

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 the version of **this 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 14 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 **117** 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.

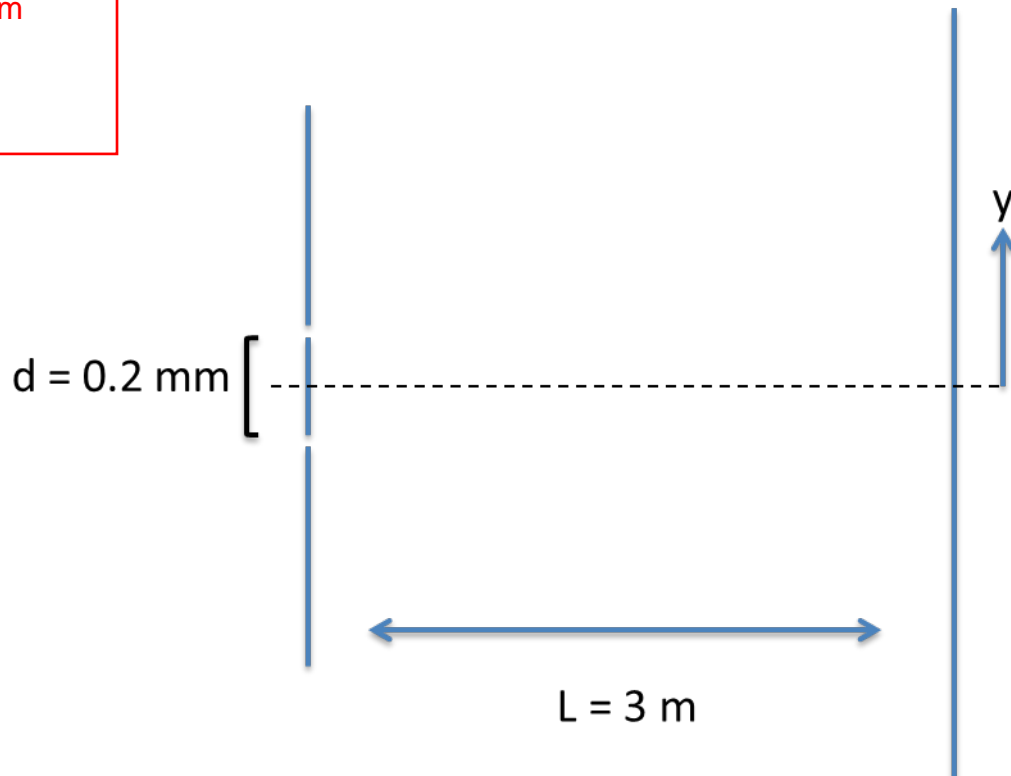
Some helpful information:

- 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} .

The next two questions pertain to the following situation.

A double slit experiment with slit separation 0.2 mm is illuminated by light with wavelength λ . The third order bright fringe for constructive interference is located at $y = 3 \text{ cm}$, where y is measured from the dashed line.

$$d \sin \theta = m \lambda$$



1. What is the wavelength λ ?

- a. 233 nm
- b. 340 nm
- c. 450 nm
- d. 566 nm
- e. 667 nm

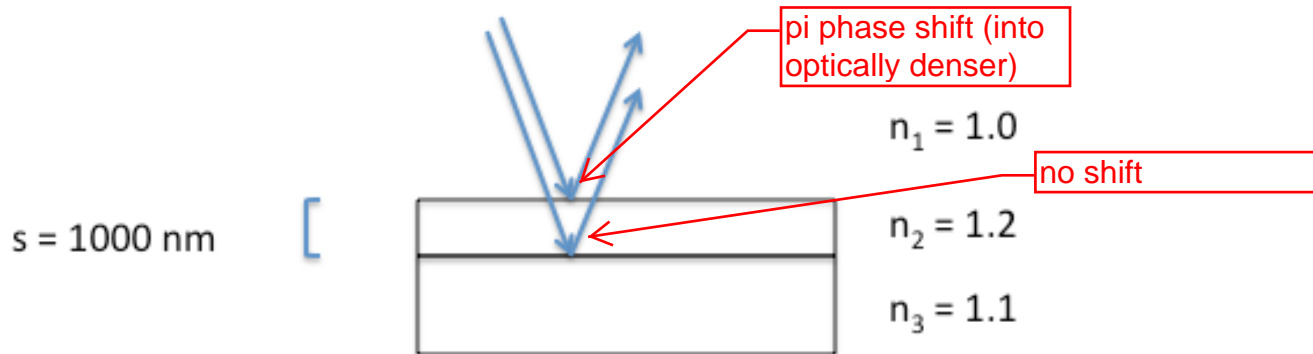
$$\begin{aligned} \lambda &= d \sin \theta / 3 \\ &= 0.2 \times 10^{-3} \cdot 0.03 / (3 \times 3) \\ &= (2/3) \times 10^{-6} \\ &= 667 \times 10^{-9} \end{aligned}$$

