

Optics

Mentor Science
Olympiad Invitational
February 11, 2017



INSTRUCTIONS

1. Turn in all exam materials at the end of this event. **DO NOT WRITE IN THIS TEST PACKET.**
2. Cell phone policy: Do NOT have your cell phone out – this risks disqualification. If you have an emergency requiring that you use your cell phone, please approach one of the members of the event supervisor team and explain the situation so that the call or communication can be confirmed to be not related to Optics.
3. Put your team number on **EVERY** page of the **ANSWER SHEET**. Put your team name and individual names on the front page of the **ANSWER SHEET** in the space provided.
4. **DO NOT WRITE IN THIS TEST PACKET.**
5. You may separate the exam pages and the answer sheet pages. Re-clip them as you submit your materials to the event supervisor team.
6. You are free to write anywhere on the **ANSWER SHEET**, but provide the answers in the appropriate area on the **ANSWER SHEET**. Answers provided outside the intended answer area will not be counted.
7. Point values for each question are indicated on the **ANSWER SHEET**.
8. Tie Breakers: sub score on Section C, sub score on section A, sub score on section B, questions in order on section C, questions in order on section A, and questions in reverse order on section B.
9. You will be notified when it is your turn to visit the Laser Shoot station. Please move as quietly as possible so as to not disturb other teams.
10. When the time is up, *the time is up*. Continuing to write after the time is up risks immediate disqualification.
11. Use the International System of Units (standard metric system) unless otherwise instructed.
12. Read the directions for each section in the exam packet and answer sheet packet.
13. You must show your work on Section C where applicable to get full credit.
14. **DO NOT WRITE IN THIS TEST PACKET**

Section A: Optics - Short Answer

Fill in the blank on the **ANSWER SHEET** with the answer to the question or with the word or words that best completes the sentence. **DO NOT WRITE IN THIS TEST PACKET**

1. For question 1, 2, and 3, list the primary colors of light in order from largest to smallest wavelength

2.

3.

4. What secondary color of light results when the colors from 1 and 2 above are mixed?

5. What secondary color of light results when the colors from 1 and 3 above are mixed?

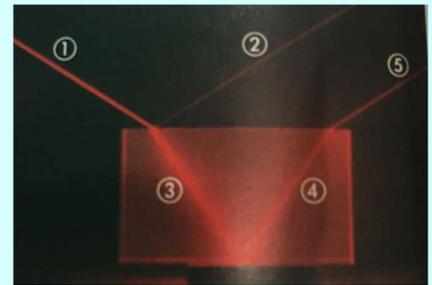
6. What secondary color of light results when the colors from 2 and 3 above are mixed?

7. What is the speed of an electromagnetic wave in a vacuum?

8. An image is _____ when it is formed by diverging rays.

9. The spreading of white light into its full spectrum of wavelengths is called _____

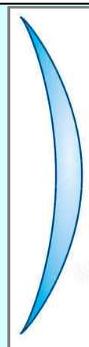
10. In the image, Beam 1 is the incoming beam. Which labeled beam(s) are due to reflection?



11. In the image above, Beam 1 is the incoming beam. Which labeled beam(s) are due to refraction?

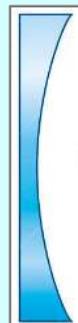
12. What type of lens is this?

13. Is it converging or diverging?



14. What type of lens is this?

15. Is it converging or diverging?



Section B: Optics – Multiple Choice

Fill in the circle(s) on the **ANSWER SHEET** that represent the answer(s). Fill in the circle completely. Make sure to erase mistakes completely. Note that you may need to fill in more than one circle to have a correct answer. completes the sentence. **DO NOT WRITE IN THIS TEST PACKET**

1. Which of the following best describes the image produced from a plane mirror?

A: virtual, inverted, magnification greater than 1	B: real, inverted, magnification less than 1	C: virtual, upright, magnification equal to 1	D: real, upright, magnification equal to 1	E: virtual, inverted, magnification less than 1
--	--	---	--	---

2. If you stand 2.5 m in front of a plane mirror, how far away from you would your image be in the mirror?

A: 2.5 m	B: 5.0 m	C: 1.125 m	D: 10.0 m	E: 5.2 m
----------	----------	------------	-----------	----------

3. For a spherical mirror, the focal length is equal to _____ the radius of curvature of the mirror.

A: one-fourth	B: one-third	C: one-half	D: twice	E: the square of
---------------	--------------	-------------	----------	------------------

4. A concave mirror with a focal length of 10.0 cm creates a real image 30.0 cm away on its principal axis. How far from the mirror is the corresponding object?

