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1. [5 pts] How does the width of the central maximum in a single-slit diffraction pattern change if the slit width is halved? Consider this problem in the small angle limit.

   A) The width is halved.

   B) The width is doubled.

   C) The width is quadrupled.

   D) The width remains the same.

   E) The pattern splits into two distinct maxima.

2. [5 pts] A diffraction grating with 500 lines/mm is illuminated by light from a red laser ($\lambda$ = 600 nm). What is the angle (from the central axis) to the first-order ($m$ = 1) bright fringe

   A) 10.4°

   B) 17.5°

   C) 20.0°

   D) 30.0°

   E) No first-order maximum exists.

3. [5 pts] The work function of sodium metal is 2.36 eV. What is the maximum kinetic energy (in eV) of an electron ejected by a photon with a wavelength of 420 nm?

   A) 0.60 eV

   B) 1.00 eV

   C) 2.36 eV

   D) 2.96 eV

   E) 5.32 eV

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4. [5 pts] A 100-watt microwave emitter operates at a frequency of 2.45 GHz. How many photons does it emit per second?

   A) $6.16 \times 10^{18}$

   B) $6.16 \times 10^{24}$

   C) $6.16 \times 10^{27}$

   D) $6.16 \times 10^{9}$

   E) $6.16 \times 10^{25}$

5. [5 pts] A proton and an electron are accelerated from rest through the same potential difference. Which particle has the shorter de Broglie wavelength?

   A) The electron.

   B) The proton.

   C) They both have the same de Broglie wavelength.

   D) It depends on the magnitude of the potential difference.

   E) Neither has a de Broglie wavelength.

6. [5 pts] The headlights of a car are 1.5 m apart. What is the approximate maximum distance (in km) you could be from the car and still resolve the two headlights as separate sources? Assume your eye has a pupil diameter of 5.0 mm at night, and the effective wavelength of the light is 550 nm. Use the Rayleigh criterion.

   A) 0.5 km

   B) 1.1 km

   C) 5.0 km

   D) 11 km

   E) 50 km

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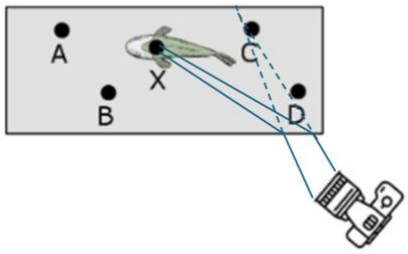



7. [5 pts] You take a photo of a fish in a fish tank. The figure shows a top view of your camera and the tank. The fish is located at position X and **imagine that the medium outside the fish tank has an index of refraction higher than that of water**. Where does the fish appear to be located in your photo?

A) A

B) B

C) C

D) D

E) X

8. [5 pts] What is the critical angle for total internal reflection when light travels from glass ($n_{glass} = 1.60$) into water ($n_{water} = 1.33$)?

A) 38.7°

B) 48.8°

C) 56.2°

D) 28.0°

E) Total internal reflection cannot occur in this situation.

9. [5 pts] Which of the following statements about the image formed by a diverging lens is correct?

A) The image must be virtual, and the size of image must be smaller than the size of the object.

B) The image must be virtual, and the size of image must be larger than the size of the object.

C) The image must be virtual, and the size of image can be smaller or larger than the size of the object.

D) The image can be virtual or real, and the size of image can be smaller or larger than the size of the object.

E) None of the above.