2. The location $y=0$ is always a point of constructive interference, independent of the slit separation.

- a. True
- b. False

The next two questions pertain to the following situation.

A thin film with index of refraction $n_2 = 1.2$ lies between a piece of plastic with $n_3 = 1.1$ and air ($n_1 = 1$). The thickness of the film is $s = 1000$ nm. White light illuminates the film from above and is reflected for some wavelengths of light in the visible spectrum ($\lambda = 400$ nm to 700 nm).



3. Which wavelengths correspond to the visibly reflected light?

- a. 419 nm, 618 nm
- b. 560 nm, 699 nm
- c. 436 nm, 533 nm
- d. 555 nm, 696 nm
- e. 411 nm, 650 nm

visible \rightarrow constructive interference

Due to the shift by π , so the optical path length difference should be λ (in the medium) times $(n + 1/2)$. $2000 \times 1.2 = 2400$ nm is the optical path length difference: $2400 / (n + 0.5)$ gives possible wavelength (in vacuum):

686, 533, 436, 369, 320...

4. The plastic with index of refraction $n_3 = 1.1$ is changed to a material with index of refraction $n_3 = 1.4$. Which of the following answers best describes the wavelengths which provide visibly reflected light?

- a. 450 nm, 550 nm
- b. 420 nm, 632 nm
- c. 522 nm, 665 nm
- d. 511 nm, 699 nm
- e. 480 nm, 600 nm

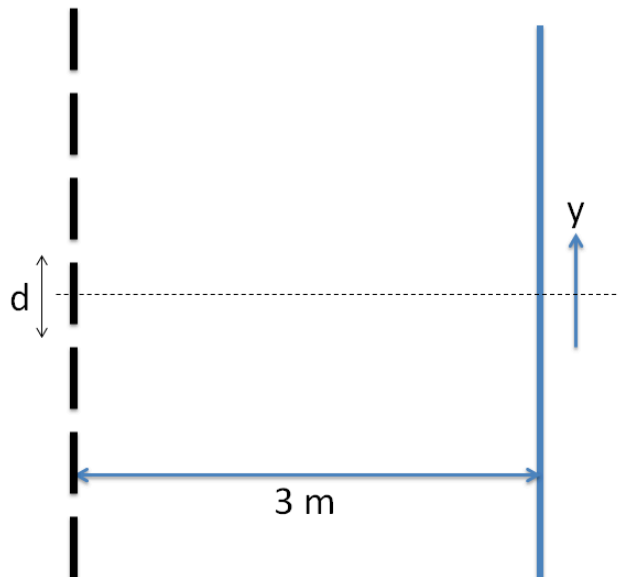
Now, there is no shift of phase due to reflection from any boundary.

$2400/n$ gives possible wavelength (in vacuum):

600, 480, 400, 345, 300...

The next two questions pertain to the following situation.

The third order bright fringe for constructive interference for a diffraction grating with a screen 3 m away is located at $y = 10.4$ cm when illuminated with light of wavelength $\lambda = 420$ nm. The vertical distance y is measured from the dashed horizontal line.



$$d (y/L) = m \lambda$$

5. What is the slit separation of the diffraction grating?

- a. 36.3 μm
- b. 50.2 μm
- c. 61.5 μm
- d. 72.2 μm
- e. 80.8 μm

$$\begin{aligned} d &= 3 \times 420 \times 10^{-9} \times 3 / 0.104 \\ &= 36346 \times 10^{-9} = 36.3 \times 10^{-6} \text{ m.} \end{aligned}$$

6. The wavelength of the light is changed by immersing the diffraction grating experiment in a transparent medium with index of refraction $n = 1.31$. What is new vertical distance y' of the third order bright fringe for constructive interference?

