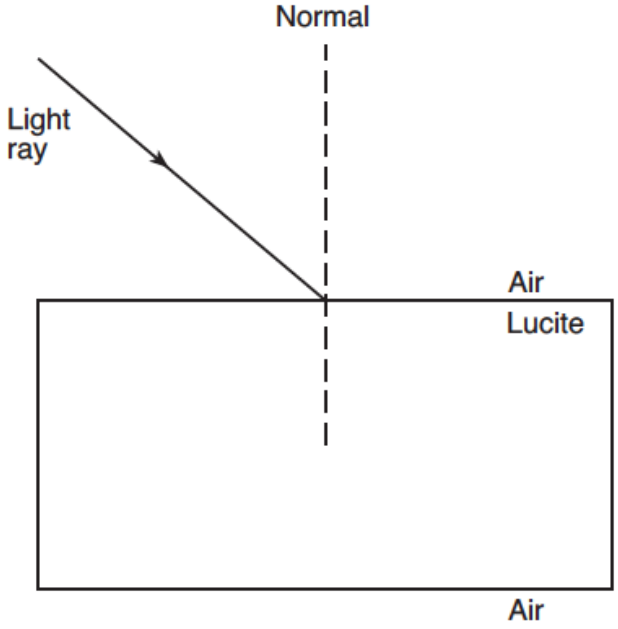
Name: _____ Period: _____

Waves-Refraction

1. In which way does blue light change as it travels from diamond into crown glass?
   1. Its frequency decreases.
   2. Its frequency increases.
   3. Its speed decreases.
   4. Its speed increases.

Base your answers to questions 2 through 4 on the information and diagram below.

A monochromatic light ray (f=5.09 × 10^{14} Hz) traveling in air is incident on the surface of a rectangular block of Lucite (n=1.50).



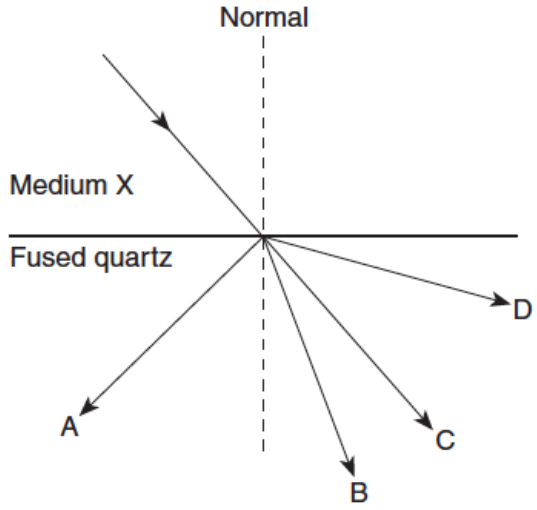
2. Measure the angle of incidence for the light ray to the *nearest degree.*

3. Calculate the angle of refraction of the light ray when it enters the Lucite block. {Show all work, including the equation and substitution with units.]

4. What is the angle of refraction of the light ray as it emerges from the Lucite block back into the air?

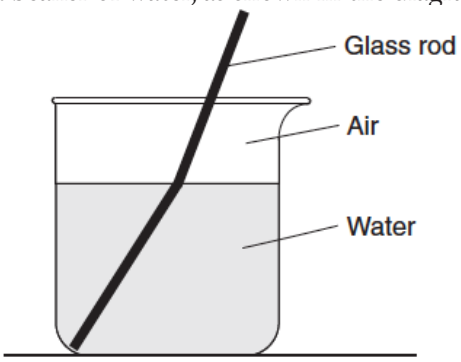
5. A change in the speed of a wave as it enters a new medium produces a change in
   1. frequency
   2. period
   3. wavelength
   4. phase

6. The diagram below represents a ray of monochromatic light (f=5.09 × 10^{14} Hz) passing from medium X (n=1.46) into fused quartz (n=1.46).