**Lab Multiple Choice Questions**

10. [5 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 $v_{\text{ball}}$ 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) $F_{\text{fric}}$

B) $w_i$

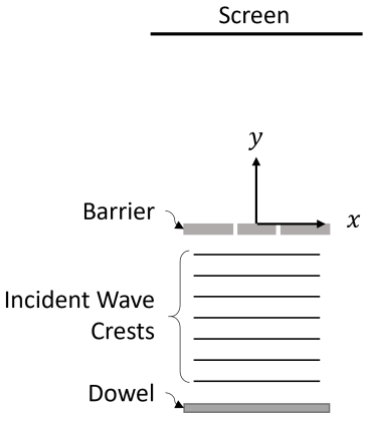
C) $h_2$

D) $f$

E) $h_i$

*The group controls for the initial height and the initial width. These are the control variables. They then vary the value of f, so this is the independent variable. They then measure the new height, $h_2$, which is the dependent variable.*

11. [5 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 0.20 m, and a barrier with slit $L$ at (-0.50 m, 0.00 m) and slit $R$ at (0.50 m, 0.00 m).

Consider a point P on the screen with ($x$,$y$) coordinate of (-1.05 m, 4.00 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

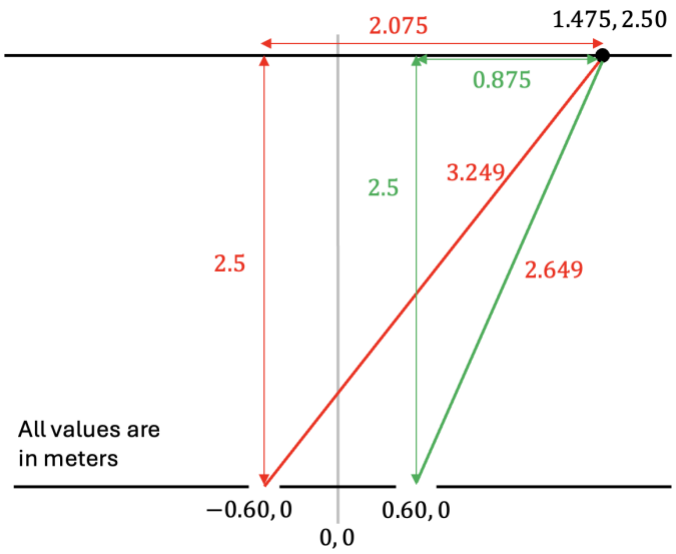
B) Complete destructive interference

C) Something in between

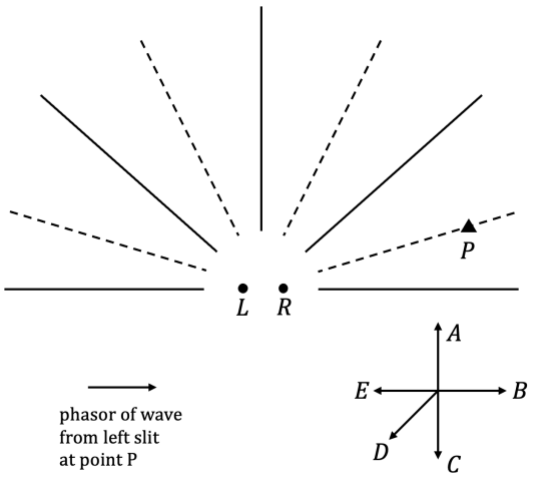
D) Not enough information

*Consider the two wavefronts that are shown in the diagram at right. The path length to point P for the wavefront from the left slit is 4.038 m and the path length for the wavefront from the right slit is 4.290 m. The path length difference is therefore 0.252 m.*

*We are told that the wavelength is 0.20 m. This means that the path length difference is equal to* $1.26\lambda$. *Since the ratio is neither a whole integer multiple of wavelengths nor an integer plus a half wavelengths, the interference at point P is between max constructive interference and complete destructive interference.*




12. [5 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 left slit at point *P* is also shown at right. Which of the arrows (A to E) represent the phasor of the wave from the right slit at point *P* at the same instant?




