Physics 123A Autumn 2024	**123A - MAJUMDAR**	Midterm 2 November 7^{th}, 2024

Please use the boxes below to <u>clearly print</u> your name and UW NetID.
<u>Please write within the boxes</u>.

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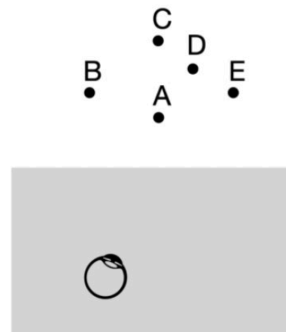
Clearly fill out this cover page and the top portion of the provided bubble sheet with the necessary information.

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

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



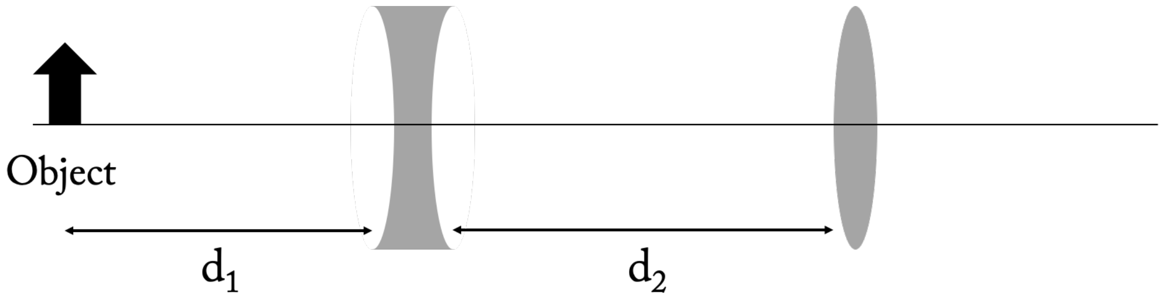
2. An 80.0-mm tall object is placed 170.0 mm in front of a converging mirror with a radius of curvature of 70.0 mm. What is the height of the image formed? Follow the sign convention.

   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: 1nm=$10^{-9}m$ and 1THz=10^{12}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^o. 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.

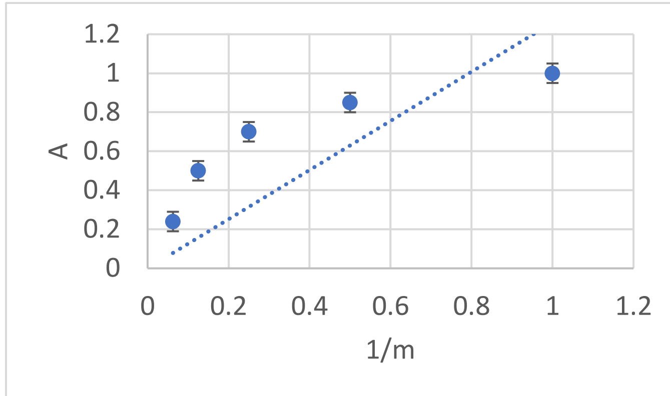
   A. Equal
   B. Greater
   C. Smaller
   D. Cannot be determined

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]

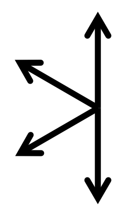
10. In lab A3 your group chose to alter m, the factor by which the mass of the balls for the second half of the string was greater than the first half, and measure A, the amplitude of the transmitted pulse. You attempted to see if A is proportional to $1/m$ and obtained the graph at right. Based on your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

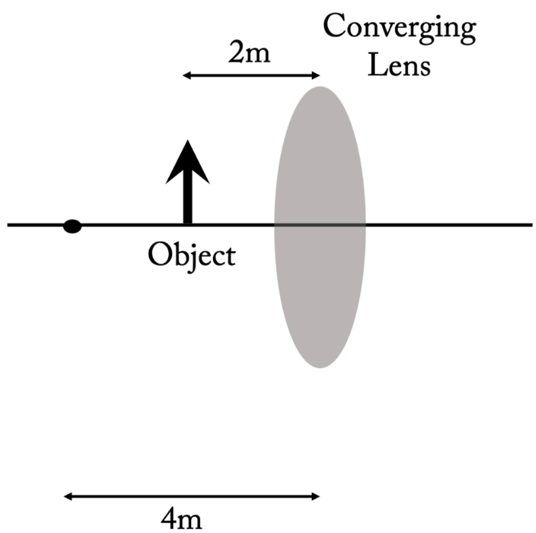
A. The intensity decreases but is still nonzero.
B. The intensity decreases to zero.
C. The intensity increases but not to the maximum intensity possible with two slits.
D. The intensity increases to maximum intensity possible with two slits.
E. More information needed.