Which path will the ray follow in the quartz?
1. A
2. B
3. C
4. D

7. A straight glass rod appears to bend when placed in a beaker of water, as shown in the diagram below.



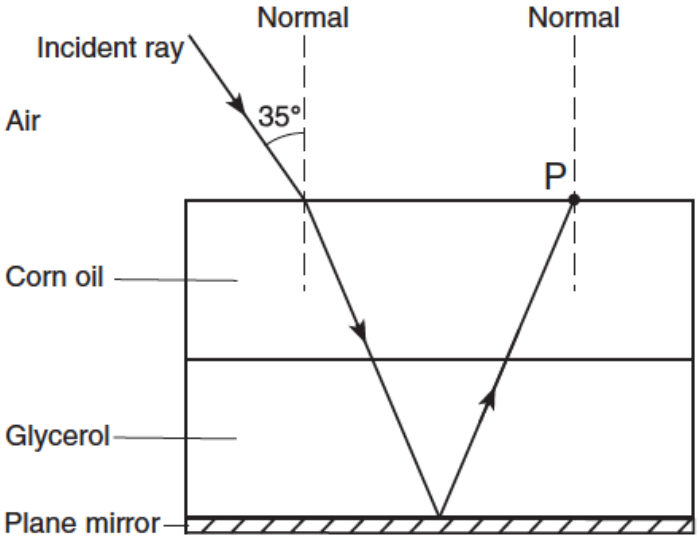
What is the best explanation for this phenomenon?
1. The water is warmer than the air.
2. Light travels faster in water than in air.
3. Light is reflected at the air-water interface.
4. Light is refracted as it crosses the air-water interface.

Name: _____ Period: _____

Waves-Refraction

Base your answers to questions 8 through 10 on the information and diagram below.

A ray of monochromatic light having a frequency of 5.09×10^{14} hertz is incident on an interface of air and corn oil (n=1.47) at an angle of 35° as shown. The ray is transmitted through parallel layers of corn oil and glycerol (n=1.47) and is then reflected from the surface of a plane mirror, located below and parallel to the glycerol layer. The ray then emerges from the corn oil back into the air at point P.



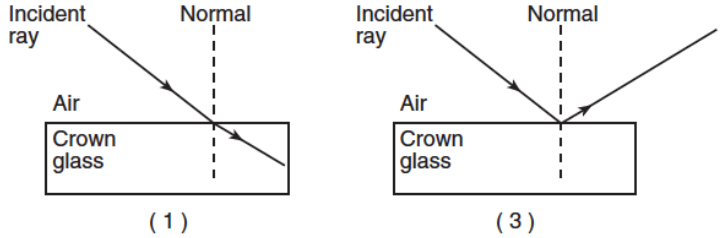
8. Calculate the angle of refraction of the light ray as it enters the corn oil from air. [Show all work, including the equation and the substitution with units.

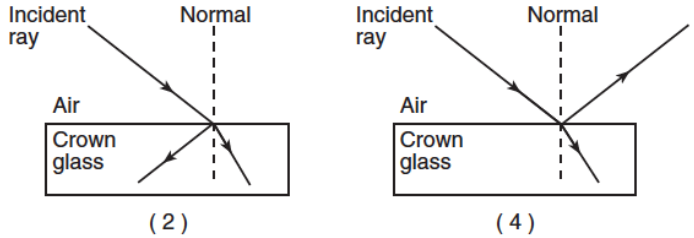
9. Explain why the ray does not bend at the corn oil-glycerol interface.

10. On the diagram, use a protractor and straightedge to construct the refracted ray representing the light emerging at point P into air.

---

11. Which diagram best represents the behavior of a ray of monochromatic light in air incident on a block of crown glass (n=1.52)?



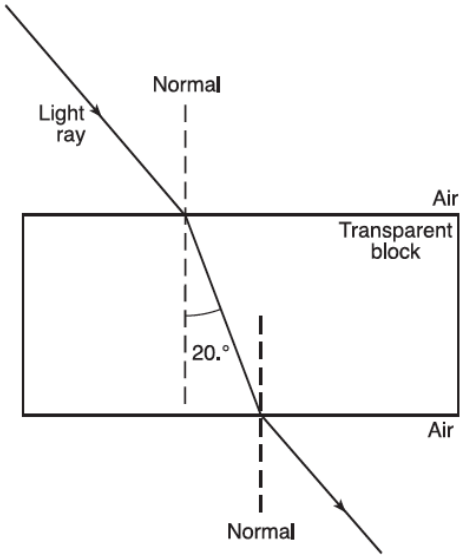


Name: _____ Period: _____

Waves-Refraction

Base your answers to questions 12 through 14 on the information below.

A ray of monochromatic light (f= 5.09×10^{14} Hz) passes through air and a rectangular transparent block, as shown in the diagram below.



