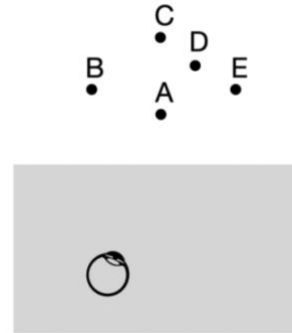


Lecture Multiple Choice [9 questions; 45 points total; 5 points each]

1. Your head is under the surface of a lake. A hummingbird hovers at point A, above the surface of the lake. At which one of the positions in the diagram would you see the hummingbird?

A. Point A
B. Point B
C. Point C
D. Point D
E. Point E



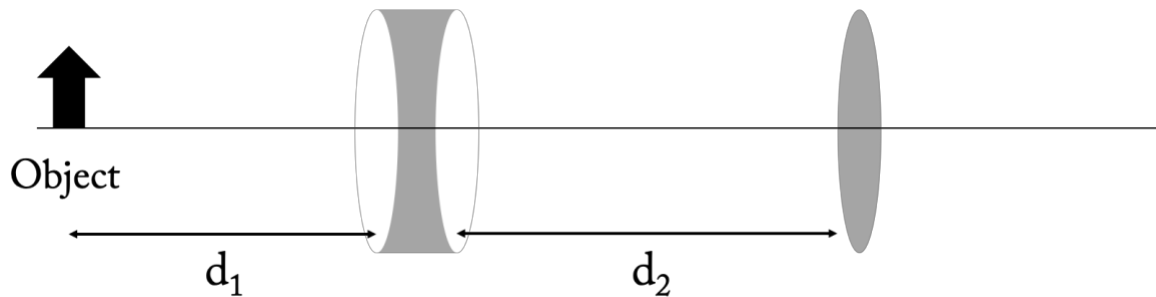
2. An 80.0-mm tall object is placed 170.0 mm in front of a converging mirror with a radius of curvature of 70.0 mm. What is the height of the image formed? Follow the sign convention.

A. -20.7 mm
B. 20.7 mm
C. 80 mm
D. -80 mm
E. 56 mm

3. Red light has a wavelength of 630 nm in air. What are the wavelength and frequency of red light in diamond (index of refraction $n = 2.42$)? Note: $1\text{nm}=10^{-9}\text{m}$ and $1\text{THz}=10^{12}\text{Hz}$.

A. 630 nm, 476 THz
B. 1524.6 nm, 196.7 THz
C. 1524.6 nm, 1152 THz
D. 260 nm, 476 THz

4. An object is placed $d_1=100$ cm to the left of a diverging lens with a focal length of magnitude 25 cm. A converging lens having a focal length of magnitude 33.33 cm is placed $d_2=30$ cm to the right of the first lens. Where is the final image formed?

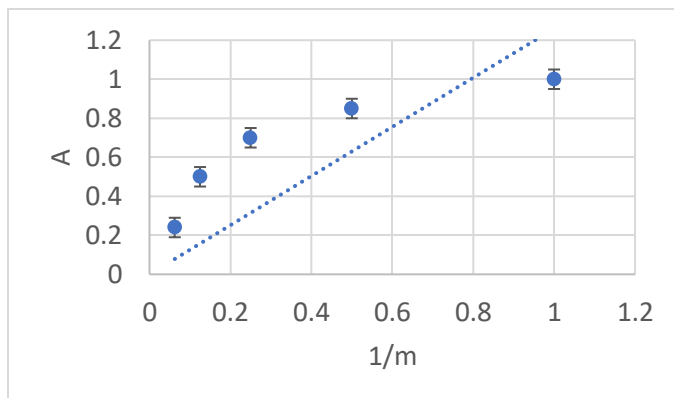


- A. 30 cm right of the second lens
B. 20 cm left of the first lens
C. 3.0 m left of the second lens
D. 3.0 cm left of the second lens
E. 100 cm right of the second lens
5. A converging mirror with radius of curvature R faces the Sun. Rays of light coming from the Sun are approximately parallel. Where is the image of the Sun formed?
- A. A distance $R/2$ behind the mirror.
B. A distance $R/2$ in front of the mirror.
C. A distance R behind the mirror.
D. A distance R in front of the mirror.
E. No image of the Sun is formed.
6. The critical angle of a light ray at the interface between a material and a vacuum is 45° . What is the speed of light at the material, if c_o is the speed of light in vacuum.
- A. $0.7c_o$
B. $0.6c_o$
C. $0.5c_o$
D. $0.4c_o$
E. $0.3c_o$