A: 15 cm	B: 5 cm	C: 3 cm	D: 20 cm	E: 12 cm
----------	---------	---------	----------	----------

5. What is the wavelength of green light that has a frequency of 6.00×10^{14} Hz

A: 1.8 nm	B: 500 nm	C: 180000 m	D: 5.0×10^{-6} nm	E: 180 nm
-----------	-----------	-------------	----------------------------	-----------

6. Which electromagnetic waves have the longest wavelengths and lowest frequencies?

A: Gamma rays	B: Radio waves	C: X-rays	D: Visible light	E: Ultraviolet rays
---------------	----------------	-----------	------------------	---------------------

7. A concave mirror forms a real image 25.0 cm from the mirror surface along the principal axis. If the corresponding object is at a distance of 10.0 cm from the mirror, what is the mirror's focal length?

A: 1.4 cm	B: 2.5 cm	C: 5.25 cm	D: 7.14 cm	E: 9.26 cm
-----------	-----------	------------	------------	------------

8. A source emits monochrome light of wavelength 495 nm in air. When the light passes through a liquid, its wavelength reduces to 434 nm. What is the liquid's index of refraction?

A: 1.26	B: 1.49	C: 1.14	D: 1.33	E: 2.03
---------	---------	---------	---------	---------

9. Carbon disulfide ($n = 1.63$) is poured into a container made of crown glass ($n = 1.52$). What is the critical angle for total internal reflection of a light ray in the liquid when it is incident on the liquid-to-glass surface?

A: 89.2°	B: 76.4°	C: 21.2°	D: 68.8°	E: 43.0°
-----------------	-----------------	-----------------	-----------------	-----------------

10. How many 800-nm photons does it take to have the same total energy as four 200-nm photons?

A: 1	B: 2	C: 4	D: 8	E: 16
------	------	------	------	-------

11. An object is 29 cm away from a concave mirror's surface along the principal axis. If the mirror's focal length is 9.50 cm, how far away is the corresponding image?

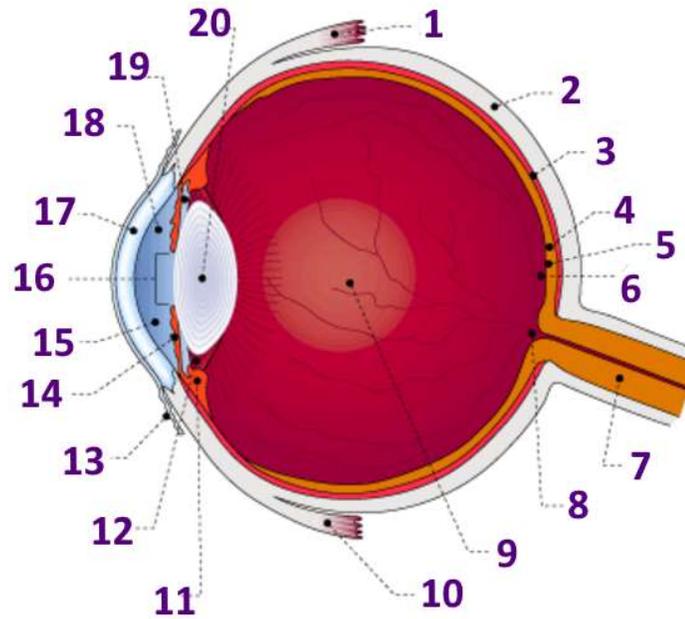
A: 12 cm	B: 14 cm	C: 18 cm	D: 29 cm	E: 36 cm
----------	----------	----------	----------	----------

12. When light is refracted from passing from one medium to another, what changes?

A: frequency of light	B: speed of light	C: wavelength of light	D: none of these
-----------------------	-------------------	------------------------	------------------

13. The image falling on the retina in a human eye is

A: virtual	B: real	C: inverted	D: erect	E: magnified
------------	---------	-------------	----------	--------------



