Name: Solutions

ID:

Physics 203

Midterm Exam 1

4/24/2024

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, 1 page of scratch paper, writing utensils, and the exam. You will have 80 minutes to complete this exam.

For questions 1 through 4 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **6** correct answers in this section and only the first **6** filled in answers will be graded. There is no partial credit.

1. In which of these circumstances is the wave model the best model to use?

   ☑ (a) Thin film interference.
   ☐ (b) Snell's law refraction.
   ☐ (c) Converging thin lenses.
   ☐ (d) Diverging thin lenses.
   ☑ (e) Diffraction gratings.
   ☐ (f) Total internal reflection.

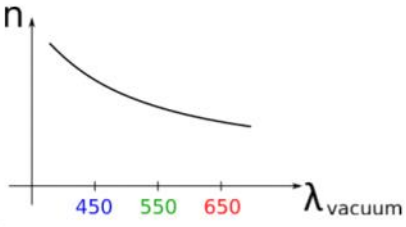
2. Light travels from glass (index of refraction of 1.52) into water (index of refraction 1.33). Which of the following are true of this situation?

   ☑ (a) The **effective speed** of the light **increases**.
   ☐ (b) The **effective speed** of the light **decreases**.
   ☐ (c) The **wavelength** of the light **decreases**.
   ☐ (d) The **frequency** of the light **decreases**.
   ☐ (e) The **amplitude** of the light **increases**.
   ☑ (f) The light **could** experience total internal reflection depending on the incident angle.
   ☐ (g) The light **cannot** experience total internal reflection no matter the incident angle.

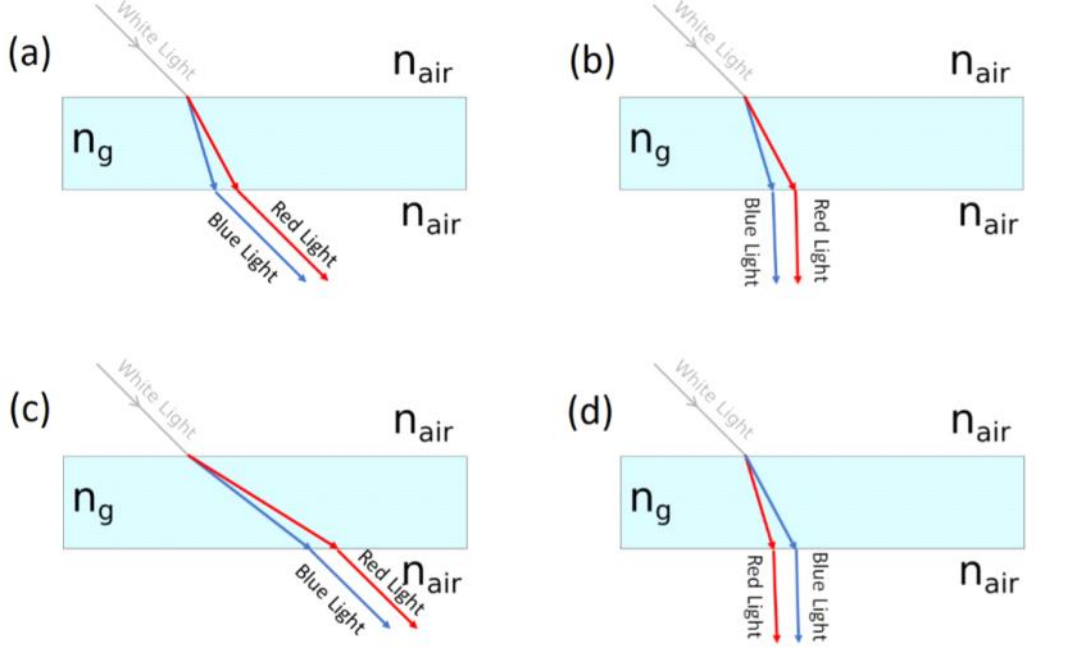
$\uparrow v = \frac{c}{n} \downarrow$

$n_1\lambda_1 = n_2\lambda_2$

3. White light shines into a rectangular slab of glass at an angle. The glass is surrounded by air on all sides. Which of the following diagrams could depict the result? The index of refraction of glass as a function of wavelength is given in the graph.

