Name: Solns ID: ~~Lab~~ (day/time): _____

Physics 203
Midterm Exam 1
4/25/2018

Collaboration is not allowed. Allowed on your desk are: up to ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating scientific calculator, 1 page of scratch paper, writing utensils, a ruler, and the exam. You will have 80 minutes to complete this exam.

Constants:

$n_{air} = 1$, $n_{water} = 1.33$, $n_{oil} = 1.48$, $n_{glass} = 1.51$, $c = 2.998 \times 10^8 m/s$

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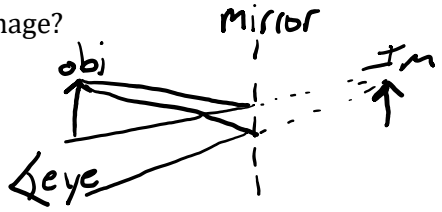
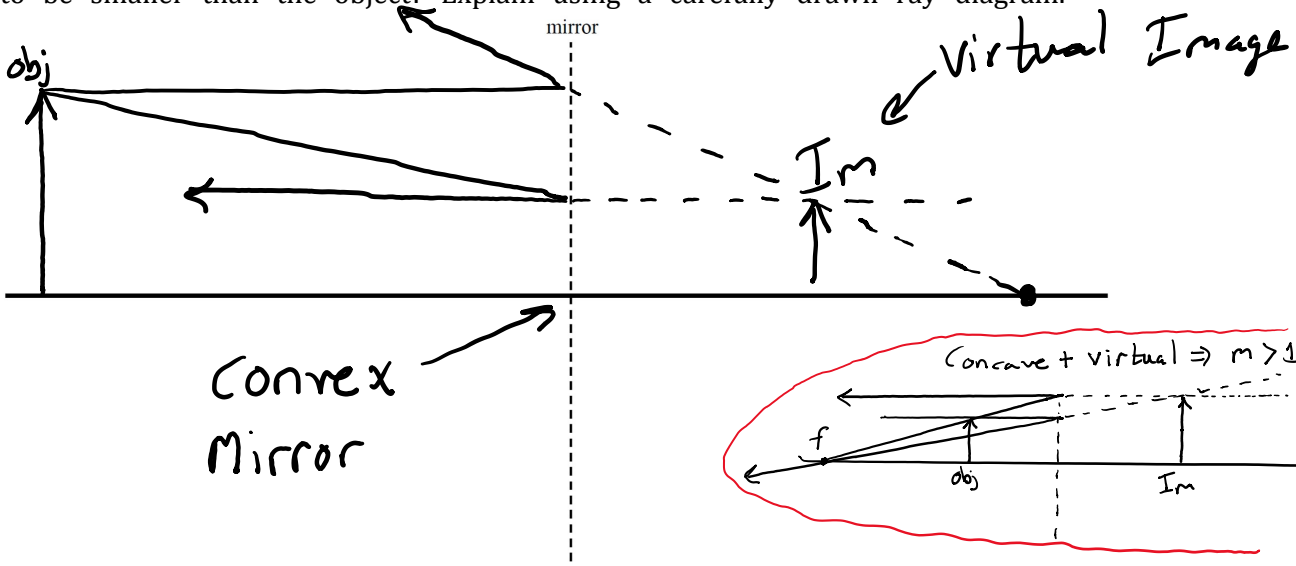
1. (6 points) In the USA, the side mirrors of cars have a warning printed on them that say "Objects in mirror may be closer than they appear." This warning is due to the image being smaller than the object.

(a) Does a car side mirror create a real or virtual image?

Virtual



(b) In this situation, what type of mirror (plane, concave, convex) would cause an image to be smaller than the object? Explain using a carefully drawn ray diagram.



For questions 2 through 5 **fill in the square** next to all correct answers, a given problem may have more or less than one correct answer. Each correctly chosen 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.

2. A diffraction grating with slit spacing of 10 slits per mm is made of individual slits of width 10 μm. Each individual slit creates a diffraction pattern, as does the diffraction grating as a whole. Compare the width of the central maximum due to the individual slits, $W_{individual}$, with the width between maximums of the diffraction pattern from the grating, $W_{grating}$.

$W_{individual} = W_{single\ slit} = 2\frac{L\lambda}{a}$

$W_{grating} = y_{m+1} - y_m = (m+1)\frac{L\lambda}{d} - m\frac{L\lambda}{d} = \frac{L\lambda}{d}$

$d = \frac{1\ mm}{10\ slits} = (10^{-1})(10^{-3}\ meters) = 10^{-4}\ m = 100\ \mu m$

