror that extends vertically upward from the floor. On the floor 1.4 m in front of the mirror is a small table that is 0.5 m tall and 0.6 m wide.



What is the minimum height the mirror must have for the person to see the bottom of leg A? Show your work.

21. [4 pts] Consider the system of two lenses below. The original object is shown to the left of the converging lens. On the diagram, accurately draw the final image produced by the two-lens system. Draw three principal/special rays for each lens.



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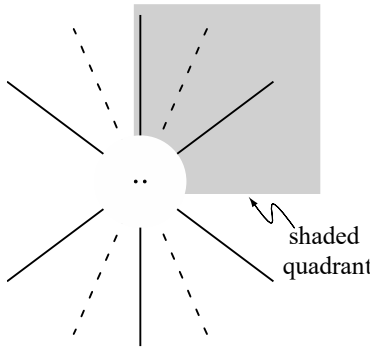
Tutorial Free Response [16 pts total]

The diagram at right shows all the nodal lines (dashed) and all the antinodal lines (or lines of maximum constructive interference) (solid) due to two point sources that generate periodic waves in a tank of water.



22. [4 pts] Determine the source separation in terms of λ. If it is not possible to determine the source separation exactly, determine the source separation as closely as you can by giving the smallest range into which the source separation must fall. Explain.

Suppose the previous experiment is changed so that the frequency of the waves generated by the two point sources is increased by a factor of 2.

23. [4 pts] How many antinodal lines (or lines of maximum constructive interference) will now appear in the shaded quadrant on the diagram? Explain.

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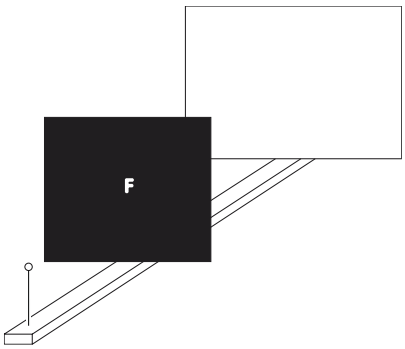
24. [4 pts] A small bulb is placed in front of a mask with an "F" shaped hole as shown in the diagram at right.

    The height of the "F" in the mask is 3.50 cm, and the bulb is placed 40.0 cm from the mask. If the screen is placed 50.0 cm behind the mask, what is the height of the image? Show your work.



25. [4 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 as right. (Assume that the room is dark before the bulb is turned on and ignore any interference or diffraction effects.)

    On the diagram, sketch what you will see on the screen when the bulb is lit.