- a. 10.1 cm
- b. 13.1 cm
- c. 7.9 cm

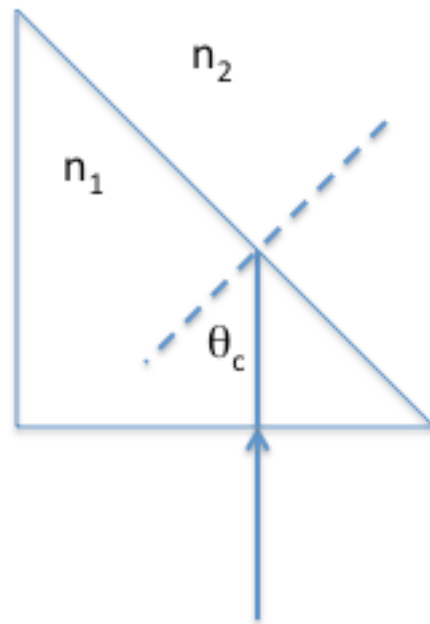
$$\lambda \rightarrow \lambda/n$$

In the formula d , L , m do not change, but λ is scaled, so y must also be scaled in the same way

$$10.4/1.31 = 7.938 \text{ cm}$$

The next two questions pertain to the following situation.

The critical angle for total internal reflection from a prism with index of refraction $n_1 = 2.5$ is $\theta_c = 33^\circ$.



$$n_1 \sin \theta_c = n_2$$

7. What is the index of refraction (n_2) of the material in which the prism is immersed?

- a. 2.65
- b. 1.78
- c. 1.53
- d. 1.36**
- e. 1.22

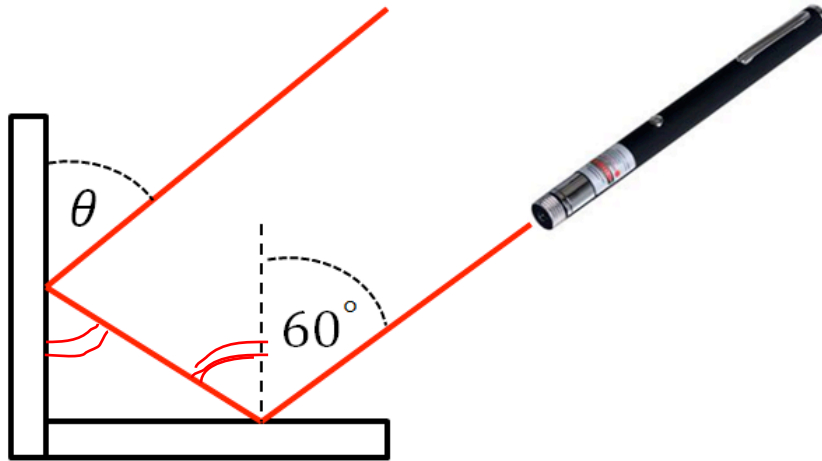
$$\begin{aligned} n_2 &= n_1 \sin \theta_c \\ &= 2.5 \sin 33 = 1.36 \end{aligned}$$

8. The index of refraction of the prism remains the same while the index of refraction of the outside material decreases. The critical angle

- a. increases.
- b. decreases.**
- c. remains the same.

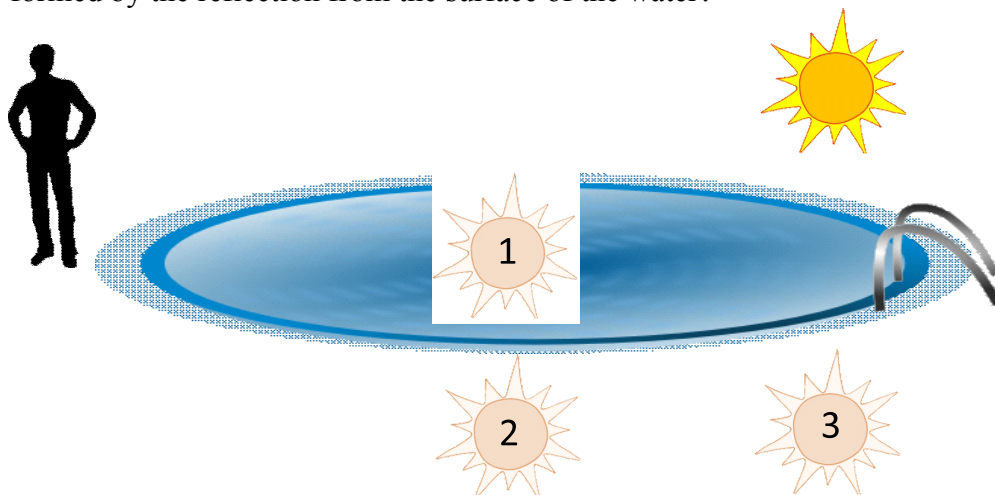
$$\begin{aligned} n_1 \sin \theta_c &= n_2 \\ \text{and } n_2 \text{ decreases, so is } \theta_c. \end{aligned}$$

