

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. 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.
3. 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**.
4. 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 middle of your answer sheet. **DO THIS NOW!**
5. Do not write in or mark the circles in any of the other boxes (STUDENT NUMBER, DATE, SECTION, SCORES, SPECIAL CODE).
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 17 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 of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **124** 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.*

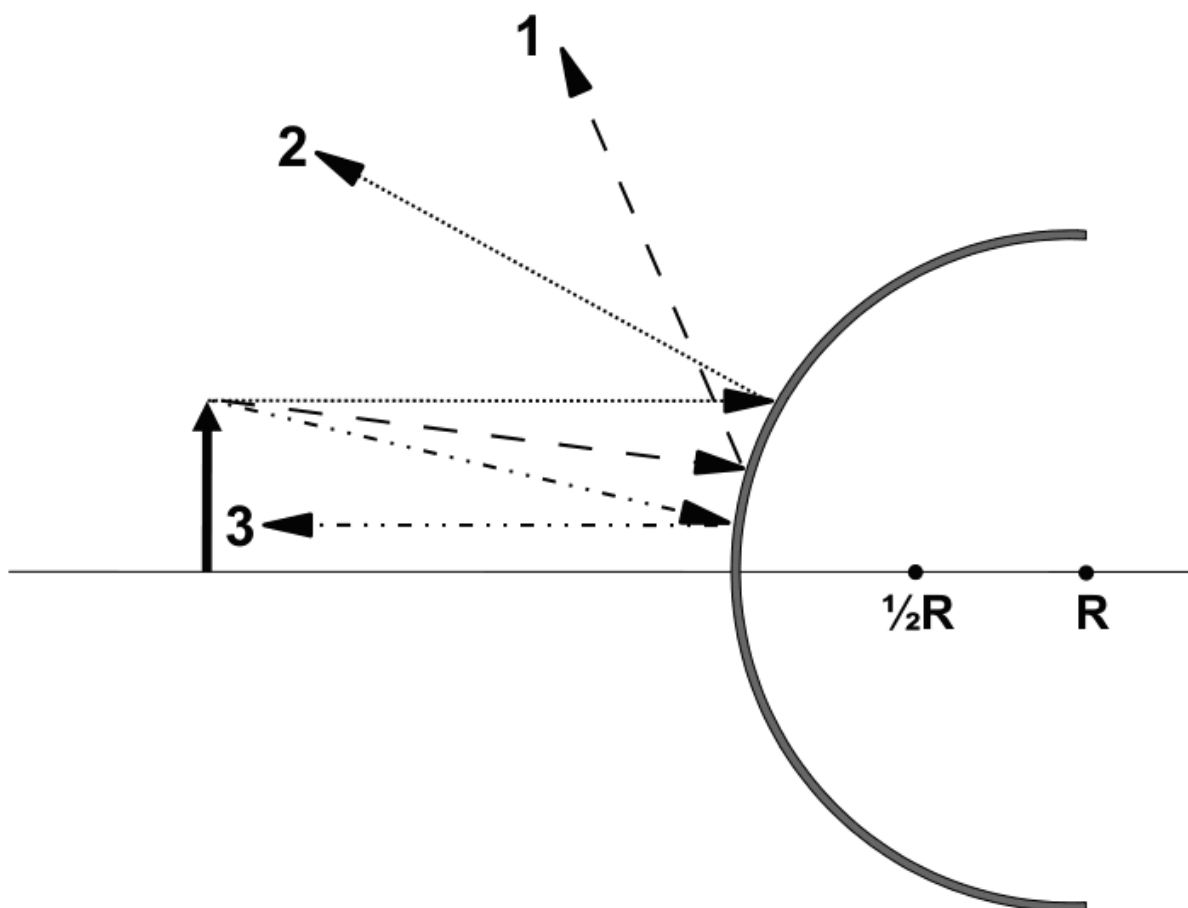
No partial credit.