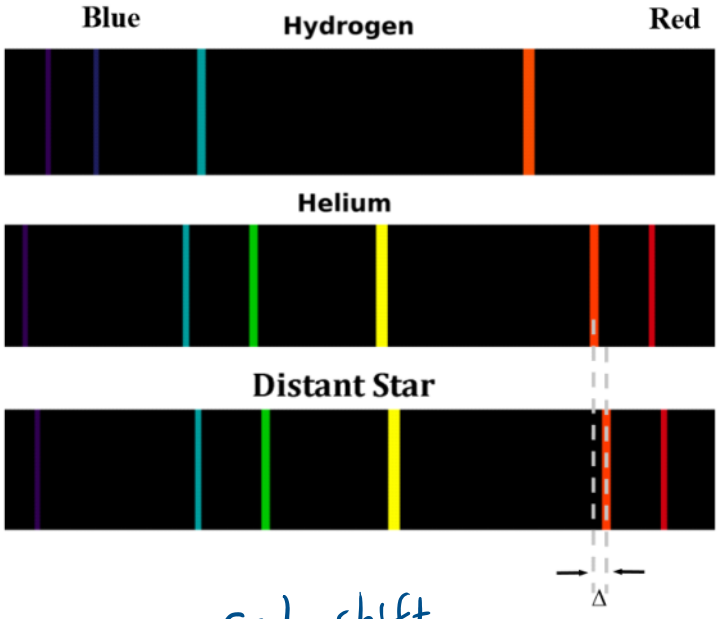


   ☑ (a)
   ☐ (b)
   ☐ (c)
   ☐ (d)



4. The spectral lines emitted from hydrogen and helium that are visible by the human eye are shown in the figure. The red end of the spectrum is to the right. Light from a distant star is sent through a diffraction grating and the that spectrum is also shown in the figure. Which of one of the following statements is most likely true?

- ☐ (a) The distant star is composed of Hydrogen and is not moving relative to Earth.
- ☐ (b) The distant star is composed of Hydrogen and is moving away from Earth.
- ☐ (c) The distant star is composed of Hydrogen and is moving towards Earth.
- ☐ (d) The distant star is composed of Helium and is not moving relative to Earth.
- ☑ (e) The distant star is composed of Helium and is moving away from Earth.
- ☐ (f) The distant star is composed of Helium and is towards Earth.