9. Two mirrors are glued together at a 90° angle, as shown below. A laser beam is incident on one mirror at a 60° angle. What is the angle θ indicated in the diagram?



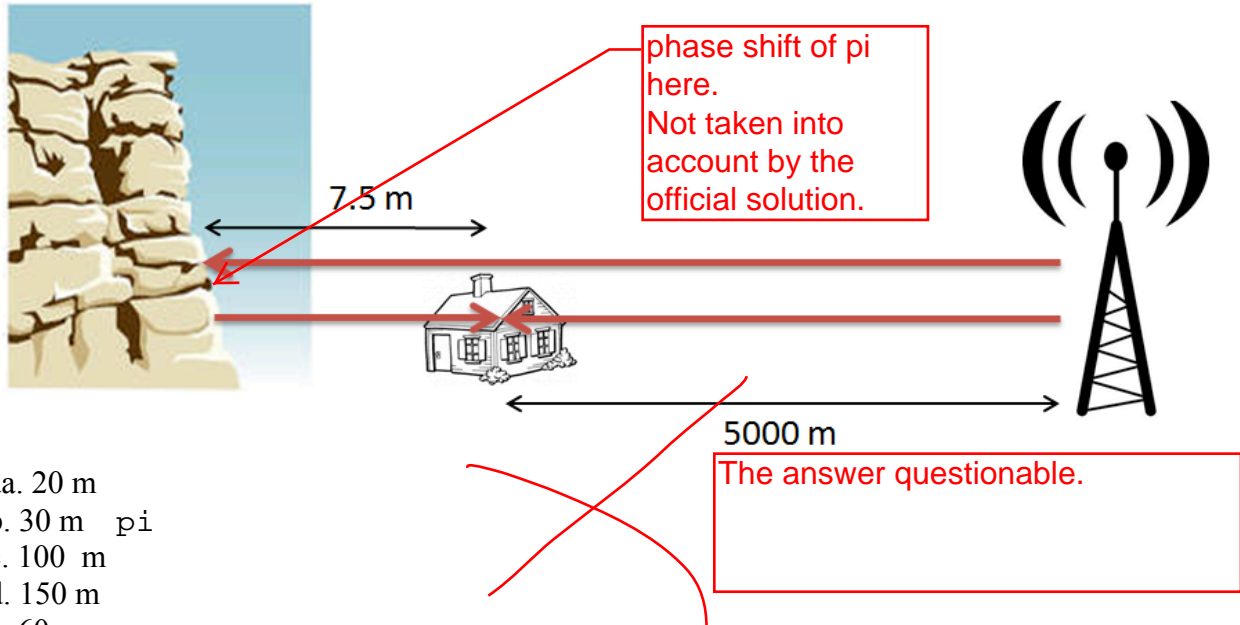
- a. 30°
- b. 60°
- c. 45°

10. A person is standing at the edge of a pool watching the sun set, as shown in the figure below. The surface of the water acts like a plane mirror. Which picture best shows where the image of the sun is formed by the reflection from the surface of the water?



