Last Name:_____First Name_____Network-ID_____

Discussion Section:_____Discussion TA Name:_____

Turn off your cell phone and put it out of sight.
Keep your calculator on your own desk. Calculators cannot be shared.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the **center** of its circle.

2. You may find this version of t**his Exam Booklet at the top of page 2**. Mark the **version** circle in the **TEST FORM** box near the bottom right on the face of your answer sheet. **DO THIS NOW!**

3. Print your **NETWORK ID** in the designated spaces at the *right* side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

4. Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

5. Print your UIN# in the **STUDENT NUMBER** designated spaces and mark the corresponding circles. You need not write in or mark the circles in the **SECTION** box.

6. Sign your name **(DO NOT PRINT)** on the **STUDENT SIGNATURE** *line*.

7. On the **SECTION** *line*, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. You should have 16 ***numbered pages*** *plus three Formula Sheets.*

Academic Integrity—**Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box near the bottom right on the face of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **110** points, composed of three types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

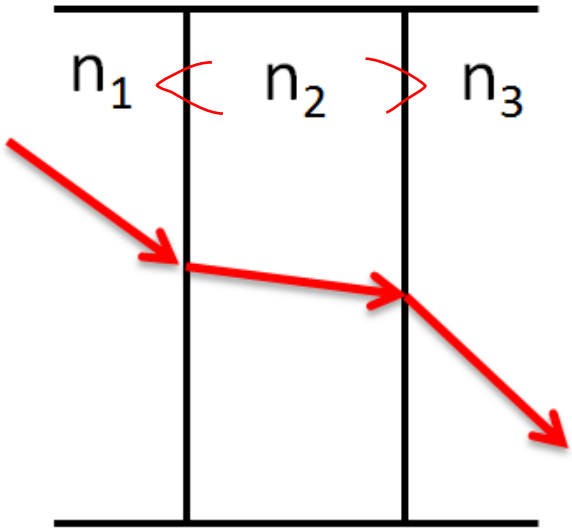
MC2: *multiple-choice-two-answer questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

Some helpful information:

- A reminder about prefixes: p (pico) = 10^{-12}; n (nano) = 10^{-9}; μ (micro) = 10^{-6}; m (milli) = 10^{-3}; k (kilo) = 10^{+3}; M or Meg (mega) = 10^{+6}; G or Gig (giga) = 10^{+9}.

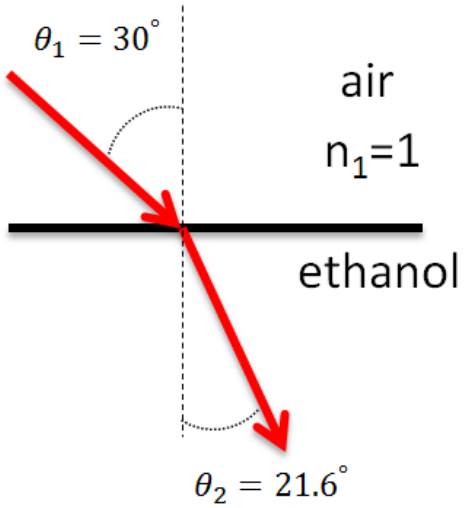
1. A ray of light passes through three materials with different indices of refraction n_1, n_2, and n_3, as shown below.



Which of the following statements is correct?

a. n1>n2
b. n2>n3
c. n1=n2

2. A laser beam passes from air into a container of ethanol and refracts, as shown below. What is the speed of light in ethanol?



Snell's law
n1 sin theta1 = n2 sin theta2

The angles are measured from the normal direction (as always wrt a surface)

