Name: Solutions

ID: ______________________

Physics 203

Midterm 1

4/23/2025

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating graphing scientific calculator, a page of scratch paper, writing utensils, a straight edge or ruler, and the exam. You will have 80 minutes to complete this exam.

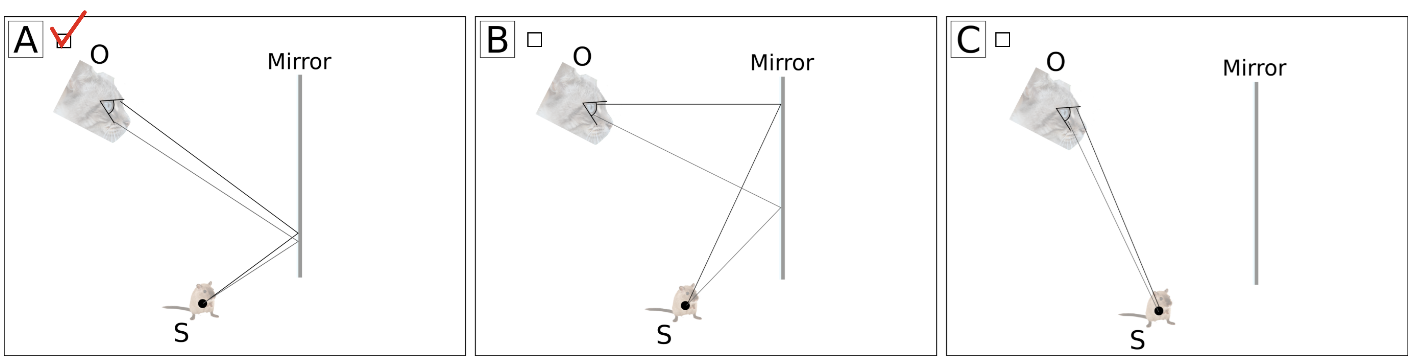
For questions 1 through 3 select next to all correct answers. A given problem may have more than one correct answer. Each correctly selected answer will receive two points. There are **5** correct answers in this section and only the first **5** filled in answers will be graded. There is no partial credit.

1. Light is shone through a single small slit and an interference pattern is observed on a screen behind the slit. For which of the two following cases would the small angle approximation be most acceptable to use when studying the first destructive location off the central maximum.
   - ☑ (a) λ = 650 nm, a = 7000 nm
   - ☐ (b) λ = 650 nm, a = 700 nm
   - ☐ (c) λ = 650 nm, a = 70 nm
   - ☑ (d) First dark fringe at an angle of 5°
   - ☐ (e) First dark fringe at an angle of 35°
   - ☐ (f) First dark fringe at an angle of 75°

$p\lambda = a \sin\theta$

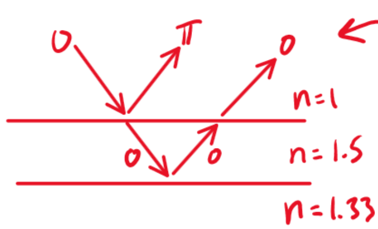
$p=1 \Rightarrow \frac{\lambda}{a} = \sin\theta \Rightarrow \lambda \ll a$

2. A cat is looking at a mouse through a plane mirror. Which of the following physical representations correctly models this system?



3. A researcher measures the thickness of a layer of benzene (**n = 1.50**) floating on water (**n = 1.33**) by shining monochromatic light onto the film and varying the wavelength of the light. She finds that light of wavelength **575 nm** is reflected most strongly from the film. Which of the following statements are true regrading this situation.

   - ☑ (a) A strong reflection corresponds to constructive interference.
   - ☐ (b) A strong reflection corresponds to destructive interference.
   - ☐ (c) d $\sin(\theta_m) = m\lambda$ would be the best equation to use to study this situation.
   - ☐ (d) a $\sin(\theta_p) = p\lambda$ would be the best equation to use to study this situation.
   - ☐ (e) $2t = m\lambda_{film}$ would be the best equation to use to study this situation.
   - ☑ (f) $2t = (m+1/2)\lambda_{film}$ would be the best equation to use to study this situation.



← relative phase shift

$\Rightarrow$ constructive $\Rightarrow (m+\frac{1}{2})\lambda$

4. (3 points) An experiment to explore how appealing the diffraction pattern is for each country is setup. Light is sent through an aperture that is cutout in the shape of the country. The apertures of the U.S. and Egypt are shown in figure (i). The resulting interference patterns are recorded and shown in figure (ii). Match each interference pattern with the aperture it came from. Explain how you determined which pattern goes with which aperture.