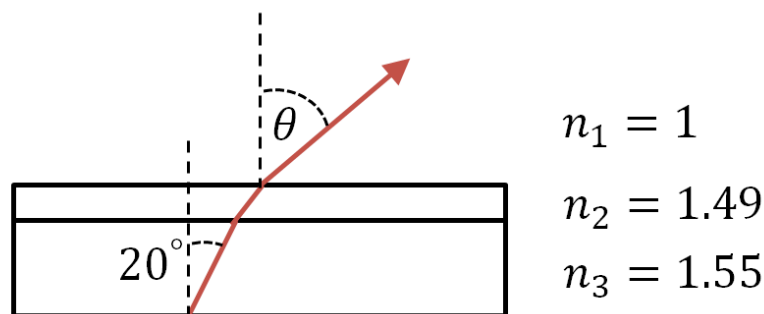
- a. 1
- b. 2
- c. 3

11. As shown in the figure below, you are in your house trying to listen to a broadcast from a radio tower that is 5000 m away. The radio waves from the station can take two paths to your house: the waves can travel directly to your house from the station, or the waves can first reflect from a nearby cliff that is 7.5 m away. You discover that you cannot listen to the station because there is complete destructive interference for these two paths. What could be the wavelength of the electromagnetic wave that is broadcast by the station?



- aa. 20 m
- b. 30 m π
- c. 100 m
- d. 150 m
- e. 60 m

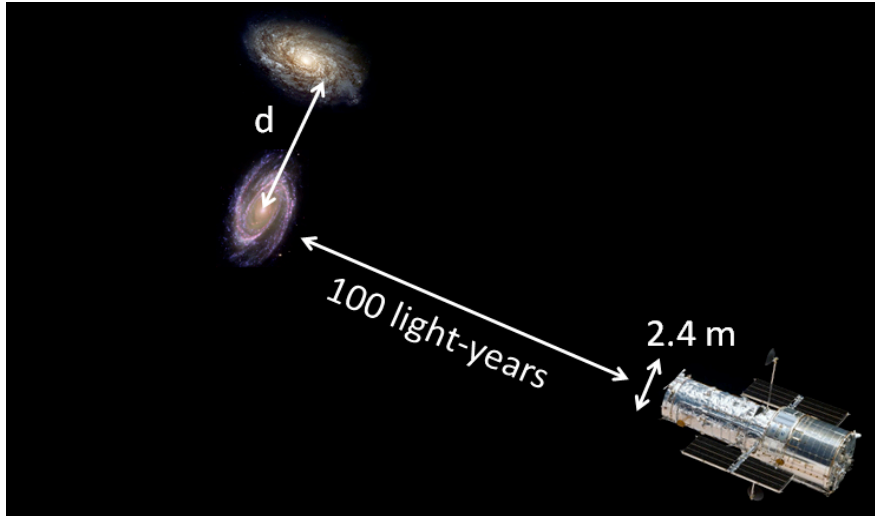
12. As shown in the figure below, acrylic with an index of refraction of $n_2=1.49$ is used to protect a piece of glass that has an index of refraction of $n_3=1.55$. A ray of light emitted by an OLED display beneath the glass makes a 20° angle with respect to the vertical dashed line. That light travels through the glass and acrylic into the air (with index of refraction $n_1=1$). What is the angle θ at the acrylic-air interface?



- a. 45°
- b. 64°
- c. 15°
- d. 7°
- e. 32°

Parallel layers, so you can skip mid layers:
 $1.55 \sin 20 = \sin \theta$
 $\Rightarrow \theta = 32.01 \text{ deg}$

13. As shown in the figure below, the mirror that forms images for the Hubble space telescope is 2.4 m in diameter. What is the minimum distance d between two galaxies that are 100 light-years away in order for the telescope to resolve them and form two distinct images? You may assume that the telescope samples light with a 500 nm wavelength. One light-year is approximately 9.5×10^{15} m.



Rayleigh's formula:
 $D \sin \theta = 1.22 \lambda$

- a. $d = 1.3 \times 10^6$ m
 b. $d = 2.4 \times 10^{11}$ m
 c. $d = 9.3 \times 10^{11}$ m
 d. $d = 3.8 \times 10^{20}$ m
 e. $d = 4.5 \times 10^{20}$ m
- $D = 2.4$ m, so
 $\theta = 1.22 \times 500 \times 10^{-9} / 2.4$
 $= 254.17 \times 10^{-9}$
 $\theta \times 100 \text{ ly} = 2414.6 \times 10^8$

14. Three separate lasers emit photons with wavelengths 532 nm, 780 nm, and 1064 nm. What is the wavelength of the photons with the most energy?