- (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:

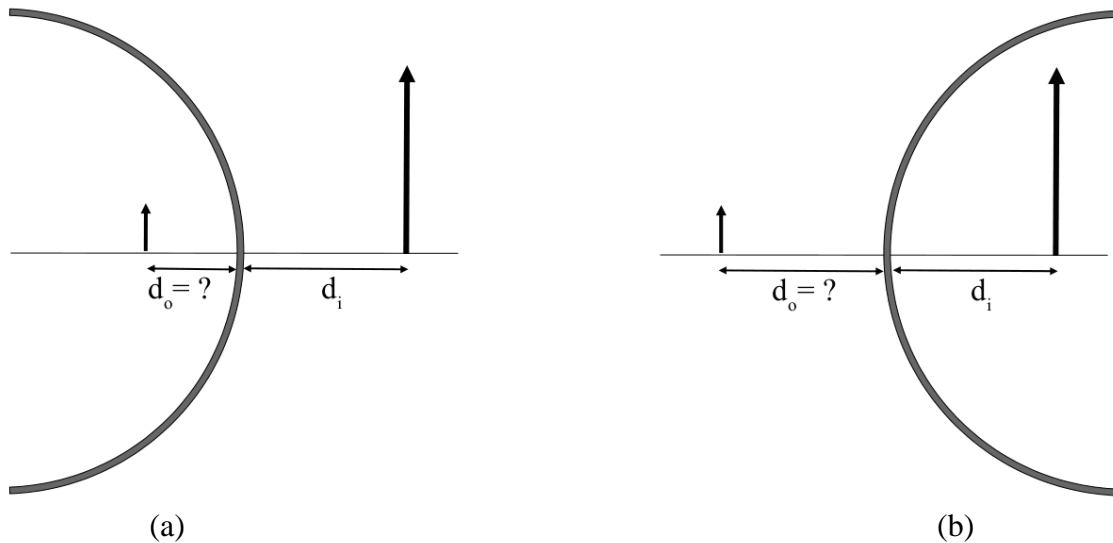
- A reminder about prefixes: p (pico) = 10^{-12} ; n (nano) = 10^{-9} ; μ (micro) = 10^{-6} ; m (milli) = 10^{-3} ; k (kilo) = 10^{+3} ; M or Meg (mega) = 10^{+6} ; G or Gig (giga) = 10^{+9} .

1. For the circular mirror pictured below, which of the following rays is drawn correctly? The radius of curvature of the mirror is R .



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

The next two questions pertain to the same situation.



2. A virtual image is formed 15 cm behind a mirror. The image's magnification m is measured to be +5. Determine whether the mirror is concave or convex.

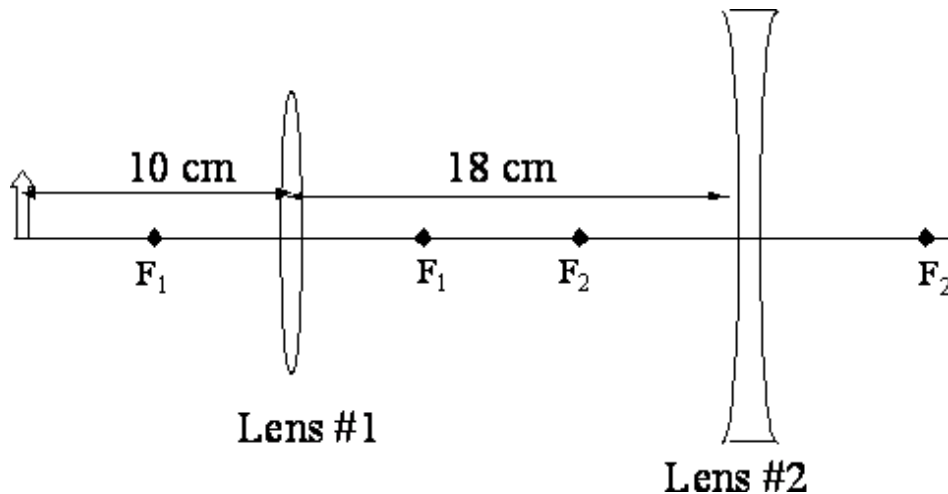
- a. convex
- b. concave

3. What is the radius of curvature of the mirror?

- a. 5 cm
- b. 15 cm
- c. 7.5 cm

The next three questions pertain to the same situation.

Two lenses are separated by 18 cm. Lens #1 is convergent and has a focal length of 5 cm. Lens #2 is divergent and has a focal length of -7 cm. An object (arrow) is located 10 cm to the left of Lens #1.