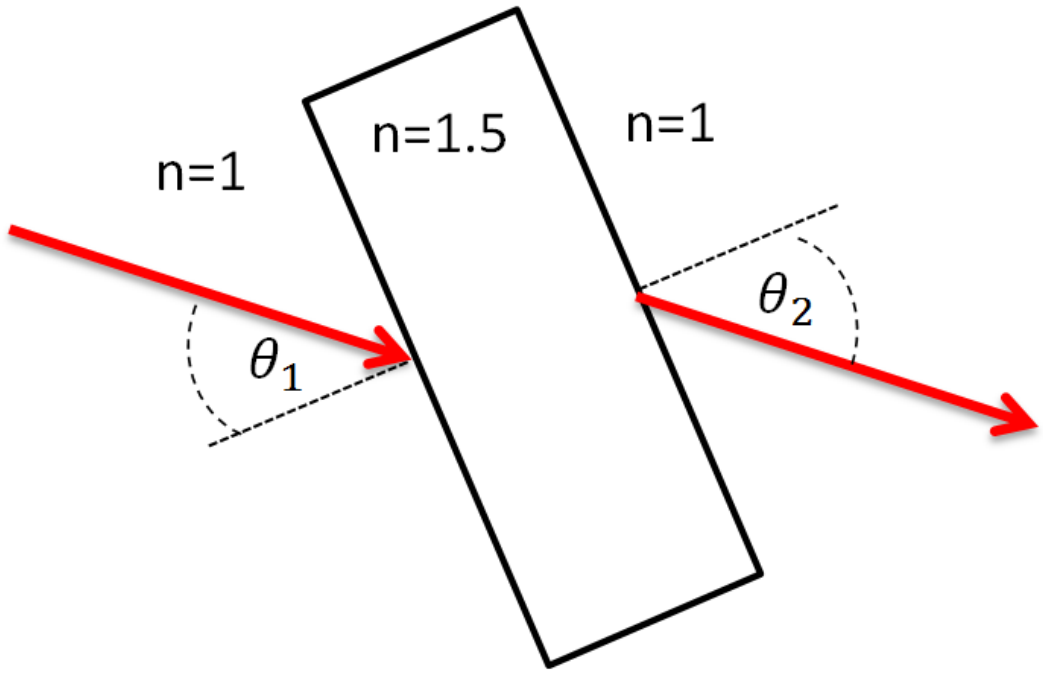
v = c/n

n sin 21.6 = sin 30 -> n = 1.358

v = c/n = 3x10^8/1,358 = 2.208 x 10^8 m/s

a. 2.11×10^8 m/s
b. 2.8×10^8 m/s
c. 3.0×10^8 m/s
d. 2.21×10^8 m/s
e. 4.07×10^8 m/s

3. A laser beam traveling in air enters and exits a piece of glass with an index of refraction of 1.5, as shown below.



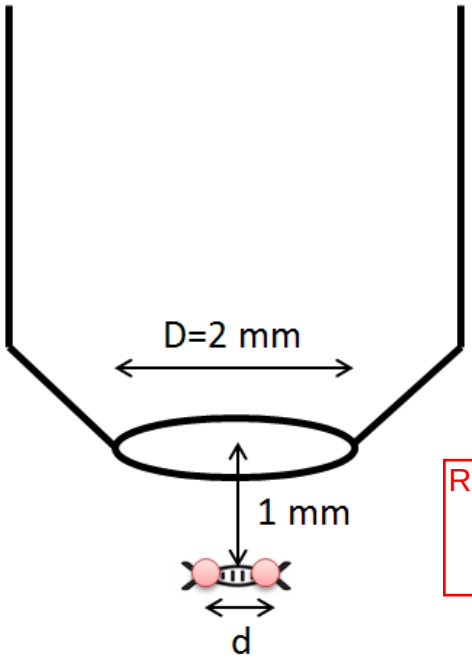
If the angle θ_1=60 degrees, what is θ_2, the angle with respect to the normal on the side of the glass where the beam exits?

You should remember that light can retrace its own ray.

a. θ_2=30 degrees
b. θ_2=60 degrees
c. θ_2=35 degrees

The next two questions pertain to the following situation.

A microscope is used to image two fluorescent markers that are attached to a strand of DNA. The markers emit light at 650 nm and are 1 mm from the lens in the microscope objective. The diameter of the microscope lens *D*=2 mm.



Rayleigh's criterion
D sin theta = 1.22 lambda

4. What is the minimum distance *d* between the markers for which they can be resolved?

a. 400 nm
b. 790 nm
c. 1600 nm
d. 330 nm
e. 100 nm

tan theta = d/1x10^{-3}
sin theta = 1.22 x 650 x 10^{-9}/2x10^{-3}.
Therefore,
theta = sin^{-1} 396.5x10^{-6} = 396.5x10^{-6} (rad),
so
d = 1x10^{-3} theta = 1x10^{-3} x 396.5 x 10^{-6}
= 396.5 x 10^{-9}