- a. 532 nm
 b. 780 nm
 c. 1064 nm

$$e = h \times f$$

The shortest wave is with the highest energy.

15. What is the speed of a basketball that has a deBroglie wavelength equal to the diameter of a basketball hoop? The diameter of a basketball hoop is about 0.5 m, and the mass of a basketball is about 0.5 kg.

- a. 2.7×10^{-33} m/s
- b. 8.5×10^{33} m/s
- c. 6.3×10^{-33} m/s
- d. 4.2×10^{-3} m/s
- e. 9.7×10^{-30} m/s

$$\lambda = h/p$$

$$p = mv$$

$$v = h/m \lambda$$

$$= 6.626 \times 10^{-34} / (0.5 \times 0.5) = 26.5 \times 10^{-34} \text{ m/s}$$

16. Light from the Advanced Light Source at Lawrence Berkeley Laboratory is used to eject electrons from a metal via the photoelectric effect. Measurements demonstrate that photoelectrons are only ejected if the wavelength of the light is smaller than 123 nm. What is the work function of the metal?

- a. 4.9×10^{18} J
- b. 7.2×10^{-18} J
- c. 3.7×10^{-18} J
- d. 1.6×10^{-18} J
- e. 1.8×10^{10} J

Higher energy than 123 nm:

$$f = c/\lambda = 3 \times 10^8 / 123 \times 10^{-9} = 0.02439 \times 10^{17},$$

so the work function

$$= h f = 6.626 \times 10^{-34} \times 0.02439 \times 10^{17}$$

$$= 0.1616 \times 10^{-17}$$

17. An object is placed 25 cm in front of a spherical mirror of unknown focal length. The image forms at 37.5 cm on the same side of the mirror. What is the focal length of the mirror?

- a. $f = -75$ cm
- b. $f = -10$ cm
- c. $f = +5$ cm
- d. $f = +15$ cm
- e. $f = +25$ cm

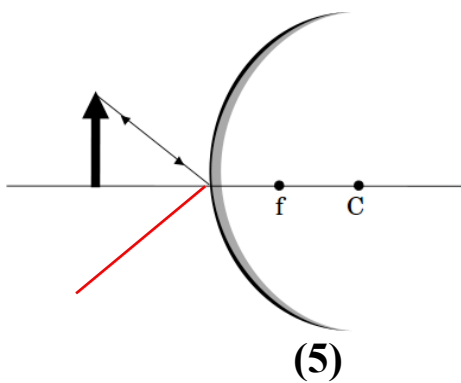
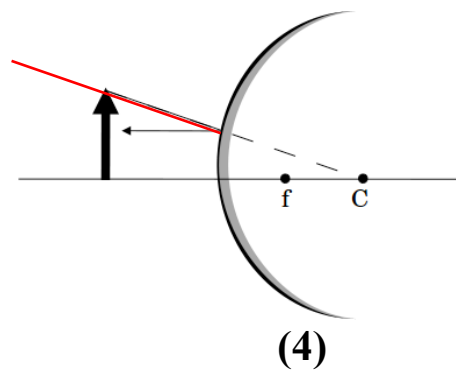
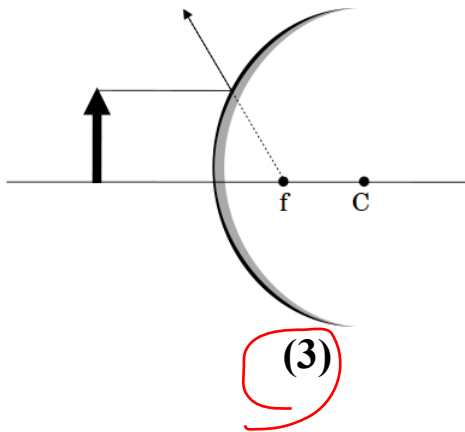
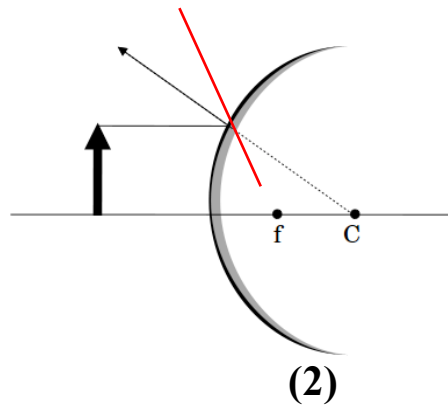
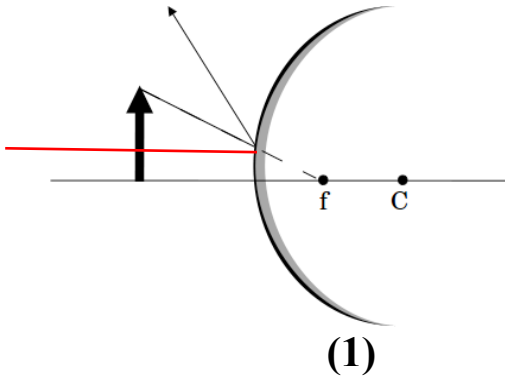
$$1/f = 1/d_o + 1/d_i$$

