



Exploring the World of Science

Inaugural University of Michigan Science Olympiad Invitational Tournament

Optics

Test length: 50 Minutes

Team number: _____

Team name: _____

Student names: _____

Instructions: Do not open this test until told to do so. You will have 50 minutes to complete this test, but you will be called up at some point during the hour to do the Laser Shoot. You may write on this test, but only answers written on the answer sheet will be graded. You may ignore significant figures – use a reasonable number of decimal places. Include units on answers!!! Answers without units that should have units will be marked incorrect! Each separate blank on the answer sheet is worth one point.

Tiebreakers: Questions 7, 9, 10, 15, 47, 52. If there is still a tie, the team who had the most right answers at the beginning before getting a wrong answer will win.

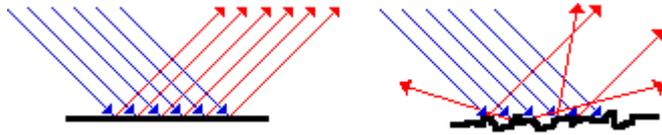
Please write all answers on the answer sheet; only answers on the Answer Sheet will be graded!

Speed of Light in a vacuum: $c = 3.00 \times 10^8$ m/s

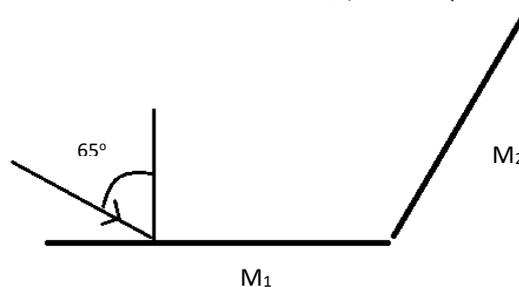
Planck's Constant: $h = 6.626 \times 10^{-34}$ J*s

Energy of a Photon: $E = hc/\lambda = pc$ (p is momentum, units kgm/s)

For questions 1-2, consider the different types of reflection and the images below.



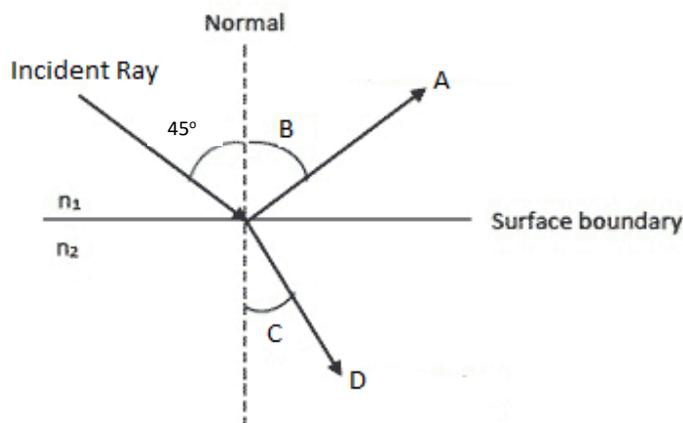
1. The image on the left is an example of _____.
2. The image on the right is an example of _____.
3. True or false: According to the law of reflection, the incident ray, reflected ray, and the normal to the surface of the mirror must all be in the same plane.
4. According to Fermat's principle, light travels the path of least _____.
5. Two mirrors make an angle of 120° with each other as shown below (image not to scale). A ray is incident on mirror M_1 at an angle of 65° to the normal. Find the angle of reflection of the ray after it has been reflected from mirror M_2 (with respect to the normal of M_2).



6. I shine a flashlight (unpolarized light) at a vertical polarizer. What percentage of the incident light passes through the polarizer?
7. I shine a flashlight (unpolarized light) at a vertical polarizer. Behind the vertical polarizer is a horizontal polarizer. What percentage of the incident light passes through the horizontal polarizer?
8. I shine a flashlight (unpolarized light) at two polarizers. The light first passes through a vertical polarizer, and then passes through a polarizer rotated at an angle of 45° with respect to the vertical. What percentage of the incident light passes through the rotated polarizer?
9. Suppose I add a horizontal polarizer to the scenario in problem 8, placed third in line after the rotated polarizer. What percentage of the incident light passes through the horizontal polarizer?
10. Unpolarized light is incident on a lake ($n = 1.33$) at an angle such that all of the reflected light is linearly polarized. Calculate this angle (with respect to the vertical).
11. What is the name of the angle in problem 10?

12. True or false: The light reflected in problem 10 will be polarized perpendicular to the ground.
13. Some light in problem 10 is refracted. True or false: The refracted light cannot be polarized.
14. Fill in the blanks: Rainbows form because of the (i) of light. This occurs because the index of refraction is dependent on the (ii) of the light.
15. Calculate the critical angle for light incident in water towards air ($n_{\text{water}} = 1.33$).
16. Optical fibers primarily use (write letter) to propagate light through long distances.
- A) Polarization by Reflection
 B) Refraction
 C) Dispersion
 D) Total Internal Reflection
 E) None of the above
17. True or false: Light has both particle-like and wave-like properties.