A) Arrow A

B) Arrow B

C) Arrow C

D) Arrow D

E) Arrow E

*Point P lies on a nodal line which indicates that the waves from both slits destructively interfere at this point. The sum of the two phasors at this point is zero. Only arrow E will sum to zero with the phasor shown for the left slit.*

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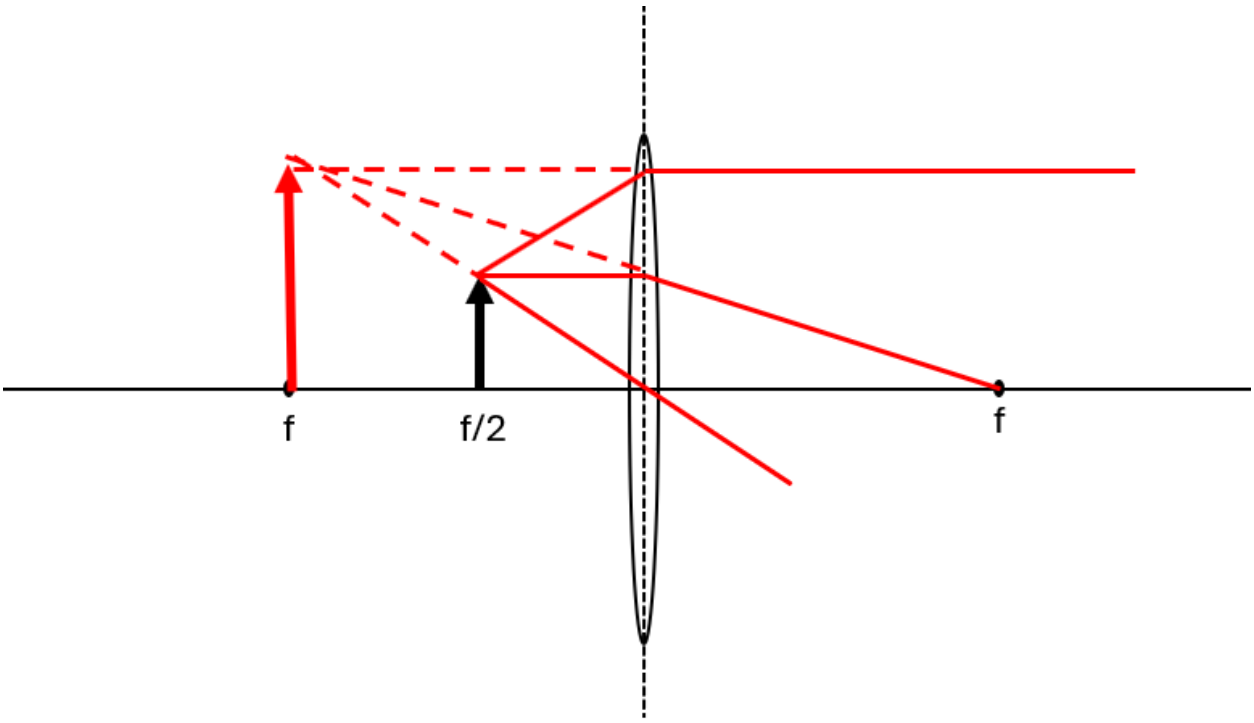
**Lecture Free Response**

Use the figure below to answer $Q$13, 14 and 15. As shown, an object is located at a distance that is half of the focal length from a converging lens.




13. [5 pts] Please draw the three special rays and determine the location of the image.

14. [5 pts] Is the image real or virtual? Please explain.

The image is virtual, because the image is formed on the same side as the object, and the light rays do not actually converge to one point.

15. [5 pts] What is the image distance, $s'$, in terms of focal length, $f$? Show your work.