14. Consider the diagram, what is the name of the component of the human eye labeled as "14"?

A: lens B: iris C: lens D: aqueous humor E: cornea

15. Consider the diagram, what is the name of the component of the human eye labeled as "15"?

A: lens B: cornea C: lens D: aqueous humor E: pupil

16. Consider the diagram, what is the name of the component of the human eye labeled as "16"?

A: lens B: cornea C: lens D: aqueous humor E: pupil

17. Consider the diagram, what is the name of the component of the human eye labeled as "17"?

A: cornea B: ciliary body C: conjunctiva D: lens E: iris

18. Consider the diagram, what is the name of the component of the human eye labeled as "18"?

A: vitreous body B: anterior chamber C: sclera D: pupil E: macula

19. Consider the diagram, what is the name of the component of the human eye labeled as "19"?

A: cornea B: lens C: iris D: pupil E: posterior chamber

20. Consider the diagram, what is the name of the component of the human eye labeled as "20"?

A: vitreous body B: aqueous humor C: lens D: pupil E: rods

21. Consider the diagram, what is the name of the component of the human eye labeled as "4"?

A: retina B: choroid C: macula D: sclera E: vitreous body

22. Consider the diagram, what is the name of the component of the human eye labeled as "5"?

A: retina B: fovea C: ciliary body D: macula E: optic nerve

23. Consider the diagram, what is the name of the component of the human eye labeled as "6"?

A: retina B: fovea C: ciliary body D: macula E: optic nerve

24. Consider the diagram, what is the name of the component of the human eye labeled as "7"?

A: retina B: fovea C: ciliary body D: macula E: optic nerve

25. What component of the human eye refracts light?

A: retina B: iris C: lens D: cornea E: ciliary body

26. What component of the human eye controls the amount of light that enters the eye?

A: iris B: cornea C: lens D: fovea E: macula

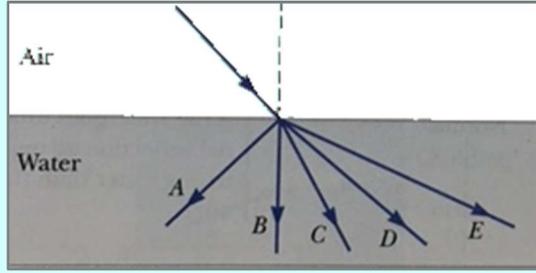
27. What component of the human eye contains only cones and provides acute eyesight?

A: iris B: cornea C: lens D: fovea E: macula

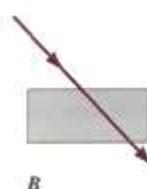
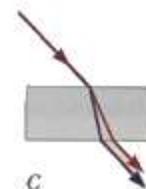
28. Which eye structure is comparable to the film of a camera because it senses light focused on it?				
A: pupil	B: retina	C: optic nerve	D: vitreous humor	E: lens

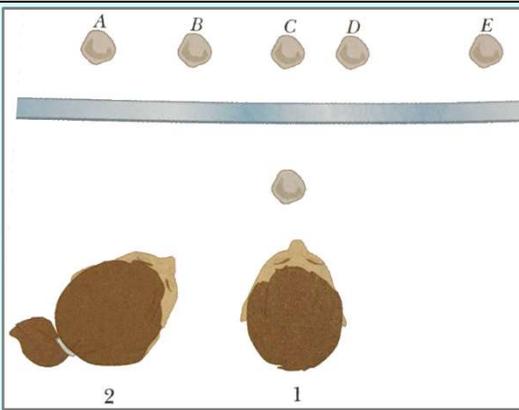
29. The absolute index of refraction of a material is defined as				
A: The speed of light in a vacuum divided by the speed of light in the material	B: The speed of light in the material divided by the speed of light in a vacuum	C: $\frac{c}{v}$	D: $\frac{v}{c}$	E: the ratio of the speeds of light in any two materials

30. Catoptric optical instruments use			
A: reflective elements only	B: refractive elements only	C: a combination of reflective and refractive elements	D: neither refractive or reflective elements

31. Possible paths for light to travel when crossing from air to water are shown. Which path the best choice to represent this scenario?				
A: A	B: B	C: C	D: D	E: E

32. Astigmatism means				
A: The vitreous humor blurs the image	B: The light entering the eye focuses to one point, but not on the retina	C: Light entering the eye focuses in more than one point	D: The light entering the eye focuses to one point, on the retina	E: The light entering the eye is focused in front of the retina

33. A light ray containing both blue and red wavelengths is incident at an angle on a slab of glass. Which of the following best represents the outcome?			
 <p>A</p>	 <p>B</p>	 <p>C</p>	 <p>D</p>

34. In the overhead view shown, the image of the stone seen by observer 1 is at C. Where does observer 2 see the image?				
A: A	B: B	C: C	D: D	E: E

35. An object is placed to the left of a converging lens. What of the following statements are true?		
A: The image is always to the right of the lens	B: The image can be upright or inverted	C: The image is always smaller or the same size as the object

36. If Alex's face is 30.0 cm in front of a concave shaving mirror creating an upright image 1.5 times as large as his actual face, what is the mirror's focal length?				
A: 12.0 cm	B: 20.0 cm	C: 2.0 cm	D: 15.0 cm	E: 18.0 cm