4. If lens #2 were not present, the image formed by lens #1 would be:

- inverted relative to the object
- upright relative to the object

5. Where is the final image of the pair of lenses?

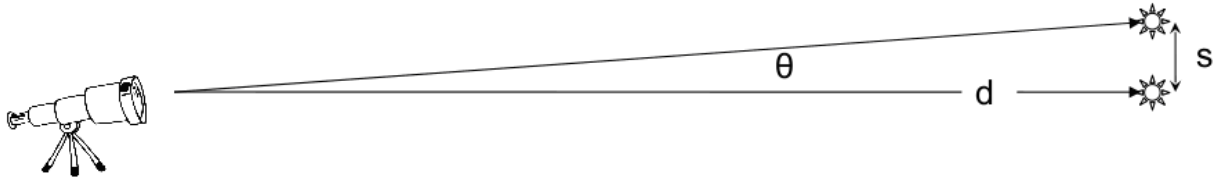
- to the right of lens #2 and less than 7cm away from lens #2
- to the left of lens #2 and more than 7 cm away from lens #2
- to the right of lens #2 and more than 7 cm away from lens #2
- infinity
- to the left of lens #2 and less than 7cm away from lens #2

6. The final image formed by the pair of lenses is:

- larger than object
- the same height as the object
- shorter than the object

The next two questions pertain to the same situation.

Two sister stars are found to emit the same average wavelength $\lambda = 230 \text{ nm}$ and are located a distance $d = 3.75 \times 10^{18} \text{ m}$ away from Earth.



7. The stars are estimated to be separated by $s = 4.50 \times 10^{11} \text{ m}$. What minimum diameter of telescope lens is needed to resolve their images?

- a. 5.4 m
- b. 4.1 m
- c. 1.9 m
- d. 0.8 m
- e. 2.3 m

8. About how long does it take for light to reach Earth after leaving one of these stars?

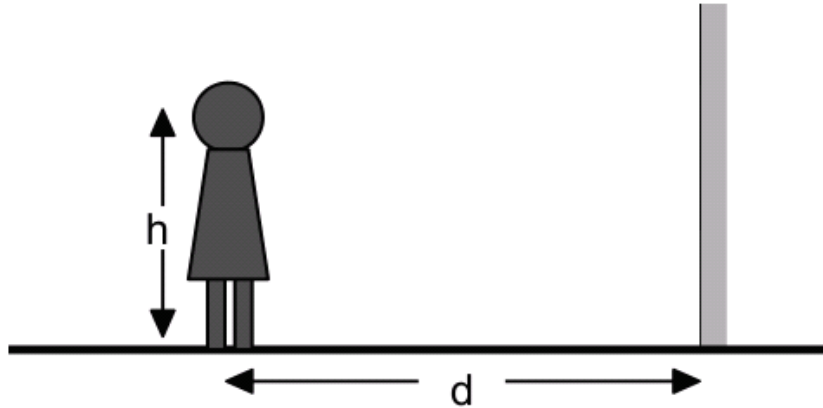
- a. 1.25×10^{10} seconds = 396 years
- b. 6.31×10^7 seconds = 2 years
- c. 3.89×10^{10} seconds = 1232 years
- d. 4.67×10^9 seconds = 148 years
- e. 2.18×10^{10} seconds = 690 years

9. Which of the following statements is NOT true about light?

- I. Light waves do not require a medium to carry energy.
- II. The electric and magnetic fields of a light wave are mutually inducing.
- III. Light is a longitudinal wave.

- a. II
- b. III
- c. I

10. A person stands 3.6 m in front of a wall that is covered floor-to-ceiling with a plane mirror. Her eyes are 1.8 m above the floor. She holds a flashlight between her feet and manages to point it at the mirror. At what angle of incidence must the light strike the mirror so the light will reach her eye?



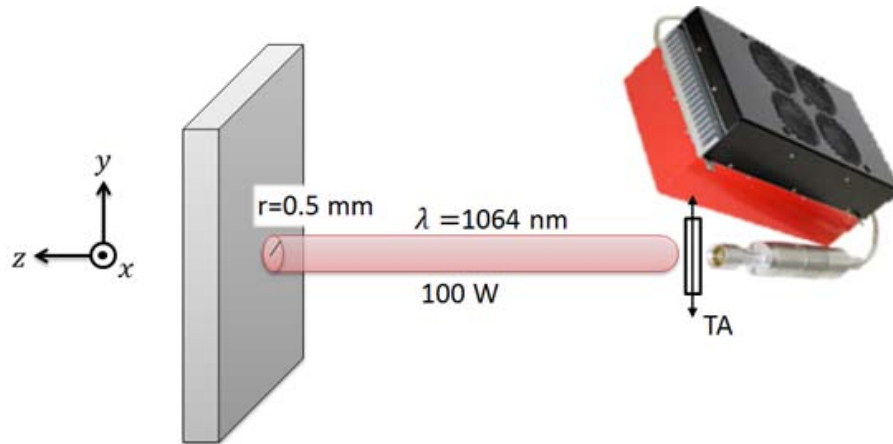
- a. 37°
- b. 82°
- c. 0°
- d. 25°
- e. 14°