$$\frac{1}{s'}+\frac{2}{f}=\frac{1}{f}$$

$$\frac{1}{s'}=-\frac{1}{f}$$
$$s'=-f$$

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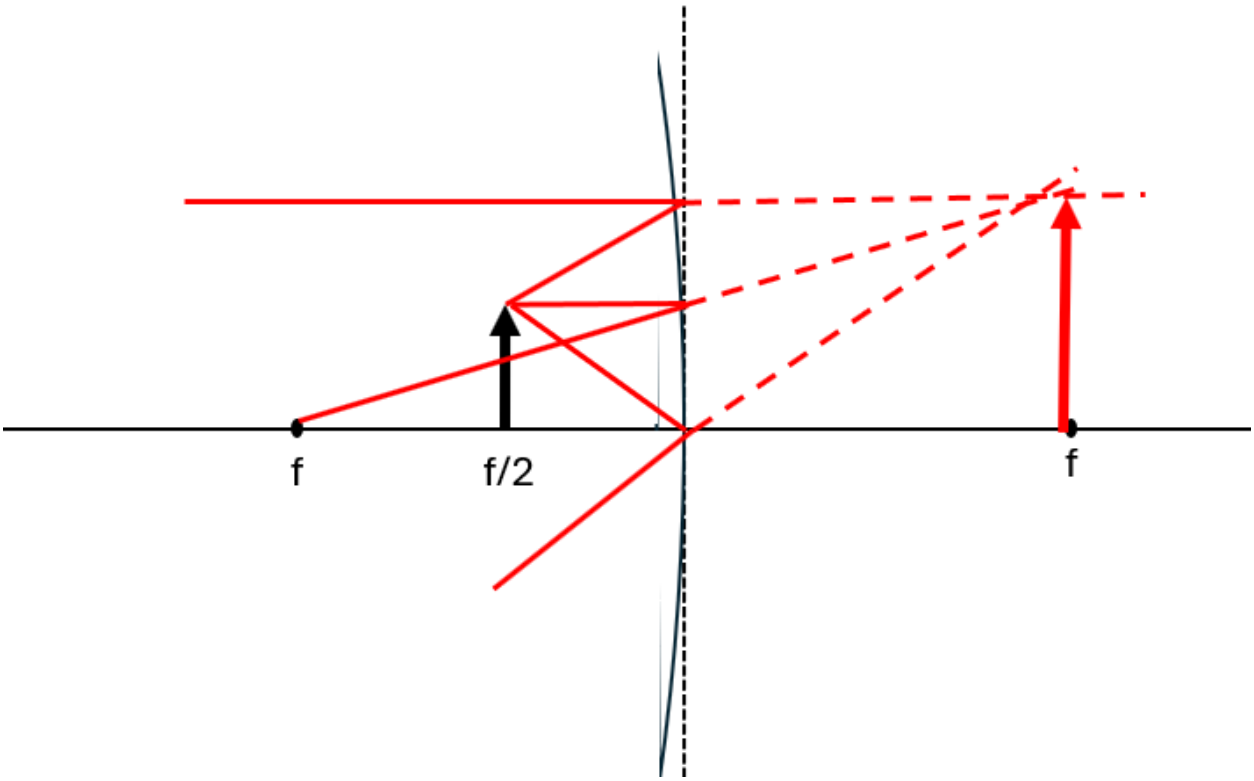
Use the figure below to answer *Q*16 and 17. As shown, an object is located at a distance that is half of the focal length from a converging mirror.




16. [5 pts] Please draw the three special rays and determine the location of the image.

17. [5 pts] Is the image real or virtual? Please explain.

The image is virtual, because the image is formed behind the mirror, and the light rays do not actually converge to one point.

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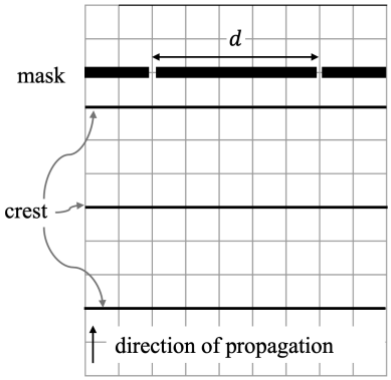
**Tutorial Free Response Questions**

Note: In the diagrams representing interference patterns below, lines of **maximum constructive** interference are represented by **solid lines** and *nodal lines* are represented by *dashed lines.*

In Experiment 1, a periodic wave is generated by a dowel in a big tank of water. The diagram at right shows successive crests of the periodic wave incident on a mask with two very narrow slits.