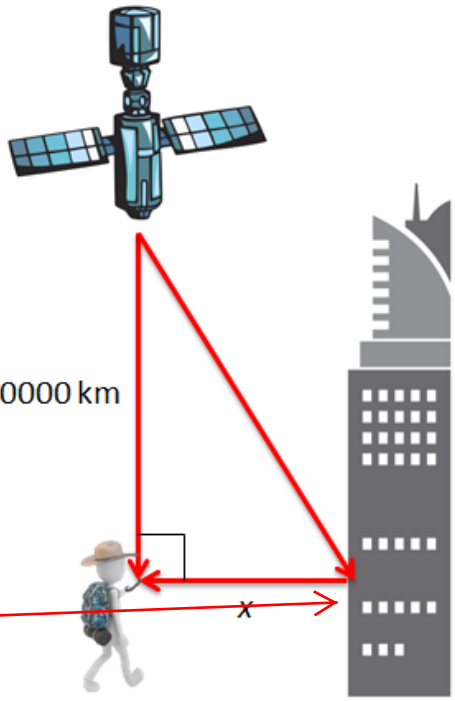
5. What could you do to decrease *d*, i.e., improve the resolving power of the microscope?

a. decrease *D*
b. use markers that emit light at 532 nm
c. use markers that emit light at 800 nm

to make theta smaller.

The next two questions pertain to the following situation.

A GPS satellite in an orbit 20,000 km above the surface of the earth sends signals as an electromagnetic wave with a frequency of 1575 MHz to a receiver. The signal takes two paths, as shown in the picture below. One path goes straight to the receiver, and another bounces off of a building first. The person stands a distance *x* from the building. *Hint*: approximate the distance from the satellite to the building as 20,000 km.



I believe this and the nest problems have some serious problems

pi phase shift here? If we ignore this, we can solve the problems as follows.

c = f x lambda

6. What is a distance *x* for which the electromagnetic waves from the two paths constructively interfere?

a. 0.286 m
b. 3.810 m
c. 5.205 m

`Constructive' means that x is an integer multiple of the wavelength.
lambda = c/f = 3x10^8/1575x10^6 = 0.19047 m
3.810 = 20 lambda
0.286 = 1.5 lambda
5.205 = 27.3 lambda

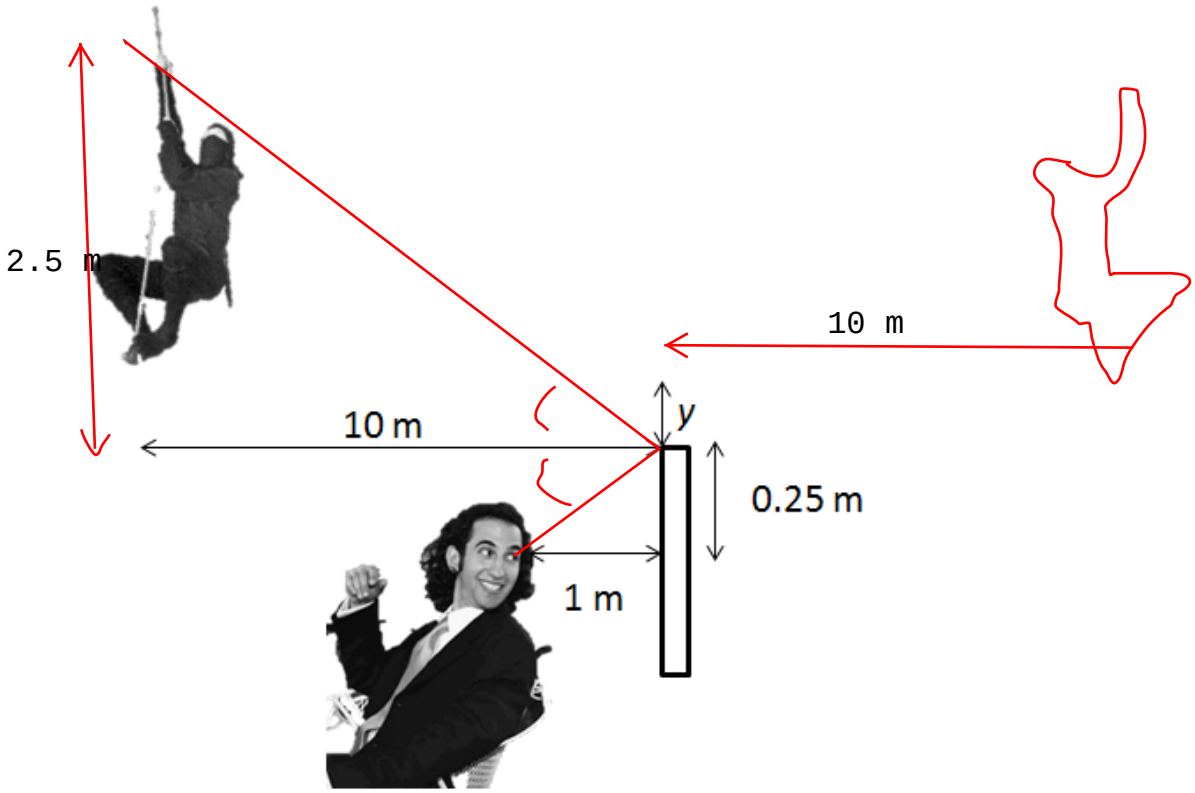
7. What is the smallest distance *x* for which the electromagnetic waves from the two paths destructively interfere?