11. What is the near point for a person's unaided eye if he needs a corrective lens with a power of +1.5 diopters to read a book held 25 cm away from his eyes?

- a. 67 cm
- b. 50 cm
- c. 25 cm
- d. 40 cm
- e. 17 cm

The next five questions refer to the following situation:

A laser that emits light with a wavelength of 1064 nm is used to cut a steel plate. A polarizer is mounted after the laser output with its transmission axis along the y direction. The power after the polarizer is 100 W. The radius of the laser beam is 0.5 mm.



12. What is the frequency of the laser light?

- a. $1.2 \times 10^{14} \text{ Hz}$
- b. $2.8 \times 10^5 \text{ Hz}$
- c. $3.5 \times 10^{-15} \text{ Hz}$
- d. $3.5 \times 10^{14} \text{ Hz}$
- e. $2.8 \times 10^{14} \text{ Hz}$

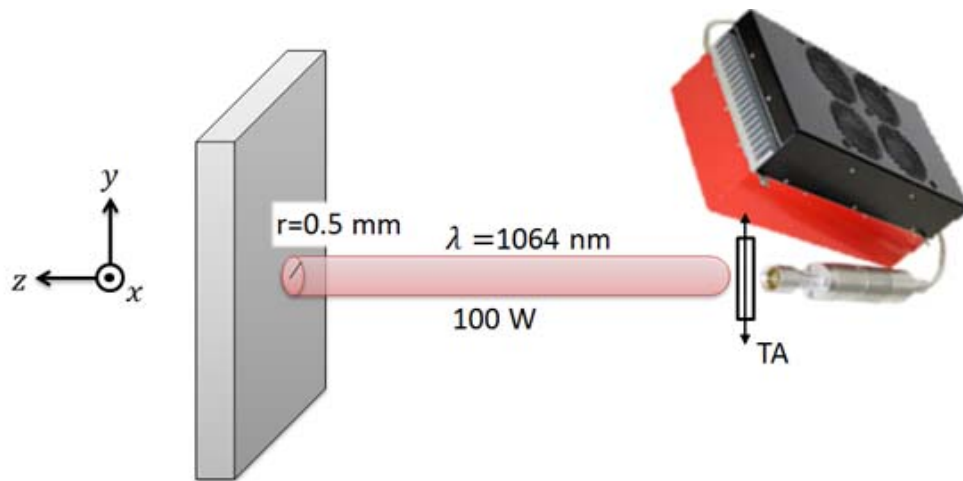
13. The magnetic field of the laser light after the polarizer is along which direction?

- a. z
- b. y
- c. x

14. What is the intensity of the laser beam after the polarizer, assuming that the power is uniformly distributed across the beam?

- a. $1.3 \times 10^8 \text{ W/m}^2$
- b. $4.0 \times 10^8 \text{ W/m}^2$
- c. $3.2 \times 10^7 \text{ W/m}^2$

The next two questions continue from the previous page:



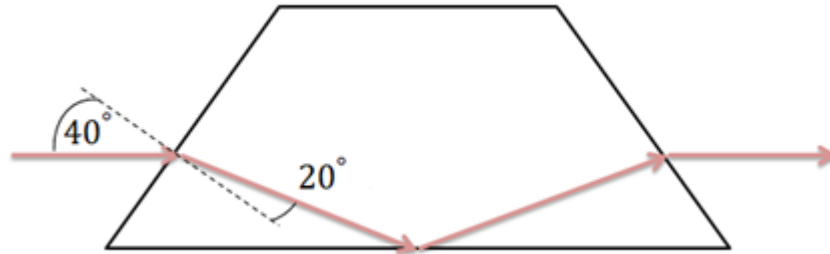
15. What is the rms electric field of the laser beam?