7. A beam of monochromatic light with a wavelength of 650 nm passes through a diffraction grating with slits 2500 nm apart. How many spots are observed on a large screen placed a small distance in front of the diffraction grating?
- A. 1
 - B. 3
 - C. 5
 - D. 7
 - E. 9
8. You shine a red laser beam on a diffraction grating and then shine a green laser beam on the same grating. Is the spacing between the bright fringes for the red beam greater than, smaller than, or equal to the spacing of the bright fringes for the green beam? Note: Red light has a longer wavelength than green light.
- A. Equal
 - B. Greater
 - C. Smaller
 - D. Cannot be determined
9. Monochromatic light strikes a metal surface and electrons are ejected from the metal. If the intensity of the light is increased, what will happen to the ejection rate and maximum energy of the electrons?
- A. greater ejection rate; same maximum energy
 - B. greater ejection rate; greater maximum energy
 - C. same ejection rate; same maximum energy
 - D. same ejection rate; greater maximum energy

Lab Multiple Choice [15 Points; 5 points each]

10. In lab A3 your group chose to alter m , the factor by which the mass of the balls for the second half of the string was greater than the first half, and measure A , the amplitude of the transmitted pulse. You attempted to see if A is proportional to $1/m$ and obtained the graph at right. Based on your graph, which of the following relationships would you suggest testing next?

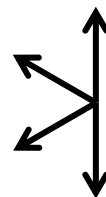


- A. A is proportional to m
- B. A is proportional to \sqrt{m}
- C. A is proportional to m^2
- D. A is proportional to $\frac{1}{\sqrt{m}}$**
- E. A is proportional to $1/m^2$

Monochromatic light of wavelength λ is normally incident on a mask containing four equally spaced slits as shown at right. Each slit is very narrow and may be treated as a point source.

The phasor diagram at bottom right corresponds to point X on a distant screen.

Magnified view of mask



11. Which one of the following statements is correct?

- A. The intensity at X is currently zero, and it will change intensity with time.
- B. The intensity at X is currently zero, and it will remain zero.
- C. The intensity at X is currently nonzero, and it will change intensity with time.
- D. The intensity at X is currently nonzero, and it will remain that value.**
- E. More information needed.

12. What happens to the intensity if the middle two slits are covered up?

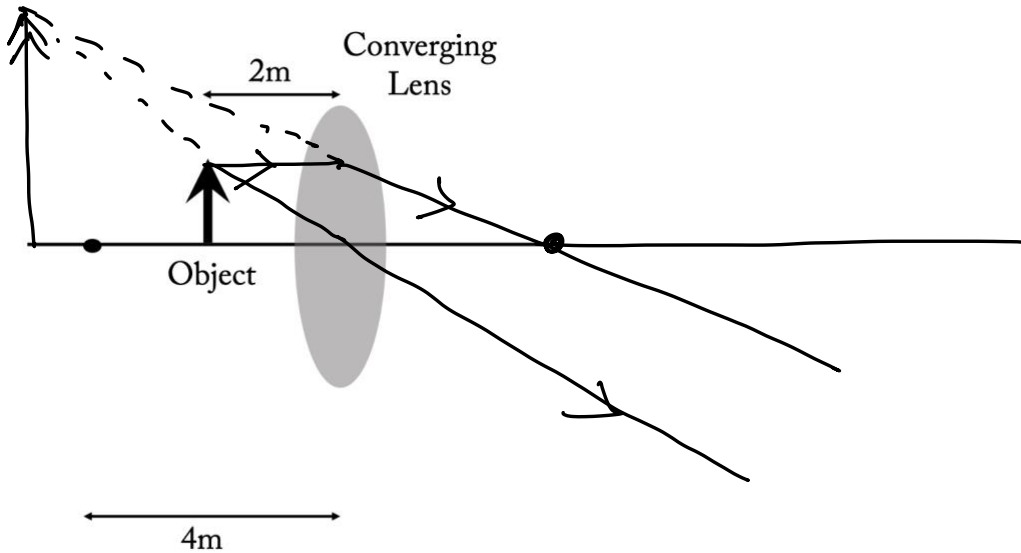
- A. The intensity decreases but is still nonzero.
- B. The intensity decreases to zero.**
- C. The intensity increases but not to the maximum intensity possible with two slits.
- D. The intensity increases to maximum intensity possible with two slits.
- E. More information needed.

Lecture Free Response [25 Points]

Show detailed work to get full credit.

An object is placed 2 m to the left of a converging lens with a focal length of 4 m.

1. [5 pts] Draw a ray diagram to show any image formed due to the lens. Draw any real rays as solid lines, and any virtual rays as dashed lines.



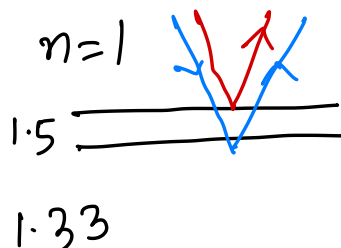
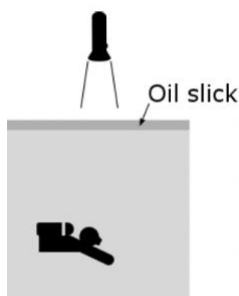
2. [5 pts] Calculate the distance of any image from the lens and state whether the image is real or virtual.