a. 0.19 m
b. 0.381 m
c. 2.627 m
d. 5.254 m

e. 0.095 m half the wave length

The next two questions pertain to the following situation:

As shown below, a ninja assassin hired by Physics 102 students is trying to sneak up on Professor DeMarco while he admires his hair in a mirror. The ninja is 10 m from the mirror, and Professor DeMarco is 1 m from the mirror. Professor DeMarco's eyes are 0.25 m below the top of the mirror.



8. What is the minimum distance *y* that the ninja has to be above the top of the mirror so that Prof. DeMarco cannot see him?

y/10 = 0.25/1

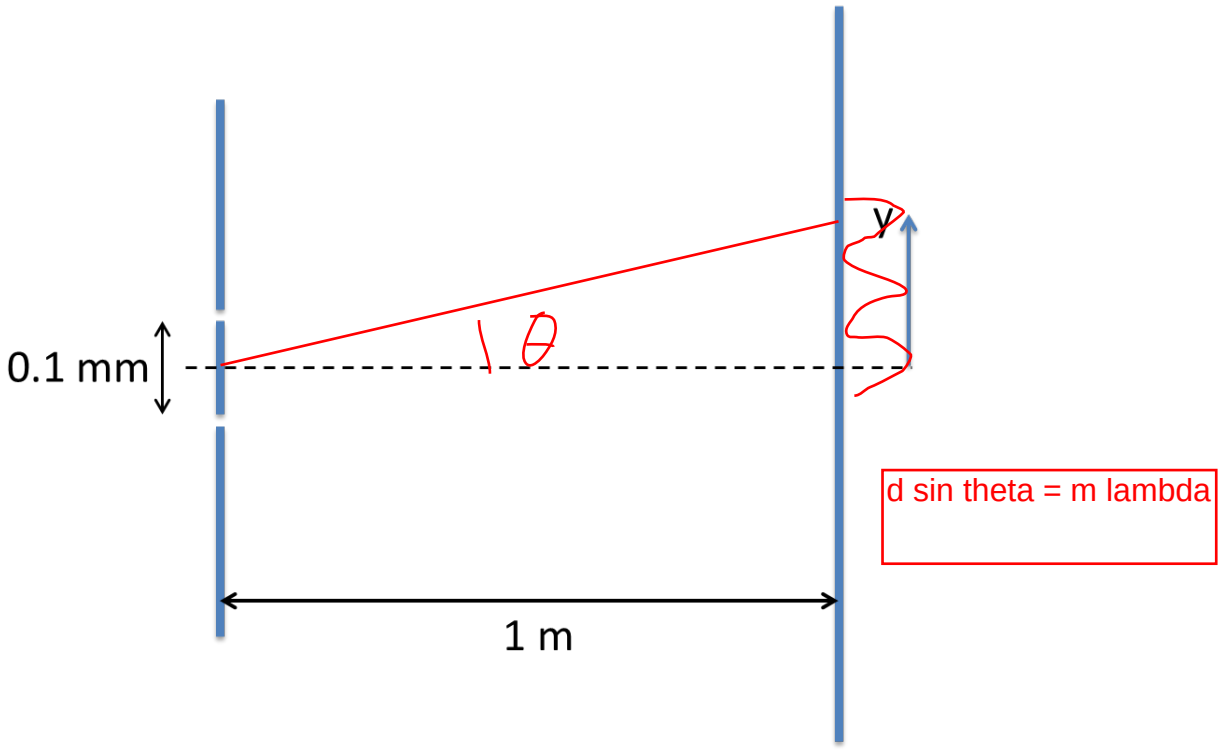
a. 2.5 m
b. 0.025 m
c. 0.25 m
d. 10 m
e. Professor DeMarco will be able to see the ninja for any height *y*.

9. If the ninja is visible in the mirror, what is the horizontal distance between Professor DeMarco and the image he sees of the ninja in the mirror?

a. 1 m
b. 10 m
c. 11 m

The next two questions pertain to the following situation.