- a. $2.2 \times 10^5 \text{ V/m}$
- b. $5.2 \times 10^5 \text{ V/m}$
- c. $3.8 \times 10^9 \text{ V/m}$
- d. $2.2 \times 10^2 \text{ V/m}$
- e. $4.8 \times 10^{10} \text{ V/m}$

16. The light directly emitted from the laser (before the polarizer) is unpolarized. How much power is emitted from the laser before the light hits the polarizer?

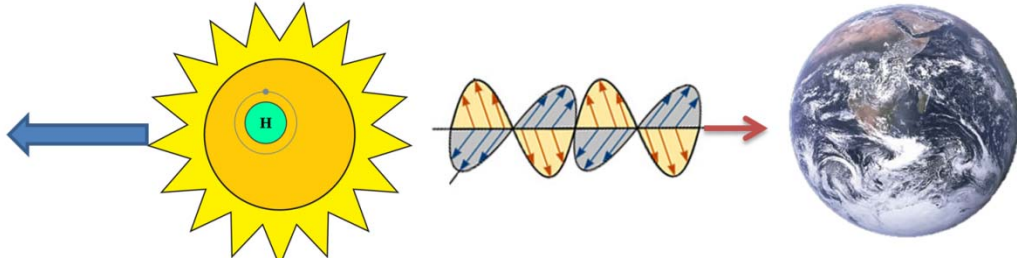
- a. 50 W
- b. 100 W
- c. 200 W

17. A laser beam travels from air into a dove prism as shown below. The dashed line is a normal to the surface at which the beam enters the prism. What is the index of refraction of the prism?



- a. 1.50
- b. 0.76
- c. 1.88
- d. 1.44
- e. 2.50

18. A star is traveling away from the earth. In the star, hydrogen atoms at rest with respect to the star emit electromagnetic waves with a frequency of 1.4×10^9 Hz. On the earth, a radio-astronomer measures the frequency of this light as 1.35×10^9 Hz. How fast is the star moving relative to the earth?

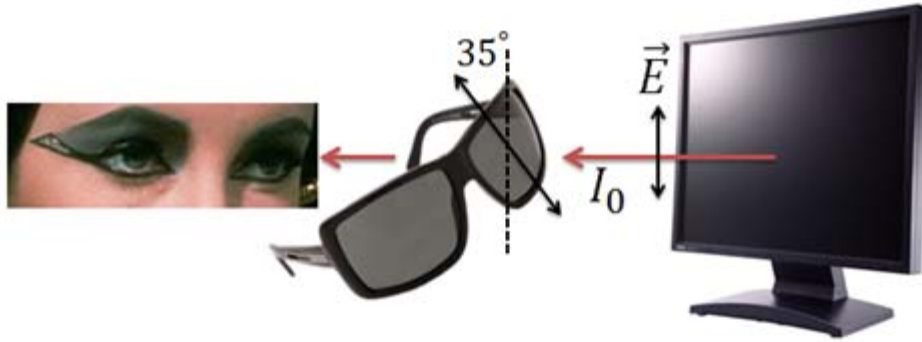


- a. 3.12×10^8 m/s
- b. 1.11×10^5 m/s
- c. 1.42×10^7 m/s
- d. 1.02×10^6 m/s
- e. 1.07×10^7 m/s

19. Cesium atoms in an atomic clock in a spaceship emit electromagnetic waves with a frequency of 9.19×10^9 Hz. A scientist on the earth receives these electromagnetic waves and measures their frequency as 9.33×10^9 Hz. The spaceship is