For problems 18-24, consider the scenario shown below. $n_1 = 1.00$, $n_2 = 1.50$.



18. Calculate the angle B.
19. Angle B is called the _____.
20. Calculate the angle C.
21. Angle C is called the _____.
22. Ray A is called the _____ ray.
23. Ray D is called the _____ ray.
24. Calculate the speed of light in the medium with index of refraction $n_2 = 1.50$.

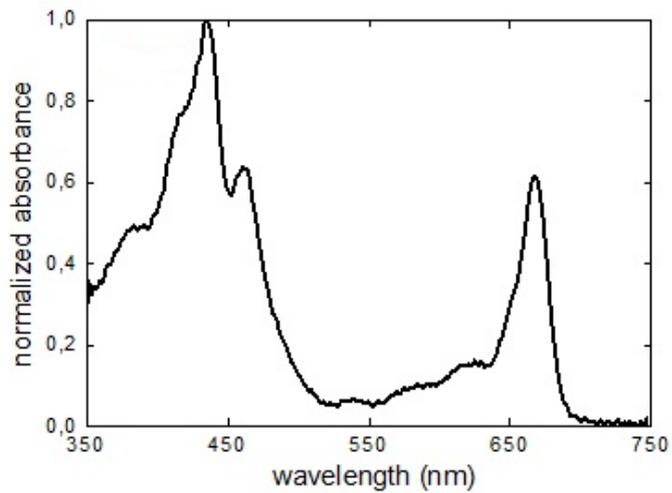
For problems 25-26, consider the following list of materials.

Material	Index of Refraction
Vacuum	1.0000
Air	1.0003
Ice	1.31
Water	1.333
Diamond	2.417

25. Which material is the most optically dense?
26. Through which material will light travel the fastest?
27. A pair of prescription eyeglasses has a diopter strength of +0.75 D. What is the focal length of the lens?
28. Convex mirrors form images that are (real / virtual) and (upright / inverted).
29. Concave mirrors form images that are (real / virtual) and (upright / inverted) when the object is located further away than the focal point.
30. What is the magnification of a plane mirror?
31. The focal length of a concave mirror is +10.0cm.
 - (i) Calculate the image distance for an object at a distance of 25.0cm.
 - (ii) Calculate the magnification of the image.
32. A converging lens has focal length 10.0cm. Suppose an object is placed 30.0cm from the lens.
 - (i) Calculate the image distance.
 - (ii) Calculate the magnification.
 - (iii) Is this image real or virtual?
 - (iv) Is this image upright or inverted?
33. A diverging lens has focal length 10.0cm. Suppose an object is placed 30.0cm from the lens.
 - (i) Calculate the image distance.
 - (ii) Calculate the magnification.
 - (iii) Is this image real or virtual?
 - (iv) Is this image upright or inverted?
34. A fish is swimming 2.0m beneath the surface of a lake ($n = 1.33$). What is the apparent depth of the fish as viewed from directly above the surface of the water ($n = 1.00$)?
35. The visual light spectrum ranges from wavelengths of _____ nm to _____ nm (round to nearest hundred).
36. Calculate the frequency of 500nm light (in Hertz).

37. True or false: Light travels at 3×10^8 m/s in all media.
38. Which of the following is primarily responsible for why stars “twinkle”? (Choose one letter)
- A) Reflection
 - B) Refraction
 - C) Polarization
 - D) Dispersion
 - E) All of the above
39. Calculate the energy in Joules of a photon with wavelength 500nm.
Note – Photons are massless particles, so you do not need to take into account any classical mechanics equations such as kinetic or potential energy. It turns out that since the photon is traveling at the speed of light, it can still have energy even as a massless particle! An equation on the front page might help you with this question.
40. Calculate the momentum of this photon in kgm/s.
Photons have momentum too, even though they are massless!
41. True or false: Rods are very sensitive to color.
42. True or false: Cones are concentrated in the fovea.
43. People with myopia can focus their eyes well on (nearby/distant) objects.
44. A compound microscope consists of two lenses. One of these lenses is called the (i) lens and the other lens is called the (ii).
45. A refractive telescope creates an (upright / inverted) image.
46. A Galilean telescope creates an (upright / inverted) image.

For problems 47-48, consider the graph below.



47. Approximately what wavelength of light is absorbed the most by this object?
48. This object will have a color of: (choose one letter)
A) Red
B) Green
C) Blue
49. True or false: If a substance primarily absorbs light at green wavelengths, then the object will appear green.
50. Red + Green = _____
51. Yellow + Magenta = _____
52. Cyan + Yellow = _____