Lecture Free Response [25 Points]

Show detailed work to get full credit.

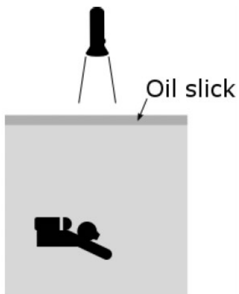
An object is placed 2 m to the left of a converging lens with a focal length of 4 m.

13. [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.



14. [5 pts] Calculate the distance of any image from the lens and state whether the image is real or virtual.

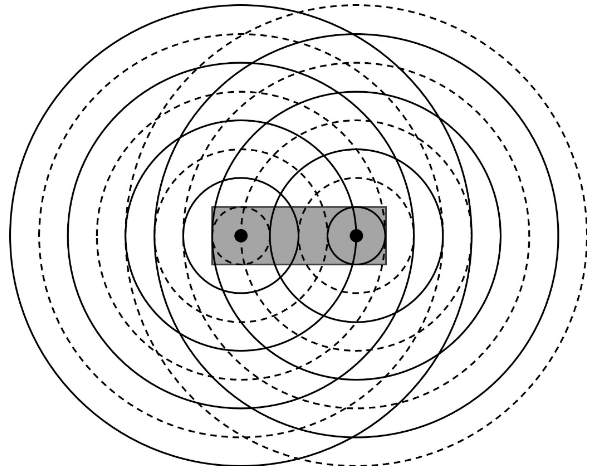
15. [10 pts] A diver is swimming underneath an oil slick with a thickness of 200 nm and an index of refraction of 1.50. A white light shines straight down towards the diver from above the oil slick. The index of refraction of water is 1.33. What is the longest wavelength of the light **in water**, that 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.



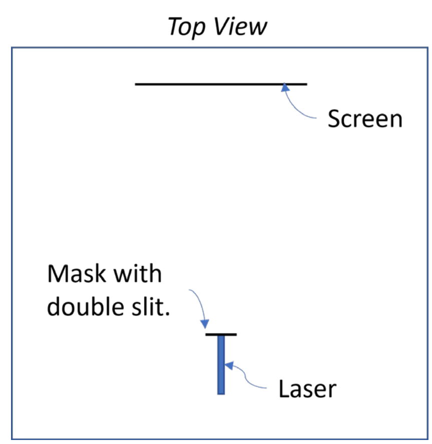
16. [5 pts] A laser emits light of wavelength 463 nm during a brief pulse that lasts for 25 ms and has a total energy of 1.2 J. How many photons are emitted in that single pulse?

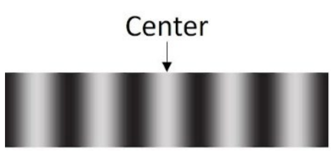
Tutorial Free Response [15 Points]

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.

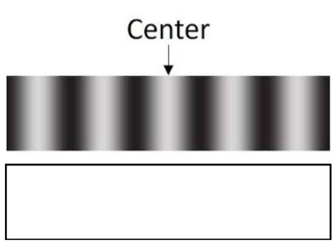


18. [7 pts] Red laser light is incident on a mask with two identical, very narrow slits, as shown in the top-view diagram at right. The image below is observed on the screen.





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. <u>Clearly label if you sketch the red light or the dark regions.</u>
<u>Explain you reasoning.</u>



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Constants

Speed of light	$c_0 = 3.0 \times 10^8\,\mathrm{m/s}$
Speed of sound	$c = 342\,\mathrm{m/s}$
Gravitational acceleration	$g = 9.8\,\mathrm{m/s^2}$
Plank's constant	$h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s}$

Mathematics

Standard deviation	$s = \sqrt{\dfrac{\Sigma_{i=1}^{n} (x_i - x_{\mathrm{ave}})^2}{n-1}}$

Equations from 121

Constant acceleration (x dir.)	$x_f = x_i + v_{x,i}\Delta t + \frac{1}{2}a_x \Delta t^2$
	$v_{x,f} = v_{x,i} + a_x \Delta t$
Kinetic energy	$K = \frac{1}{2}mv^2$
Equation of motion	$\vec{a} = \dfrac{\sum \vec{F}}{m}$