A double slit experiment with slit separation 0.1 mm is illuminated by light with wavelength λ. The second order bright fringe for constructive interference is located at y = 1 cm, where y is measured from the dashed line.



10. What is the wavelength λ?

```
tan theta = 1/100
lambda = d sin theta/2 = 0.1x10^{-3}/200
       = 0.05x10^{-5} = 5 x 10{-7} m
```

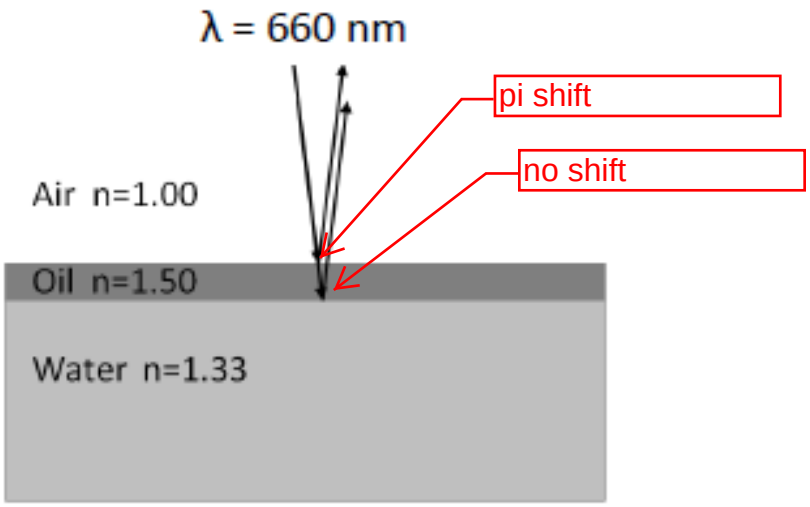
a. 250 nm
b. 333 nm
c. 425 nm
d. 500 nm
e. 667 nm

11. The location y = 0 cm is always a point of destructive interference, independent of the slit separation.

a. True
b. False

The next two questions refer to the following situation:

A beam of red light (∧ = 660 nm) is incident on a pool of water (n = 1.33). There is a thin film of vegetable oil (n = 1.5) on top of the water. The light is incident normal to the surface. The angles are exaggerated for clarity.



constructive -> phase difference = 2 pi times integers

12. What is the minimum thickness of the film that will result in constructive interference for the reflected light? Assume that the air above the film has an index of refraction of n = 1.0.

a. 11 nm
b. 22 nm
c. 110 nm
d. 220 nm
e. 330 nm

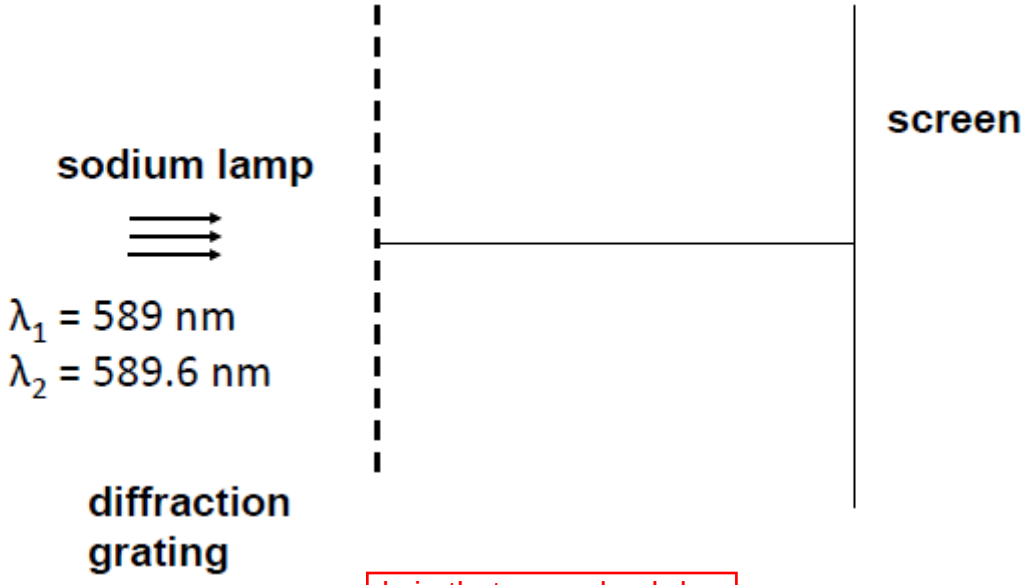
wavelength in the medium = 660/1.5 = 440 nm.
The round trip in the oil layer corresponds to half a wavelength -> t = lambda/4 = 110 nm

13. If you doubled the thickness of the oil film compared with your answer to question 12, you would see

a. constructive interference for the reflected light.
b. destructive interference for the reflected light. because now the phase difference is pi x 2.
c. neither constructive or destructive interference for the reflected light.