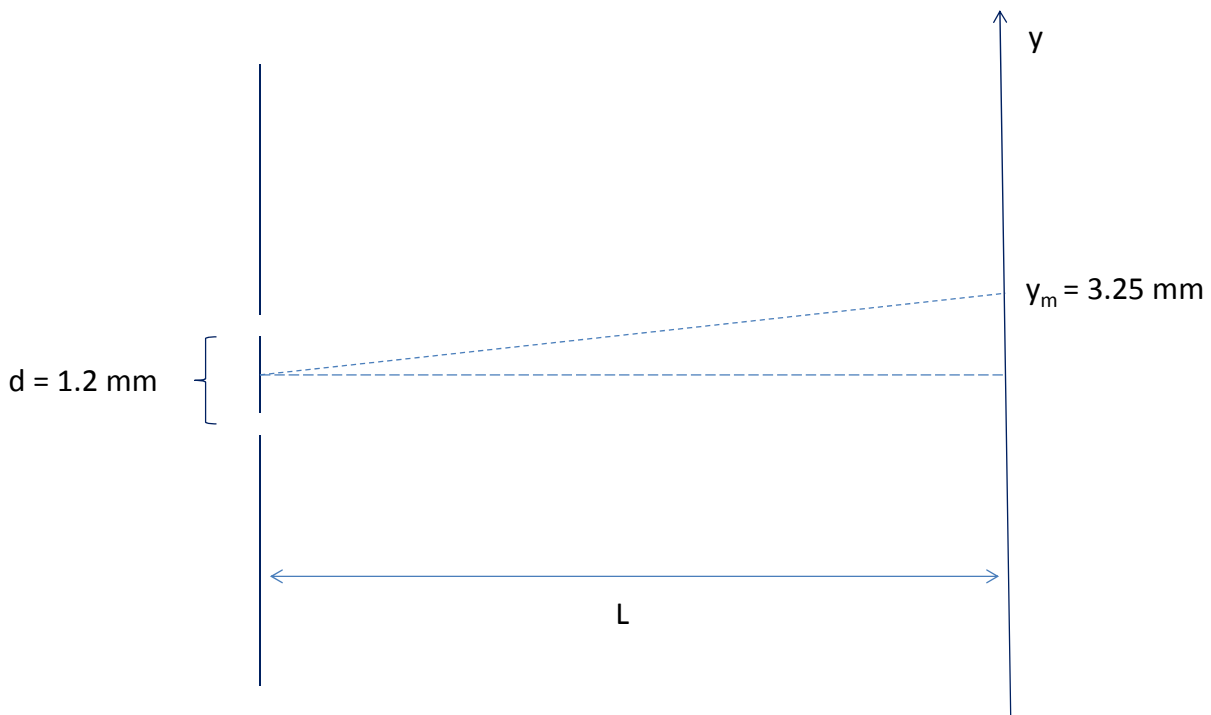
- a. moving away from the earth.
- b. moving toward the earth.
- c. not moving relative to the earth.

20. As shown below, vertically polarized light with intensity I_0 is emitted from an LCD monitor. You take your polarized sunglasses and hold them between your eyes and the monitor. How much light intensity is transmitted through your sunglasses to your eyes if their transmission axis makes a 35° angle with the vertical direction?



- a. $0.23 I_0$
- b. $0.82 I_0$
- c. $0.75 I_0$
- d. $1.12 I_0$
- e. $0.67 I_0$

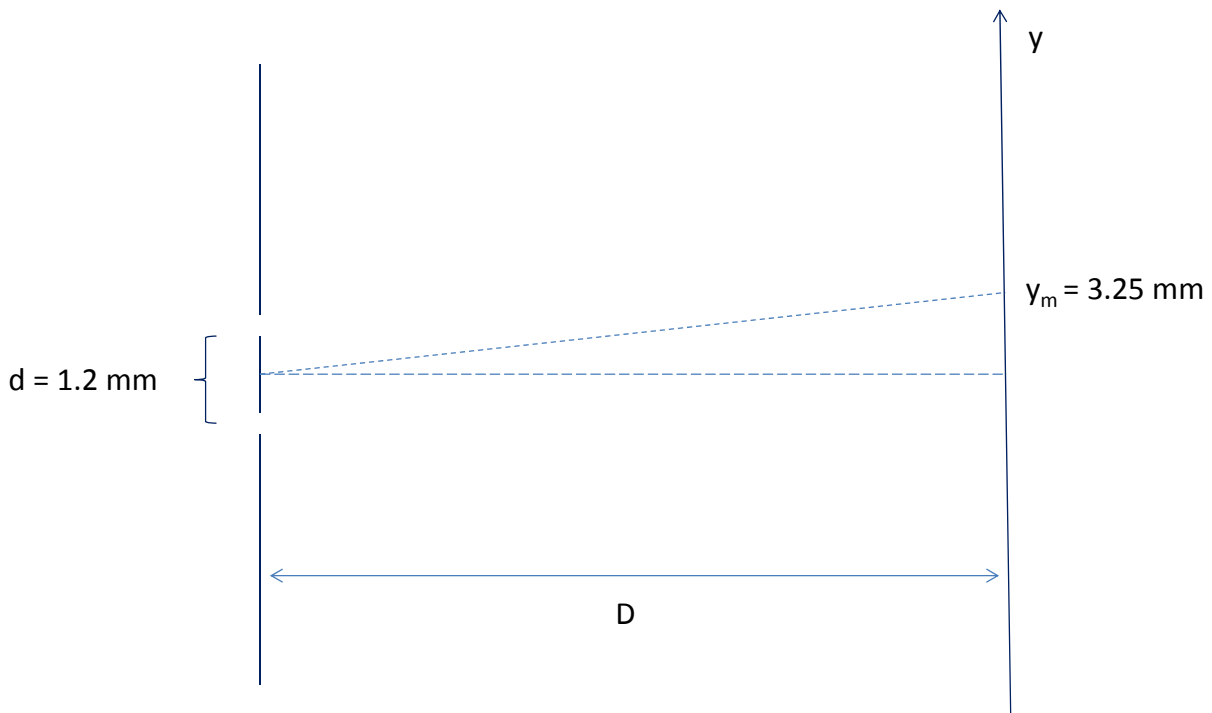
The next two questions pertain to the following situation:



21. A double slit experiment has two slits separated by a distance $d = 1.2 \text{ mm}$. Monochromatic (single-wavelength) light is impinging on the two slits with an unknown wavelength. A screen a distance $L = 2.5 \text{ m}$ away has a third interference maximum ($m = 3$) at $y = 3.25 \text{ mm}$. What is the light's wavelength?

- a. 520 nm
- b. 102 nm
- c. 341 nm
- d. 189 nm
- e. 208 nm

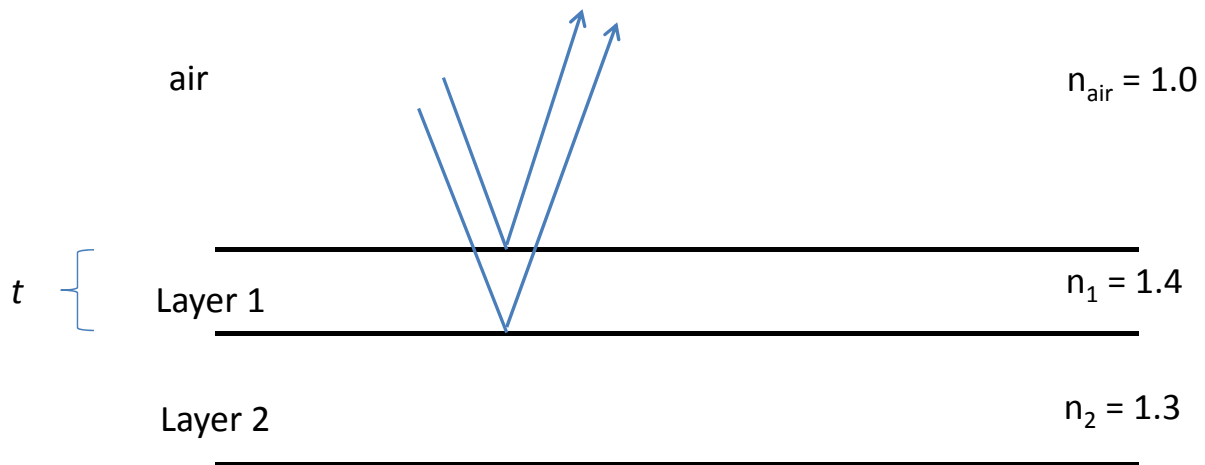
The next question continues from the previous page:



22. The screen is now moved to a new distance D . A different light source of wavelength 50 nm impinges on the two slits. A maximum of order $m = 2$ now occurs at $y = 3.25 \text{ mm}$. What is the new distance D of the screen from the double slits?