$a = 10\mu m \Rightarrow d = 10a \Rightarrow$ $W_{individ} = 2\frac{L\lambda}{a}$, $W_{grating} = \frac{1}{10}\frac{L\lambda}{a}$ $\Big\} W_i = 20\,W_g$

a) $W_{individual} = 20W_{grating}$

b) $W_{individual} = 5W_{grating}$

c) $W_{individual} = 2W_{grating}$

d) $W_{individual} = \frac{1}{2}W_{grating}$

e) $W_{individual} = \frac{1}{5}W_{grating}$

f) $W_{individual} = \frac{1}{20}W_{grating}$

g) Can't solve exactly because these are not small angles

3. Which of the following combinations of optical elements CANNOT form a real image?

a) A converging lens followed by a diverging lens

b) A diverging lens followed by a converging lens

c) A converging lens followed by a convex mirror

d) A diverging lens followed by a plane mirror

e) A converging lens followed by a plane mirror

f) A diverging lens followed by a concave mirror

g) All of the above combinations can make a real image

4. A diverging lens is made of a highly dispersive glass. Two toy dinosaurs are placed 10 cm to the left of the lens. One dinosaur is red, the other is blue. Which of the following statements is true?

a) The image of the red dinosaur appears to the left of the blue dinosaur image.

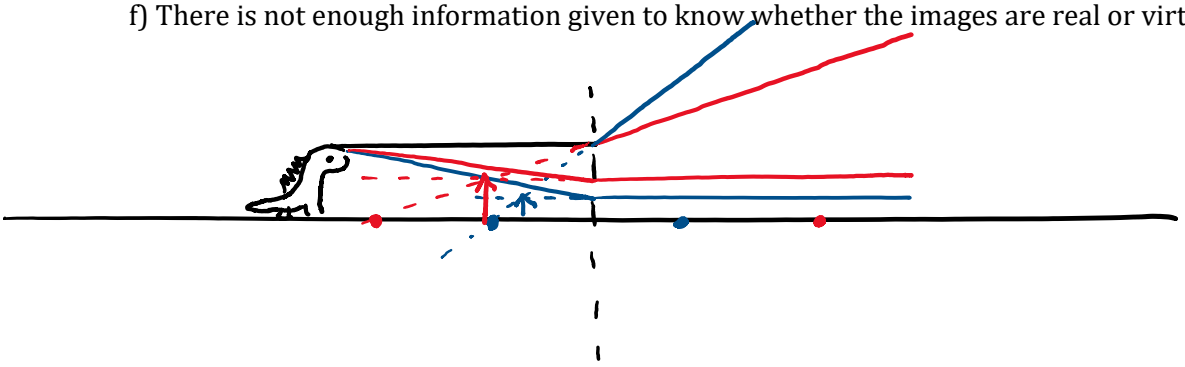
b) The image of the blue dinosaur appears to the left of the red dinosaur image.

c) Both images appear at the same location.

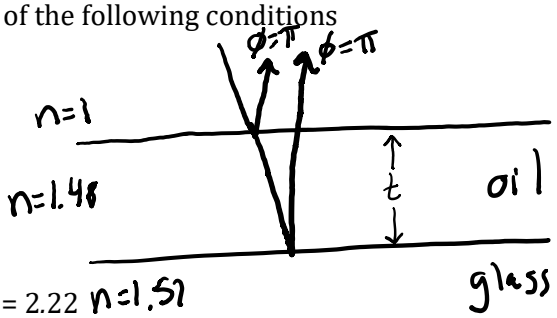
d) Both images are real.

e) Both images are virtual.

f) There is not enough information given to know whether the images are real or virtual.



5. A thin film of oil is spread on a glass plate. A laser of λ = 700 nm is normally incident on the oil side of the plate and has **maximal** reflection. Which of the following conditions could make a laser of λ = 350 nm have **minimal** reflection?



a) Leave the setup as it is.

b) Make the oil thickness 1.5 times as thick.

c) Double the thickness of oil.

d) Halve the thickness of oil.

e) Replace oil with an identical thickness of something with n = 2.22

f) Replace oil with an identical thickness of something with n = 1.85

g) Replace oil with an identical thickness of something with n = 1.11

$\phi = 0$ for ray reflected off glass!!

smallest $t \Rightarrow 2t = \lambda_{oil}^{700} = \frac{700\times10^{-9}}{n_{oil}} = 2\lambda_{oil}^{350}$ $\qquad \lambda_{oil}^{350} = \frac{350}{1.48}\times10^{-9} = 236.5$

$\Rightarrow t = \frac{350}{1.48}\times10^{-9} = 236.5$

constructive interference
- if left alone
- if t doubles
- if t halves
- if $t \to 1.5\,t$

conditions for const/dest. are flipped for e, f

$n = 2.22 \Rightarrow \lambda_{oil}^{350} = \frac{350}{2.22}\times10^{-9} = 159.1\,nm \Rightarrow 2t = 3\lambda_{oil}^{350} \Rightarrow$ destructive interference

$n = 1.85 \Rightarrow \lambda_{oil}^{350} = 189\,nm \Rightarrow 2t = 2.5\lambda_{oil}^{350} \Rightarrow$ constructive interference

$n = 1.11 \Rightarrow \lambda_{oil}^{350} = 315\,nm \Rightarrow 2t = 1.5\lambda_{oil}^{350} \Rightarrow$ destructive interference