The next two questions pertain to the following situation:

Light from a sodium lamp has two emission lines with wavelengths of 589.0 nm and 589.6 nm. The light from a sodium lamp is studied with a diffraction grating. The slits of the grating have a separation of 2 μm.



d sin theta = m lambda

14. At what angle is the first-order maximum for the emission line with a wavelength of 589.0 nm observed?

a. 0 °
b. 17.13 °
c. 24.26 °
d. 30.0 °
e. 36.2 °

```
d = 2 x 10^{-6} m, m = 1, lambda = 589 x 10^{-9}
theta = sin^{-1}(589 x 10^{-9}/2x10^{-6}) = 17.127 deg.
```

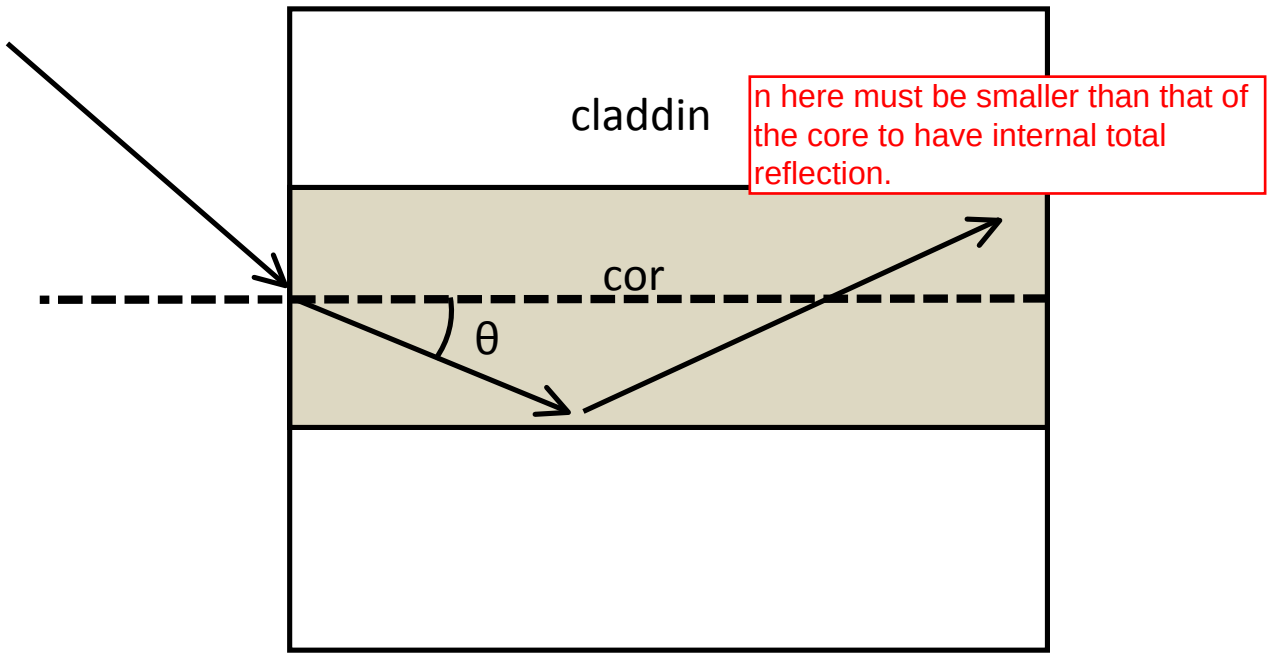
15. What is the difference in angle between the second order maxima for the two wavelengths?

a. 0.018 °
b. 0.037 °
c. 0.043°
d. 0.009°
e. 0.056°

```
theta = sin^{-1}(2x589x10^{-9}/2x10^{-6}) = 36.086 deg
theta' = sin^{-1}(2x589.6x10^{-9}/2x10^{-6}) = 36.1286 deg
difference = 0.0426 deg
```

The next two questions refer to the following situation:

An optical fiber consists of a small cylinder of optically transparent plastic called the core, shown in gray, surrounded by a layer of different plastic called the cladding. The two plastics used for the core and the cladding have different indices of refraction. The index of refraction of the core is n=1.45. Light rays enter the fiber and propagate in the fiber as shown. The maximum angle Θ with which a ray can propagate in the core of the fiber and totally internally reflect from the cladding is 10 degrees.



n here must be smaller than that of the core to have internal total reflection.