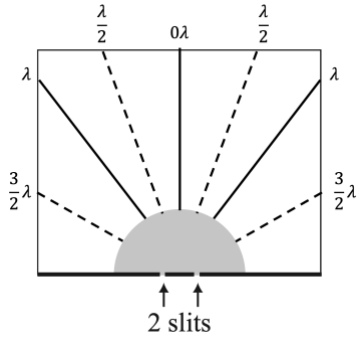



18. [3 pts] Determine the distance between the slits, *d*, in terms of the wavelength $\lambda$. Briefly explain.

*The distance between two consecutive crests of the periodic wave is the wavelength $\lambda$. Therefore, the wavelength equals 3 units (measured in terms of the length of the side of the square).*

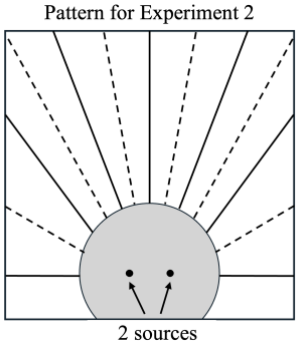
*Since the distance between the slits is 5 units, the distance in terms of $\lambda$ is* $d = \frac{5}{3}\lambda$

19. [4 pts] Sketch the approximate locations of all the lines of maximum constructive interference (solid) and nodal lines (dashed) in the region of the tank far away from the slits (the unshaded region in the box at right). You need not calculate angles. Explain briefly.




*Since $\Delta D_{horizontal}$ is the maximum possible difference in distance, and $\Delta D_{horizontal} = d = \frac{5}{3}\lambda\ (\sim 1.67\lambda)$, the lines corresponding to $\Delta D = 0\lambda, \Delta D = \lambda$ represent lines of maximum constructive interference and dashed lines corresponding to $\Delta D = \frac{\lambda}{2}$ and $\Delta D = \frac{3\lambda}{2}$ represent nodal lines. Since $d = \frac{5}{3}\lambda > \frac{3}{2}\lambda$, the $\frac{3\lambda}{2}$ nodal line does not appear on the line connecting the two sources*

In Experiment 2, two point sources generate periodic waves by tapping the surface of the water. The diagram at right shows an interference pattern for Experiment 2 in the region far away from the sources (unshaded).




20. [4 pts] Determine the source separation, *d,* in terms of the wavelength $\lambda$. If an exact value cannot be determined, give the smallest range into which *d* must fall. Explain.

*The diagram shows the $0\lambda$, $\lambda$, $2\lambda$ and $3\lambda$ antinodal lines and the $0.5\lambda$, $1.5\lambda$, and the $2.5\lambda$, nodal lines. The $3\lambda$ antinodal line is formed along the line that connects the two sources, and since $\Delta D_{horizontal} = d$, we can conclude that the source separation is equal to $3\lambda$.*

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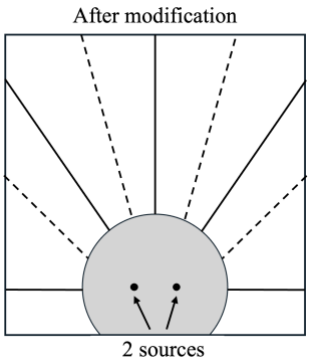
21. [4 pts] A single change is made to Experiment 2. As a result, the interference pattern is changed, as shown at right. Could increasing the frequency of the sources result in the change in the interference pattern? Explain.




*In the previous question, we concluded that $d = 3\lambda$. After the modification, the $2\lambda'$ occurs along the line connecting the two sources. We can thus conclude $d = 2\lambda'$. Therefore $\lambda'$ must be greater than $\lambda$ ($\lambda' = d/2$, while $\lambda = d/3$). An increase in wavelength is consistent with a decrease in frequency (we can assume the wave speed remains the same). This means that an increase in frequency could not have caused the change in the interference pattern.*