real object at 25 cm $d_o = 25$,

image real at 37.5 cm $d_i = 37.5$,

$$1/f = 1/25 + 1/37.5 = 1/15.$$

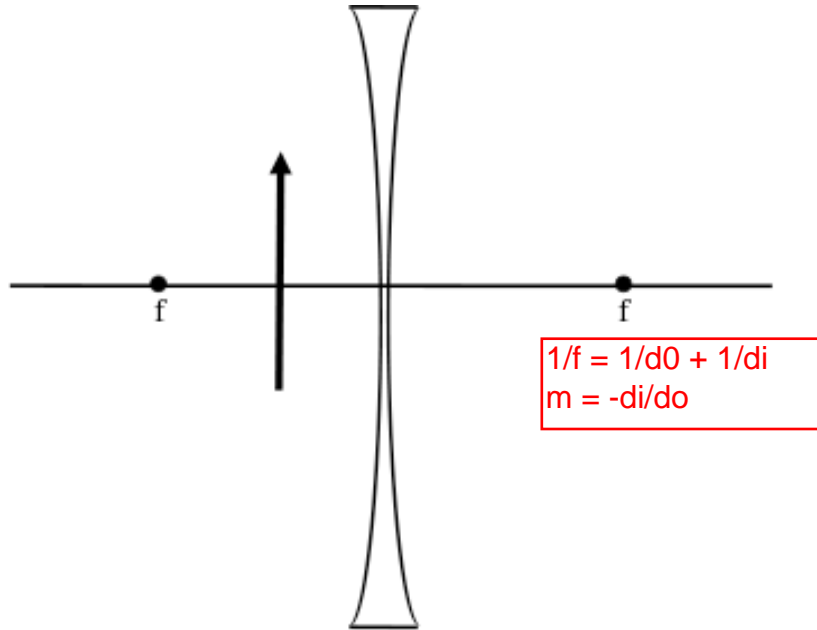
18. An arrow is placed in front of a convex mirror. The focal point f and the center of curvature C are indicated in the diagrams below. Identify the ray diagram that correctly traces the path of a principal ray.



- a. 1
- b. 2
- c. 3
- d. 4
- e. 5

The next three questions pertain to the following situation.

An object is placed 3 cm in front of a diverging lens with focal length $f = -7$ cm.



19. What is the magnification of the resulting image?

- a. -4.3
 b. -0.7
 c. +0.7
 d. +2.0
 e. +4.3
- $f = -7, d_o = 3$
 $1/d_i = -1/7 - 1/3 = -1/2.1.$
 $m = 2.1/3 = 0.7$

20. Is the image upright or inverted?

- a. upright
 b. inverted

This is not independent of 19, a bad question.