16. What is the index of refraction of the cladding?

a. 1.450
b. 1.428
c. 1.472

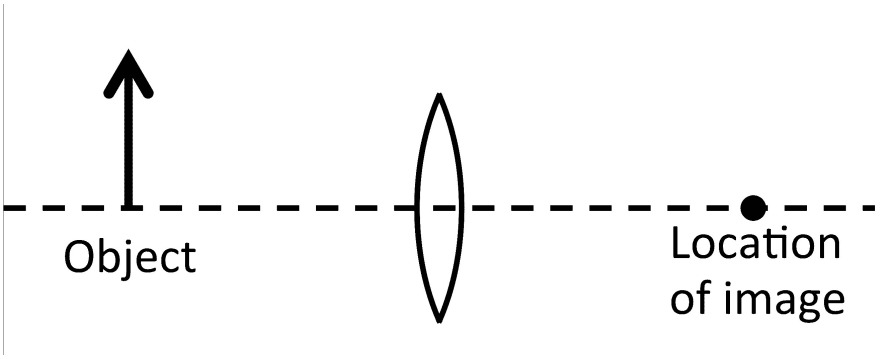
sin theta_c = n2/n1

17. The fiber is now placed in a bath of oil. The oil has an index of refraction of n=1.5. Which of the following statements is true for light that travels in the core at a Θ larger than 10 degrees?

a. The light will exit from the core to the cladding and then from the cladding into the oil.
b. The light will reflect from the surface between the core and the cladding and stay in the core.
c. The light will exit from the core but totally internally reflect from the surface between the oil and cladding.

```
1.45 sin theta_c = 1.428 -> theta_c = 80.0065, so
Theta > 10 means total reflection does not occur.
No total reflection at the cladding-oil
boundary.
```

The following two questions refer to the following situation.



1/f = 1/do + 1/di

18. Where must one put an object with respect to the convex lens (which has focal length *f*), so that the image is at the same distance from the lens as the object?

a. $d_{obj} = \frac{1}{2} f$
b. $d_{obj} = f$
c. $d_{obj} = 2f$

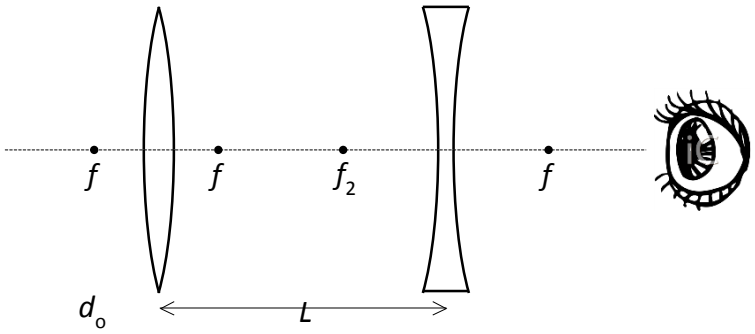
do = di -> 1/f = 2/do -> do = 2f.

m = -di/do

19. What is the magnification, *m*?

a. $m = -\frac{1}{2}$
b. $m = +\frac{1}{2}$
c. $m = -1$
d. $m = -2$
e. $m = +2$

20. A two-lens apparatus consists of a convex lens with focal length f_1 = +5 cm and a concave lens with focal length f_2 = -10 cm. The lenses are separated by L = 30 cm.



1/f = 1/do + 1/di

If an object is placed a distance d_o = 15 cm from the convex lens, where is the image that the person (eyeball) sees?

a. 6.9 cm to the left of the concave lens
b. 6.9 cm to the right of the concave lens
c. 18 cm to the left of the concave lens
d. 18 cm to the right of the concave lens
e. 22.5 cm to the left of the concave lens

```
The first lens
  1/di = 1/f - 1/do = 1/5 - 1/15 = 1/7.5
This image behaves as a real object for the
second lens: do = 30 -7.5 = 22.5 m
  1/di = -1/10 -1/22.5 = -1/6.923
This is virtual, so behind lens 2.
```

21. A shaving mirror has a +20 cm focal length. How far, d_{face}, must your face be from the mirror in order that your image is twice as large as your face?