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

$$\frac{1}{i} = \frac{1}{f} - \frac{1}{o} = \frac{1}{4} - \frac{1}{2} = -\frac{1}{4}$$

\Rightarrow image formed 4 m left of the lens and is virtual.

3. [10 pts] A diver is swimming underneath an oil slick with a thickness of 200 nm and an index of refraction of 1.50. A white light shines straight down towards the diver from above the oil slick. The index of refraction of water is 1.33. What is the longest wavelength of the light **in water**, that is transmitted most easily to the diver? For any equation you use explain where all the numbers used come from and why they are appropriate in the equation.



Transmitted easily \Rightarrow not reflected
 \Rightarrow destructive interference in reflection

$$\phi_1 = 0$$

$$\phi_2 = \pi + \frac{2\pi(1.5) \cdot 200 \times 10^{-9} \times 2}{\lambda}$$

$$\Rightarrow \frac{2\pi \times 1.5 \times (400 \text{ nm})}{\lambda} + \pi = 3\pi \Rightarrow \frac{\lambda = 600 \text{ nm}}{\lambda \text{ in water}}$$

$$\rightarrow \frac{600}{1.33} = 451 \text{ nm}$$

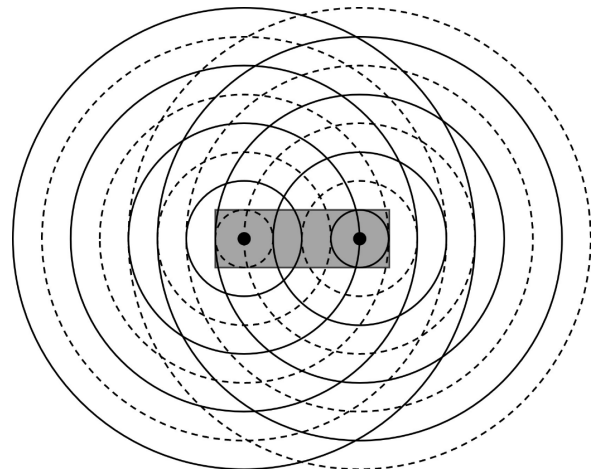
4. [5 pts] A laser emits light of wavelength 463 nm during a brief pulse that lasts for 25 ms and has a total energy of 1.2 J. How many photons are emitted in that single pulse?

photon energy : $hf = \frac{hc}{\lambda}$

$$\frac{1.2 \text{ J}}{hc/\lambda} \rightarrow \boxed{2.8 \times 10^{18}}$$

Tutorial Free Response [15 Points]

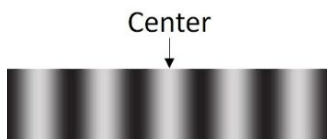
17. [8 pts] Consider two point sources oscillating up and down with harmonic motion on a water surface producing a circular wave pattern. The diagram shows the wavefronts at a particular instant in time where the solid lines represent the crests, and the dashed lines represent the troughs. Sketch all the nodal and antinodal lines in the region outside the shaded box. Clearly label which type of line it is and explain your reasoning.



First, antinodal lines
then, nodal lines

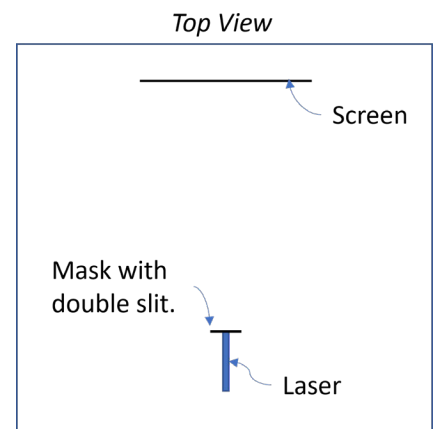
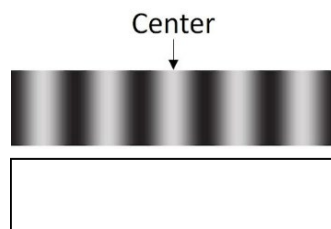
Nodal lines occur where the two waves are out of phase, so where a crest meets a trough. Antinodal lines occur where the two waves are in phase, so where a crest meets a crest or a trough meets a trough.

18. [7 pts] Red laser light is incident on a mask with two identical, very narrow slits, as shown in the top-view diagram at right. The image below is observed on the screen.



Now suppose the distance between the slits is decreased without changing anything else. Sketch the observed pattern in the spaces provided below the original image shown below. Clearly label if you sketch the red light or the dark regions.

Explain your reasoning.



The number of nodal lines and antinodal lines is determined by the number of wavelengths between the sources. As the distance between the slits decreases the number of lines decreases, and they become more spread out.