- a. 39.0 m
- b. 0.9 m
- c. 3.2 m

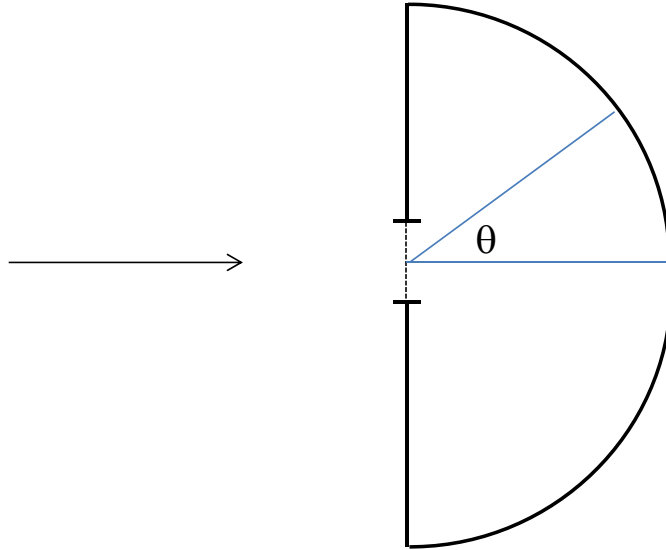
The next question pertain to the following situation:



23. Two thin films as drawn above have indices of refraction $n_1 = 1.4$ and $n_2 = 1.3$. Layer 1 has a thickness t . Light with wavelength $\lambda = 634$ nm impinges normally on the surface and produces constructive interference upon reflection. What is the minimum non-zero thickness t which produces this constructive interference?

- a. 30 nm
- b. 96 nm
- c. 288 nm
- d. 175 nm
- e. 113 nm

The next two questions pertain to the following situation.



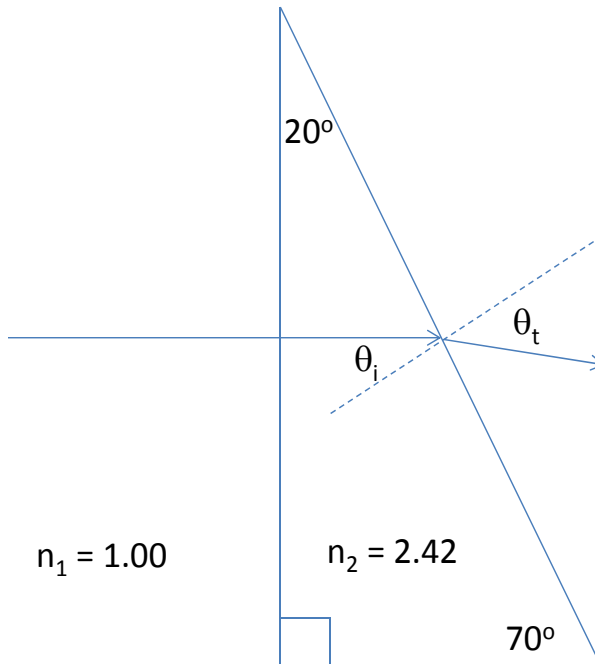
24. A diffraction grating spectrometer has a diffraction grating and a cylindrical screen. The diffraction grating has 8257 slits/cm. Light impinges on the diffraction grating. At which angle θ is the 3rd order maximum for violet light ($\lambda = 390$ nm) ?

- a. $\theta = 75^\circ$
- b. $\theta = 41^\circ$
- c. $\theta = 32^\circ$
- d. $\theta = 23^\circ$
- e. $\theta = 5^\circ$

25. The spectrometer is now immersed in a transparent fluid with index of refraction $n = 1.2$. What is the angle for the 2nd order maximum of the violet light ($\lambda = 390$ nm) ?

- a. $\theta = 50^\circ$
- b. $\theta = 23^\circ$
- c. $\theta = 75^\circ$
- d. $\theta = 5^\circ$
- e. $\theta = 32^\circ$

The next two questions pertain to the following situation.



26. A ray of light impinges normally upon a right-angle prism as shown in the diagram above. The prism is made of diamond with an index of refraction $n_2 = 2.42$. What is the transmitted angle θ_t with respect to the surface normal on the transmission side?

- $\theta_t = 55.9^\circ$
- $\theta_t = 12.1^\circ$
- $\theta_t = 62.3^\circ$
- $\theta_t = 34.2^\circ$
- $\theta_t = 73.2^\circ$

27. What angle of incidence θ_i relative to the surface normal on the transmission side would correspond to the critical angle for total internal reflection?

- $\theta_t = 43.6^\circ$
- $\theta_t = 24.4^\circ$
- $\theta_t = 31.2^\circ$

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

KEY

1. a
2. ab
3. c
4. a
5. e
6. c
7. e
8. a
9. b
10. e
11. d
12. e
13. c
14. a
15. a
16. c
17. c
18. e
19. b
20. e
21. a
22. a
23. e
24. a
25. e
26. a
27. b