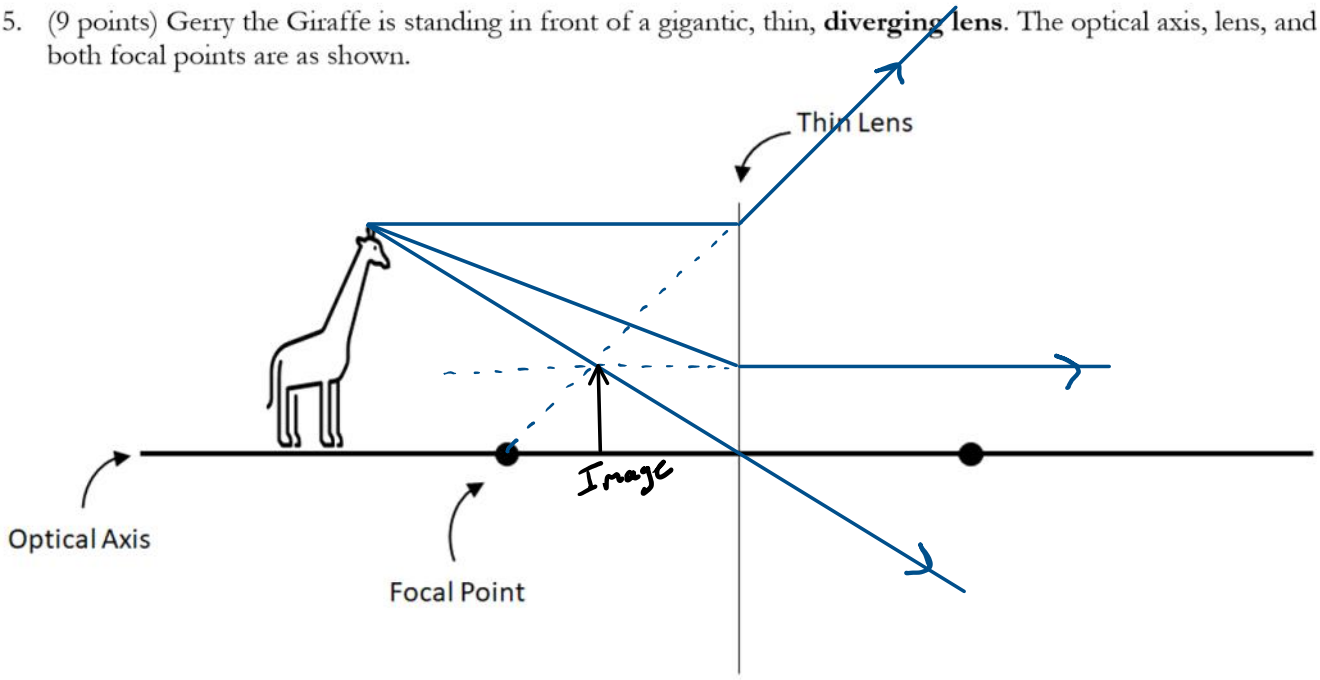


red-shift

⇒ f ↓

⇒ v = away

5. (9 points) Gerry the Giraffe is standing in front of a gigantic, thin, **diverging lens**. The optical axis, lens, and both focal points are as shown.



(a) Carefully draw all three principal rays and clearly indicate the location of the image of Gerry.

(b) Is the image real or virtual?

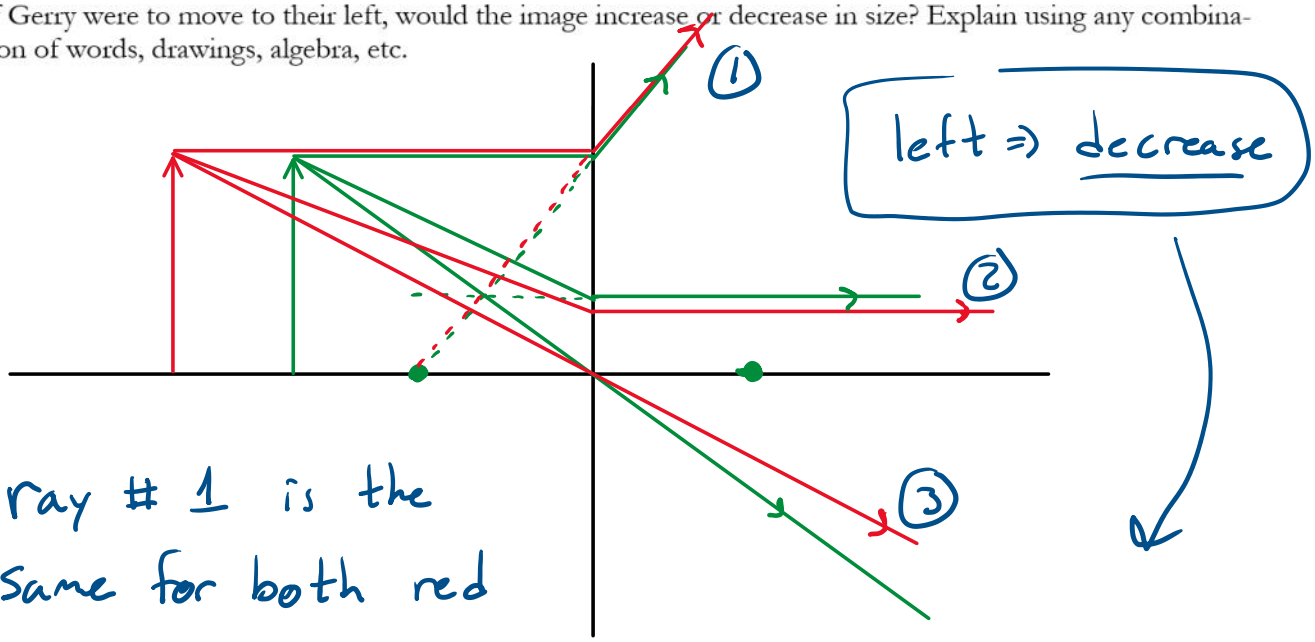
Virtual

(c) Estimate the magnification of the image.

Smaller + upright ⇒ $m \approx +0.4$

(image is a little smaller than 1/2 as big as object)

(d) If Gerry were to move to their left, would the image increase or decrease in size? Explain using any combination of words, drawings, algebra, etc.



ray # 1 is the same for both red & green objects, but rays 2 & 3 intersect w/ # 1 at a lower height for the further red object.

6. (10 points) In a Young's Double Slit experiment, laser light shines on two small slits separated by a distance **1.30 μm**. The **first non-central bright fringe** is found at an angle of **25°**.