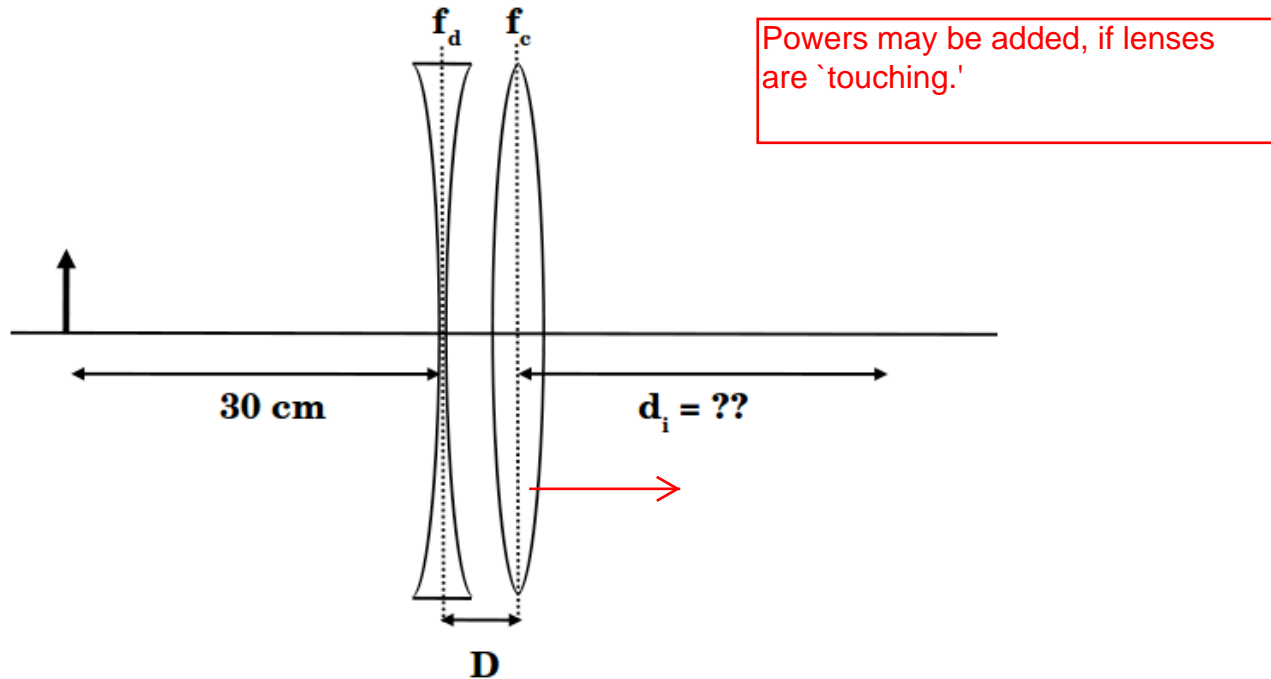
21. Is the image real or virtual?

- a. real
 b. virtual

This is not independent of 19, a bad question.

The next two questions pertain to the following situation.

A diverging lens of focal length $f_d = -15$ cm is placed a distance $D = 5$ cm to the left of a converging lens of focal length $f_c = +10$ cm. An object is placed 30 cm to the left of the diverging lens.



22. Where is the final image of the two-lens system, indicated by the distance d_i in the picture above?

- a. +30 cm
- b. +10 cm
- c. +5 cm
- d. -20 cm
- e. -45 cm

$-1/30 + 1/10 = 1/15$ gives the power of the compound lens.

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

$$\frac{1}{15} - \frac{1}{30} = \frac{1}{d_i} = \frac{1}{30}.$$

23. The diverging lens is held fixed, while the distance D is increased by moving the converging lens to the right. How does the size of the image formed by the two-lens system change?

- a. enlarged
- b. reduced
- c. no change

The position of the virtual image (= effective real object for the converging lens) is fixed.

Increasing D implies increasing d_o .

$$\frac{1}{f} - \frac{1}{d_o} = \frac{1}{d_i}, \text{ so}$$

$1 = d_i/f + m$. Increasing D increases d_i , so m is decreased.

24. A farsighted person is unable to focus objects located 30 cm or closer from his eyes. What power lens is required for the person to clearly read a book located 22 cm in front of his eyes?

- a. 0.8 diopters
- b. 13 diopters
- c. 3.2 diopters
- d. 7.9 diopters
- e. 1.2 diopters

Let us assume contact lenses.

22 cm object should give a virtual image at 30 cm.

$$1/f = 1/22 - 1/30 = 1/82.5 \rightarrow P = 1.21 \text{ D}$$

25. A nearsighted person cannot see clearly past 300 cm. What is the focal length of the lens required to correct her vision?

- a. 25 cm
- b. -50 cm
- c. -300 cm

Far objects should make a virtual image at 300 cm.

$d_o = \text{infinity}, d_i = -300.$

$$1/f = -1/300 \rightarrow f = -300 \text{ cm}$$

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