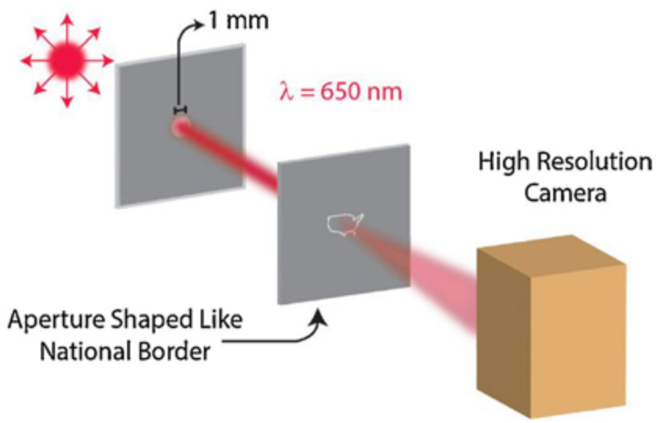


Figure (i): aperture shape

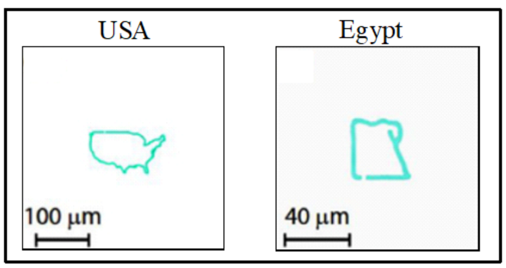
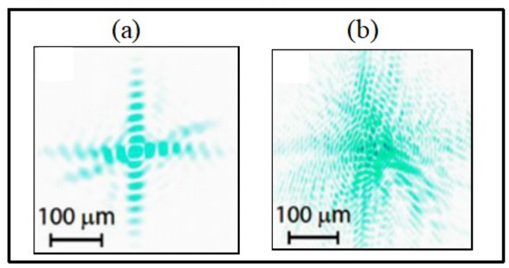


Figure (ii): interference pattern



Egypt = (a)

USA = (b)

The symmetries of the diffraction pattern will mimic the symmetries of the aparature (or reflecting / diffracting surface).

Egypt is almost a square & (a) has a pattern with 90° angles (& one that is a bit off from 90°, just like the country!)

USA has very few straight lines and is not symmetric, (b) similarly does not show any symmetries.

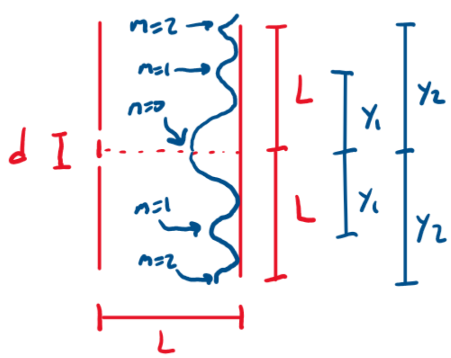
5. (10 points) A Young's double slit experiment is setup with a slit separation of **3800 nm**. A screen is of total width **2L** is placed a distance of **L** away from the slits. Light of wavelength **650 nm** is shone through the slits.

   (a) Draw a physical representation of the screen, slits, and a characteristic interference pattern (you don't have to solve for anything yet). Be sure to label the important distances and locations of constructive interference.

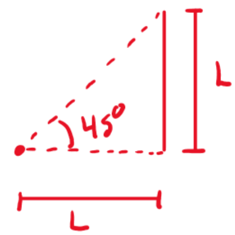
   (b) What is the maximum angle light that travels through the slits can make and still hit the screen? Hint: this is a geometry question, not an interference question.

   (c) How many **completely** constructive interference fringes appear on the screen? (this is the interference question)

a)



b)



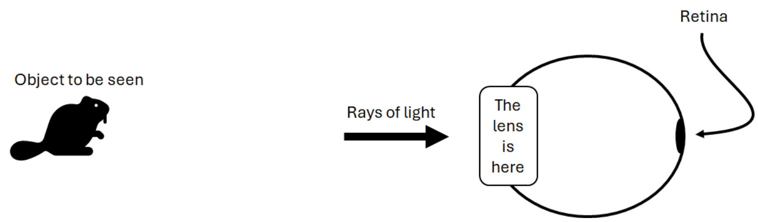
$\tan^{-1}\left(\frac{L}{L}\right) = 45°$

c) $n\lambda = d\sin\theta$

$n_{max} = \frac{d}{\lambda}\sin 45° = 4.13 \Rightarrow$ 4 bright fringes on top half

$\Rightarrow$ 4 above + 1 central + 4 below = **9 fringes**

6. (8 points) A human eye has a thin lens at its front and a "retina" at the back. The lens bends incoming rays of light onto the retina, creating a real image on the retina, which then absorbs the light and sends a signal to the brain to be interpreted as vision. An average human eye can "accommodate", or bend the lens to have focal lengths between **22 mm** and **24 mm**.



(a) Is a converging or diverging lens needed at the front of a human eye? Explain your reasoning.

Converging, a real image is needed on the retina

diverging lenses always produce virtual images when by themselves

(b) A particular human eye that has imperfect vision happens to have a retina which is **23 mm** from the lens. What is the farthest distance an object can be which will still be seen clearly by this eye? Show your work for full credit. (assume this eye has the average focal length range of **22 mm** - **24 mm**)

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{f} - \frac{1}{d_i} = \frac{1}{d_o}$$

↖ always 23 mm for clear vision

if d_i & f are the same, d_o will approach ∞. Set $f = 23$ mm & this eye can resolve the moon! (or further, out to ∞)

(c) For the same eye with imperfect vision, what is the closest distance at which an object can be placed and still be seen clearly? Show your work for full credit.