37. A thin, convergent lens has a focal length of 8.00 cm. If a real, inverted image is located 12.0 cm to the right of the lens, where is the object located?				
A: 12.0 cm to the left of the lens	B: 24.0 cm to the right of the lens	C: 24.0 cm to the left of the lens	D: 18.0 cm to the right of the lens	E: 18.0 cm to the left of the lens

38. An object is placed 16.0 cm away from a convex mirror with a focal length of magnitude 6.00 cm. What is the location of the image?				
A: 9.60 cm in front of the mirror	B: 4.36 cm in front of the mirror	C: 9.60 cm behind the mirror	D: 4.36 cm behind the mirror	E: 10.0 cm in front of the mirror

39. When the image of a real object is formed by a concave mirror, which of the following statements are true?				
A: the image is always real	B: the image is always virtual	C: if the object distance is less than the focal length, the image is real	D: if the object distance is greater than the focal length, the image is real	E: if the image distance is less than zero, the image is virtual

40. Total internal reflection is a phenomenon that occurs when all the light is reflected back into a medium from a boundary. Various pairs of materials below are given. The first material given is the material of the incident light, the second material given is the material forming the boundary with the first material. What combination(s) of materials provide the opportunity for total internal reflection to occur?	Gases at 0°C, 1 atm		Solids at 20°C	
	Air	1.000293	Diamond	2.419
	Carbon dioxide	1.00045	Fluorite	1.434
	Hydrogen	1.000139	Glass, crown	1.52
	Oxygen	1.000271	Glass, flint	1.66
	Liquids at 20°C		Ice	1.309
	Benzene	1.501	Polystyrene	1.49
	Carbon disulfide	1.628	Plexiglas	1.51
	Carbon tetrachloride	1.461	Quartz, crystalline	1.544
	Ethanol	1.361	Quartz, fused	1.458
	Glycerine	1.473	Sodium chloride	1.544
	Water, fresh	1.333	Zircon	1.923
A: Hydrogen, plexiglass	B: Ethanol, Water	C: Diamond, Benzene	D: Air, Glass	E: Polystyrene, Glycerine

41. A convex mirror forms an image of a real object. Which of the following statement(s) is always true?				
A: The image is real and upright	B: The image is virtual and larger than the object	C: The image is virtual and upright	D: The image is larger than the object	E: The image is virtual and inverted

42. A person spearfishing from a boat sees stationary fish a few meters away about 30° below the horizontal. The spear the fish (assuming the spear does not change direction, should the person....		
A: aim above where he sees the fish	B: aim below the fish	C: aim directly at the fish

43. A lens has a focal length of 25 cm. What is the power of the lens?				
A: 2.0 diopters	B: 4.0 diopters	C: 6.0 diopters	D: 8.0 diopters	E: none of these

44. Two campers wish to start a fire during the day, but forgot their matches. One camper is nearsighted, the other is farsighted. When glasses should be used to focus the sun's rays onto some paper to start a fire?

- | | | | |
|--------------------------------------|-------------------------------------|------------------------------------|--------------------------------------|
| A: either camper's glasses will work | B: the nearsighted camper's glasses | C: the farsighted camper's glasses | D: neither pair of glasses will work |
|--------------------------------------|-------------------------------------|------------------------------------|--------------------------------------|

45. A compound microscope has objective and eyepiece lenses of focal length 0.80 cm and 4.0 cm respectively. If the microscope length is 15 cm, what is the approximate magnification of the microscope?

- | | | | | |
|--------|--------|-------|--------|--------|
| A: 3.2 | B: 6.3 | C: 48 | D: 120 | E: 160 |
|--------|--------|-------|--------|--------|

46. Transmitted light through 2 polarizers has maximum intensity when

- | | | |
|--|--|--|
| A: The transmission axes are aligned with each other | B: The transmission axes are at an angle of 45 degrees with each other | C: The transmission axes are at an angle of 90 degrees with each other |
|--|--|--|

47. For a simple magnifier, if you want the greatest magnification, which should be selected?

- | | |
|--------------------------------------|---------------------------------------|
| A: a lens with a larger focal length | B: a lens with a smaller focal length |
|--------------------------------------|---------------------------------------|

48. For a simple magnifier, what focal length would be necessary if the lens were to have a maximum angular magnification of 4.0?

- | | | | | |
|-------------|------------|------------|-----------|-----------|
| A: 100.0 cm | B: 48.6 cm | C: 10.0 cm | D: 8.3 cm | E: 4.0 cm |
|-------------|------------|------------|-----------|-----------|

49. In a Newtonian microscope what would the effect on the magnification be if the focal length of the eyepiece lens was increased?