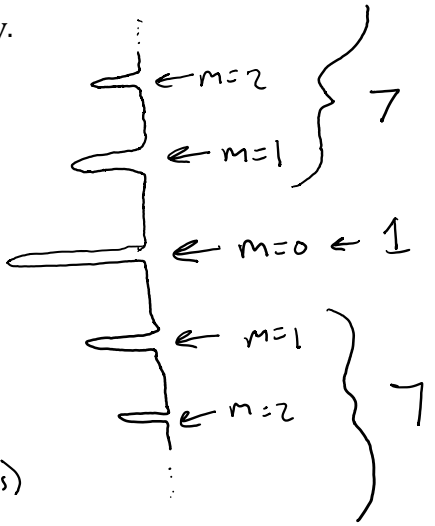
6. (10 points) A 475 nm wavelength laser produces a diffraction pattern using a diffraction grating of slit spacing D. What is the range of values D can have that will produce exactly 15 bright spots on a screen 10.0 meters away.

3.33 μm < D < 3.80 μm

$m\lambda = d\sin\theta$

$\Rightarrow \sin\theta = m\frac{\lambda}{d}$

15 fringes means →



if $m = 7$ makes $\theta \to 90°$, the 7th fringes disappear (only 13 fringes)

So: $\sin 90° = 7\frac{\lambda}{d}$

$\Rightarrow d = 7\lambda \Rightarrow d = 3.33\,\mu m$

if $m = 8$ makes $\theta \to 90°$ then the 8th fringes will appear ⇒ 17 fringes

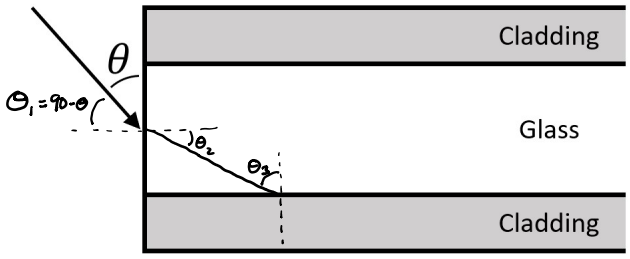
so upper limit $d = 8\lambda = 380\,nm$

8. (6 points) Fiberoptic cables send information via light pulses under entire oceans with almost zero loss. They are made of a central glass core surrounded by cladding in which light travels 82.6% of the speed of light in a vacuum. A laser is incident at an angle theta with respect to the air-glass surface at the end of a fiber optic cable.

a) What is the smallest angle theta that produces total internal refraction at the glass-cladding surface inside the cable?

$n_c = \frac{c}{.826c}$

$n_c = 1.21$



$n_g \sin\theta_3 = n_c \; 1$

$\theta_3 = \sin^{-1}\left(\frac{1.21}{1.51}\right)$

$\theta_3 = 53.3°$

$\theta_2 = 90 - \theta_3$

$= 36.7°$

$n_{air} \sin\theta_1 = n_g \sin\theta_2$

$\sin\theta_1 = 1.51 \sin(36.7)$

$\theta_1 = 64.6°$

$\theta = 90 - 64.6°$

$\theta = 25.4°$

8. (10 points) You can change the shape of the lens inside your eye to create an image on the back of your eye (your retina) of objects at different distances. Since your eye does not change size and the image needs to be made on the retina, the image distance must stay the same. Your near point is the shortest distance from the lens in your eye to an object for which you can make a clear image on your retina. A human with good vision will have a near point of 25 cm. The average eye length from front to back is 24 mm.

Assume that your lens is at the front of your eye, the lens is a spherical thin lens, and that your eye is made of air except for the lens.

a) When looking at an object placed at her near point, what is the focal length of an average human's lens?

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad \frac{1}{0.25} + \frac{1}{0.024} = \frac{1}{f}$$

$$\Rightarrow f = 21.9 \text{ mm}$$

b) What is the focal length of her lens when looking at the moon? (hint: the moon is REALLY far away)

$$\frac{1}{\infty} + \frac{1}{d_i} = \frac{1}{f} \Rightarrow f = d_i = 0.024 \text{ m}$$

$$f = 24 \text{ mm}$$

Hyperopia occurs when your eye is too short. The lens is still limited to the same range curvatures.

c) If somebody has an eye length of only 23 mm, what is their near point?

$$\frac{1}{d_o} + \frac{1}{0.023} = \frac{1}{0.0219}$$

$$d_o = 45.7 \text{ cm}$$

d) You are an eye doctor in charge of prescribing glasses for this hyperopic person. If glasses rest 2.5 cm from the eye, what focal length should you prescribe to correct their near point?

obj → normal near point $\quad d_o = 25\text{cm} - 2.5$

image → hyperopic near point $\quad d_i = -(45.7\text{cm} - 2.5\text{cm})$

$$\frac{1}{.225} + \frac{1}{-.432} = \frac{1}{f}$$

$$f = 47.0 \text{ cm}$$