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i}$$

d_i must be 23 mm

try $f = 24$ mm $\Rightarrow$ $\frac{1}{d_o} = \frac{1}{24\text{ mm}} - \frac{1}{23\text{ mm}}$

$\Rightarrow$ $d_o = -552$ mm

negative doesn't make sense

try $f = 22$ mm $\Rightarrow$ $\frac{1}{d_o} = \frac{1}{22\text{ mm}} - \frac{1}{23\text{ mm}}$

$\Rightarrow$ $\boxed{d_o = 506\text{ mm}}$

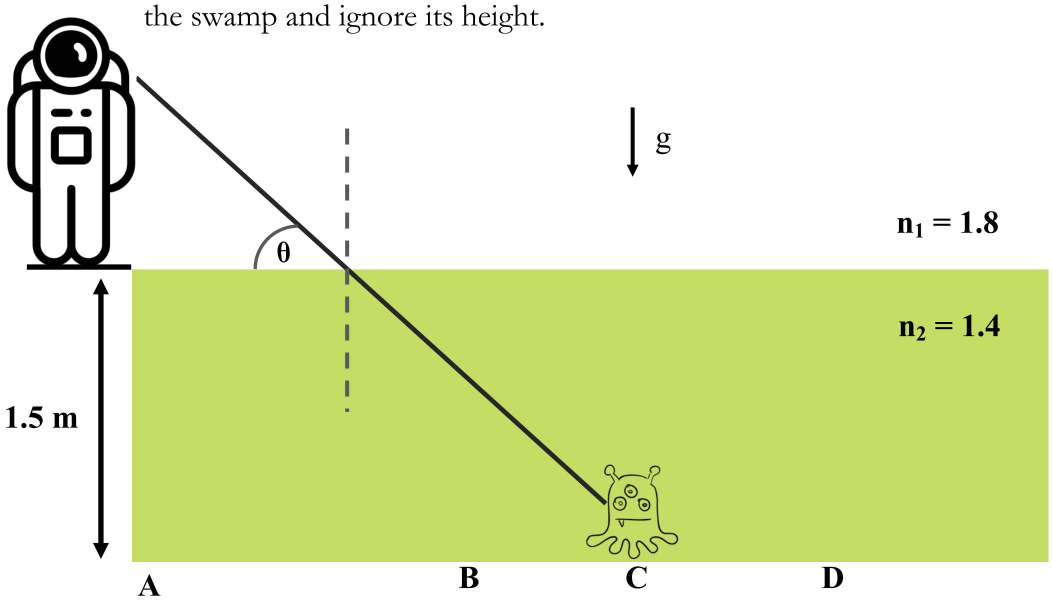
near point ⟶

7. (10 points) Katy, an astronaut exploring a distant planet, caught an alien creature and tied a string around it so she wouldn't lose her dinner. Then the creature jumps into the murky swamp and grabbed onto a rock so tight that Katy couldn't pull them out or see them. In the figure you can see the creature in the swamp and the taught string showing a direct line up to Katy. She decides she'll use her spacesuit laser to cook the creature so it will let go of the rock and she can pull it out. The problem is, she fires her laser directly along the line of the string and never hits the creature. Note: this is bizarre planet where the atmosphere has a higher index of refraction than the liquid in the swamp.

(a) For this situation, as light travels from $\mathbf{n_1}$ to $\mathbf{n_2}$, does it bend towards, or away from, the normal to the surface? Explain your reasoning.

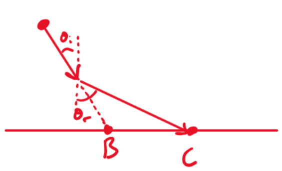
(b) If the actual location of the creature is point C, and aiming the laser towards it doesn't result in hitting it, what point (A, B, or D) could result in hitting the creature? Explain your reasoning.

(c) If the laser is fired directly along the line of the string, at angle $\boldsymbol{\theta = 50°}$, by how many meters along the bottom of the swamp, horizontally, does it miss the creature? Assume the creature is on the bottom of the swamp and ignore its height.



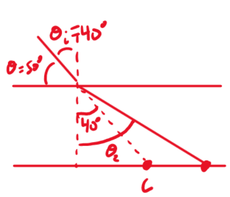
a) $n_1 \sin\theta = n_2 \sin\theta$ (↓ ↑)   if n_2 gets smaller, θ must get bigger

b) Katy should aim at point B in order to hit the creature



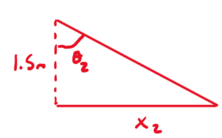
if θ_r is larger (n_2 is smaller)
then need to aim closer

c)



$\Rightarrow \tan 40° = \frac{x}{1.5\text{m}}$

$x = 1.259\text{m}$



$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\Rightarrow \theta_2 = 55.73°$

$x = 1.5 \tan(\theta_2) = 2.202\text{m}$

$\Delta x = x_2 - x_1 = \boxed{0.943\text{m}}$