- | | | |
|--|---|---|
| A: The magnification would remain the same | B: The magnification would be increased | C: The magnification would be decreased |
|--|---|---|

50. In a Newtonian microscope what would be the effect on the magnification if the focal length of the mirror was increased?

- | | | |
|--|---|---|
| A: The magnification would remain the same | B: The magnification would be increased | C: The magnification would be decreased |
|--|---|---|

Section C: Problems to Solve

Please show your work and answer clearly on the **ANSWER SHEET**. Full credit will only be given if your work is shown. **DO NOT WRITE IN THIS TEST PACKET**

1. Unpolarized light is incident upon three polarizers. The polarizer has a vertical transmission axis. The second has a transmission axis rotated 30.0° with respect to the first, and the third has a transmission axis rotated 75.0° relative to the first. The initial intensity is I_0 .

1A: Calculate the light intensity after the beam passes through the second polarizer.
Clearly note what equations you use to solve the problem, identify variables, and show your work.

1B: Calculate the light intensity after the beam passes through the third polarizer.
Clearly note what equations you use to solve the problem, identify variables, and show your work.

2. The near point of a far-sighted patient's eye is 50.0 cm.

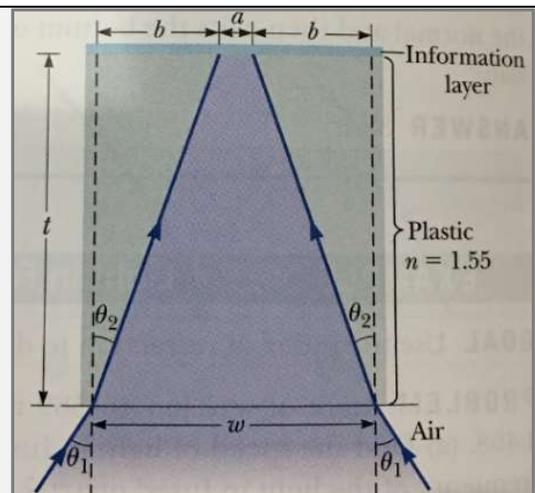
2A: What focal length must a corrective lens have to enable the eye to see clearly an object 25.0 cm away? Neglect the eye-lens distance.
Clearly note what equations you use to solve the problem, identify variables, and show your work.

2B: What is the power of this lens?
Clearly note what equations you use to solve the problem, identify variables, and show your work.

2C: Repeat problem 2A, only this time do not neglect the eye-lens distance.
Clearly note what equations you use to solve the problem, identify variables, and show your work.

2D: What is the power of the lens in 2C?
Clearly note what equations you use to solve the problem, identify variables, and show your work.

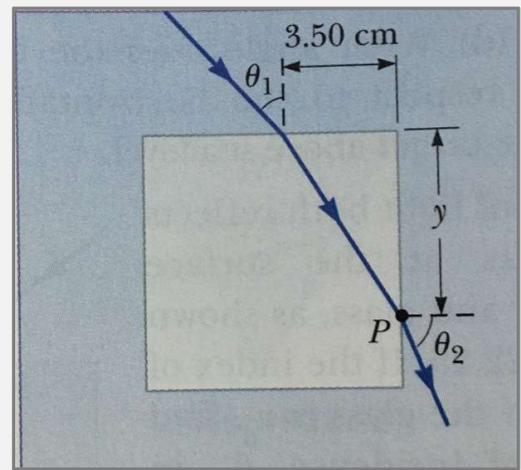
3. A DVD is a video recording consisting of a spiral track about $1 \mu\text{m}$ wide with digital information. The digital information consists of a series of pits that are read by a laser beam sharply focused on a track in the information layer. The width a of the beam at the information layer must equal $1 \mu\text{m}$ to distinguish individual tracks and the width w of the beam as it enters the plastic is 0.700 mm. The plastic has a thickness $t = 1.20 \text{ mm}$ and the index of refraction of the plastic is $n = 1.55$.



3A: Find the angle θ_2 .
Clearly note what equations you use to solve the problem, identify variables, and show your work.

3B: Find the angle θ_1 at which the conical beam should enter the plastic.
Clearly note what equations you use to solve the problem, identify variables, and show your work.

4. A block of crown glass ($n = 1.52$) is immersed in water. A light ray is incident on the block as shown with an angle of 42.0° and exits the block at point P.



4A: Find the vertical distance y from the top of the block to P.

Clearly note what equations you use to solve the problem, identify variables, and show your work.

4B: Find the angle of refraction θ_2 of the light ray leaving the block at P.

Clearly note what equations you use to solve the problem, identify variables, and show your work.