Periodic motion

Frequency	$f \equiv \dfrac{1}{T}$
Angular frequency	$\omega = 2\pi f$
SHM displacement	$x(t) = A\sin(\omega t + \phi_i)$
SHM equation	$\dfrac{d^2x}{dt^2} = -\omega^2 x$
SHM mechanical energy	$E = K + U = \dfrac{1}{2}m\omega^2 A^2$
Fourier's theorem: sum of sinusoidal functions with frequency	$f_n = \dfrac{n}{T}$
Natural angular frequency:	
mass on a spring	$\omega = \sqrt{\dfrac{k}{m}}$
torsion oscillator	$\omega = \sqrt{\dfrac{\kappa}{I}}$
pendulum	$\omega = \sqrt{\dfrac{ml_{\mathrm{cm}}g}{I}}$
simple pendulum	$\omega = \sqrt{\dfrac{g}{l}}$
Damped energy	$E(t) = E_0 e^{-t/\tau}$

Waves in one dimension

Wave number	$k = \dfrac{2\pi}{\lambda}$
Wave speed	$c = \lambda f = \dfrac{\omega}{k}$
Harmonic wave going in x dir.	$D_y = A\sin(kx - \omega t + \phi_i)$
Standing wave fixed at ends	$D_y = 2A\sin(kx)\cos(\omega t)$
Linear density	$\mu = \dfrac{m}{l}$
Wave speed on string	$c = \sqrt{\dfrac{\mathcal{T}}{\mu}}$
Power harmonic wave on string	$P_{\mathrm{av}} = \frac{1}{2}\mu A^2\omega^2 c$
Wave equation	$\dfrac{\partial^2 f}{\partial x^2} = \dfrac{1}{c^2}\dfrac{\partial^2 f}{\partial t^2}$

Waves in two and three dimension

Amplitude surface waves	$A \propto \dfrac{1}{\sqrt{r}}$
Amplitude spherical waves	$A \propto \dfrac{1}{r}$
Intensity of spherical wave	$I \equiv \dfrac{P}{A}$
Intensity of surface wave	$I_{\mathrm{surf}} \equiv \dfrac{P}{L}$
Intensity level	$\beta = (10\,\mathrm{dB})\log\left(\dfrac{I}{10^{-12}\,\mathrm{W \cdot m^{-2}}}\right)$
Beating wave	$D_x = 2A\cos(\pi f_{\mathrm{beat}} t)\sin(2\pi f_{\mathrm{av}} t)$
Beat frequency	$f_{\mathrm{beat}} = \lvert f_1 - f_2 \rvert$
Average frequency	$f_{\mathrm{av}} = \frac{1}{2}(f_1 + f_2)$
Doppler effect	$f_{\mathrm{o}} = \dfrac{c \pm v_{\mathrm{o}}}{c \pm v_{\mathrm{s}}} f_{\mathrm{s}}$
Shock wave angle	$\sin\theta = \dfrac{c}{v_{\mathrm{s}}}$

Ray optics

Refractive index	$n \equiv \dfrac{c_0}{c}$
Snel's law	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
Critical angle $n_1 > n_2$	$\theta_{\mathrm{c}} = \sin^{-1}\left(\dfrac{n_2}{n_1}\right)$
Thin lens equation	$\dfrac{1}{f} = \dfrac{1}{o} + \dfrac{1}{i}$
Magnification	$M \equiv \dfrac{h_{\mathrm{i}}}{h_{\mathrm{o}}} = \dfrac{-i}{o}$
Angular magnification	$M_\theta \equiv \left\lvert \dfrac{\theta_{\mathrm{i}}}{\theta_{\mathrm{o}}} \right\rvert$

Wave and particle optics

Bragg condition	$2d\cos\theta = m\lambda$
Two slit interference:	
Maxima, $m = 0, 1, 2, ...$	$\sin\theta_m = \pm\dfrac{m\lambda}{d}$
Minima, $n = 1, 2, 3, ...$	$\sin\theta_n = \pm\dfrac{(n-\frac{1}{2})}{d}\lambda$
Diffraction grating:	
principal max, $m = 0, 1, ...$	$d\sin\theta_m = \pm m\lambda$
min, k not integer mult. N	$d\sin\theta_{\min} = \pm\dfrac{k}{N}\lambda$
Thin film phase difference	$\phi = \dfrac{4\pi n_{\mathrm{b}} t}{\lambda} + \phi_{\mathrm{r}2} - \phi_{\mathrm{r}1}$
Single slit min, $n = 1, 2, 3, ...$	$\sin\theta_n = \pm n\dfrac{\lambda}{a}$
Rayleigh's criterion	$\theta_{\mathrm{r}} = 1.22\dfrac{\lambda}{d}$
de Broglie wavelength	$\lambda = \frac{h}{p}$
Photo electric effect	$E_{\mathrm{photon}} = K_{\max} + E_0$
Photon energy	$E_{\mathrm{photon}} = hf_{\mathrm{photon}}$
Photon momentum	$p_{\mathrm{photon}} = \dfrac{hf_{\mathrm{photon}}}{c_0}$