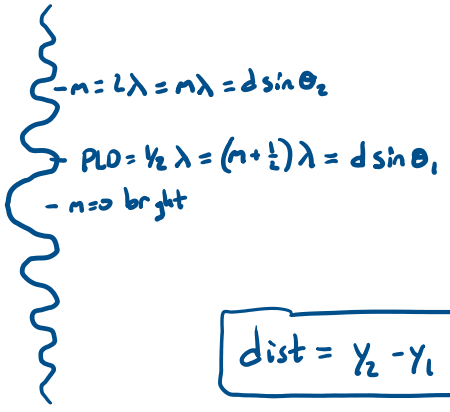
(a) Calculate the wavelength of the laser without using the small angle approximation.
(b) Without using the small angle approximation, what is the distance between the **1st dark fringe**, and the ~~3rd~~ 2nd **non-central bright fringe** (on the same side of the central maximum) on a screen **60 cm** away from the double slit?
(c) You are tasked with designing an experiment that has a tolerance for a maximum error of **5%** in the wavelength. Can you use the small angle approximation with this physical setup? Explain by finding the percent error in the wavelength introduced if you solve part (a) using the small angle approximation.

(a) $m\lambda = d\sin\theta$

(1) $\lambda = (1.3\times10^{-6}\,m)\sin(25°)$

$\lambda = 5.494\times10^{-7}\,m \approx 549\,nm$

(b)



1st dark

$\sin\theta_1 = \frac{\frac{1}{2}\lambda}{d} = \frac{\lambda}{2d}$

$\theta_1 = 12.2°$

$y_1 = L\tan(12.2°)$

$y_1 = 12.97\,cm$

2nd bright

$\sin\theta_2 = \frac{2\lambda}{d} \Rightarrow \theta_2 = 57.7°$

$y_2 = L\tan(\theta_2)$

$y_2 = 94.9\,cm$

$dist = y_2 - y_1 = 81.9\,cm$

(c) $m\lambda = d\sin\theta$

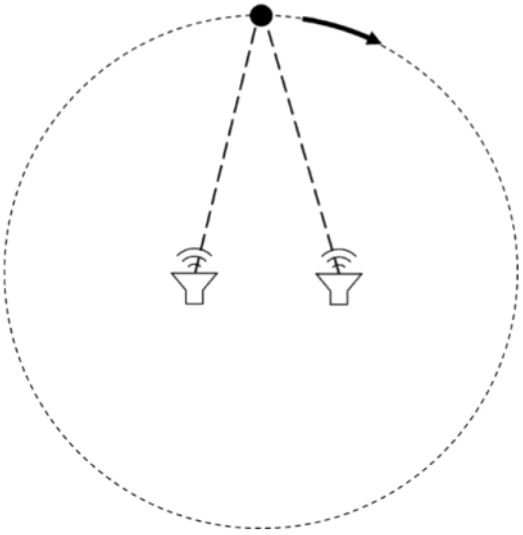
SAA $\Rightarrow \sin\theta = \theta$

$\lambda = d(25°)\left(\frac{2\pi}{360°}\right) = 567.2\,nm$

$\%\ error = \frac{567.2 - 549.4}{549.4} = 0.0325$

$\Rightarrow$ % error = 3.2 % $\Rightarrow$ yes, the SAA is accurate enough for your experiment!

7. (8 points) Two spherical speakers are placed **5 meters apart**. They emit a constant tone of **686 hz**. You are standing on the dot in the picture, equidistant from each speaker. The speed of sound in air is **343 m/s.**



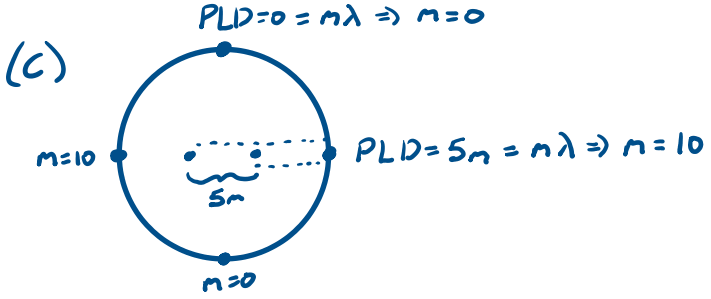
(a) What is the wavelength of the sound emitted by the speakers?
(b) Is your starting position a point of constructive or destructive interference? Explain.
(c) How many spots of constructive interference do you experience if you walk in a complete circle around the speakers?

(a) $v = f\lambda$

$\lambda = \frac{v}{f} = \frac{343\ m/s}{686\ Hz} = 0.5m$

(b) constructive, b/c the PLD is 0, so the waves are in-phase.

(c)



So, between "noon" and 3 o'clock there are 9 spots of constructive interference, plus the m=0 & m=10 pts.

⇒ in a complete circle there are $9 \times 4 + 4 =$ 40 spots of constructive interference