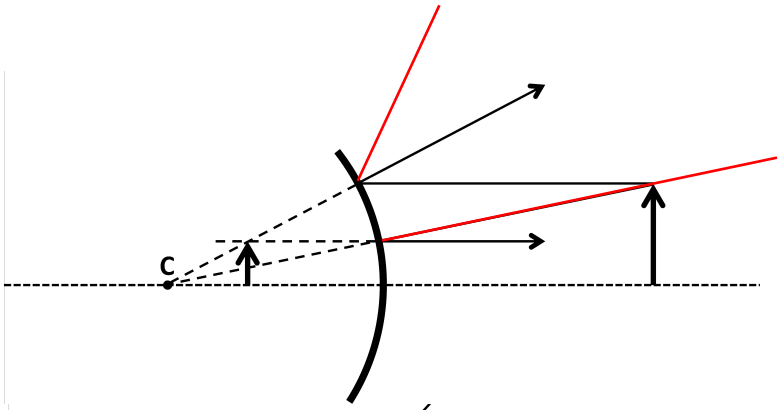
1/f = 1/do + 1/di
m = -di/do

a. d_{face} = 10 cm
b. d_{face} = 20 cm
c. d_{face} = 40 cm
d. d_{face} = 60 cm
e. It is not possible to form an image that is twice as large as your face.

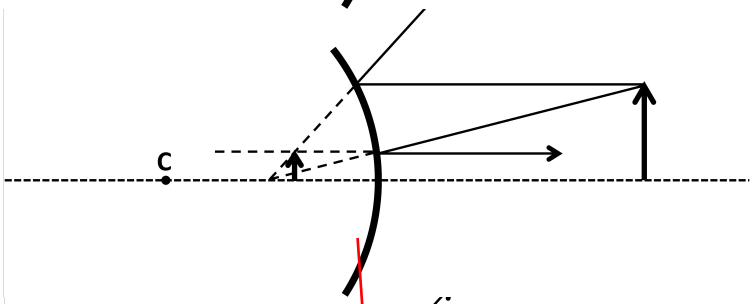
```
f = 20, m = 2, so di =-2do, so 1/f = 1/do -1/2do = 1/2do
or f = 2do -> do = 10 cm
```

22. An object is in front of a shiny spherical surface that is a convex mirror. The letter "**C**" marks the center of curvature. Which of these ray diagrams correctly describes the image location?

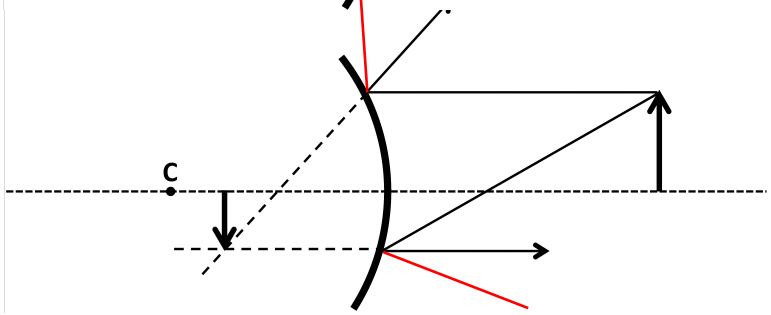
a.



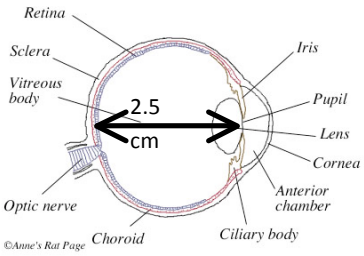
b.



c.



23. The diameter of the human eye is about 2.5 cm. One college student can focus on objects that are 10 cm in front of her face. What is the focal length, *f*, of her eye's lens when she is doing that?



a. $f =$ -5.00 cm
b. $f =$ -3.33 cm
c. $f =$ +1.25 cm
d. $f =$ +2.00 cm
e. $f =$ +2.50 cm

```
1/f = 1/10 + 1/2.5
    = 1/2
```

24. When you are young, your near point is 25 cm. Suppose an older person's near point has increased to 60 cm. What strength reading glasses, in diopters, must this person buy to regain the original 25 cm near point?

a. 0.42 diopters
b. 1.40 diopters
c. 2.33 diopters
d. 3.33 diopters
e. 5.67 diopter

```
Young eye : 4 D
Old eye: 1.666D, so 4 - 1.666 = 2.333 D
correction is needed.
```

Check to make sure you bubbled in all your answers.
Did you bubble in your name, exam version and network-ID?