12. Using a protractor, determine the angle of incidence of the light ray as it enters the transparent block from air.

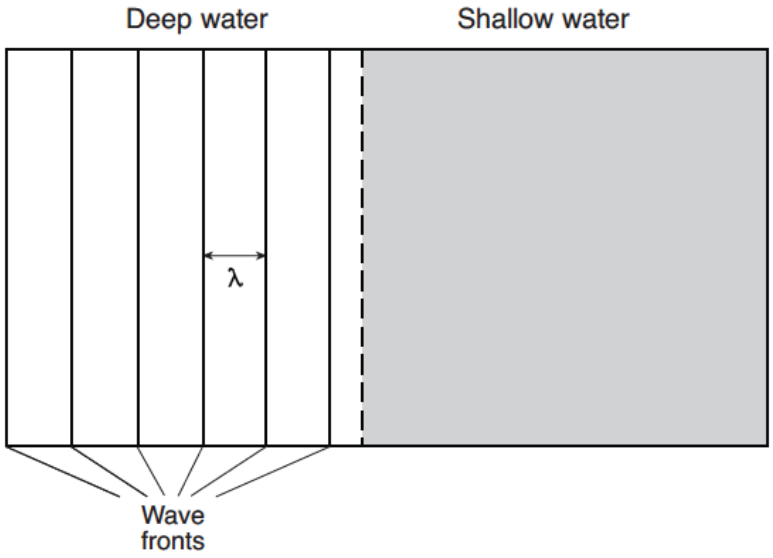
13. Calculate the absolute index of refraction for the medium of the transparent block. [Show all work, including the equation and substitution with units.]

14. Calculate the speed of the light ray in the transparent block. [Show all work, including the equation and substitution with units.]

---

15. A wave generator having a constant frequency produces parallel wave fronts in a tank of water of two different depths. The diagram below represents the wave fronts in the deep water.

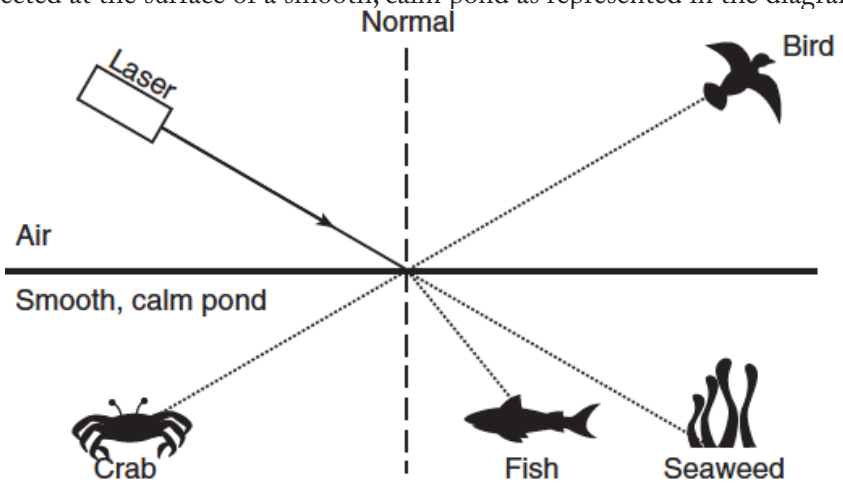
    As the wave travels from the deep water into the shallow water, the speed of the waves decreases. On the diagram at right, use a straightedge to draw *at least three* lines to represent the wave fronts, with appropriate spacing, in the shallow water.



Name: _____ Period: _____

Waves-Refraction

16. A laser beam is directed at the surface of a smooth, calm pond as represented in the diagram below.

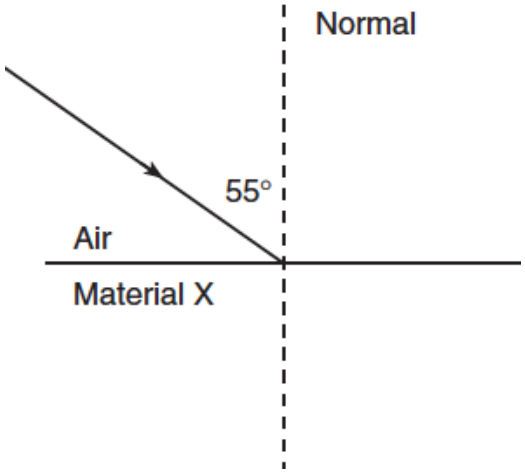


Which organisms could be illuminated by the laser light?

1. the bird and the fish
2. the bird and the seaweed
3. the crab and the seaweed
4. the crab and the fish

Base your answers to questions 17 through 19 on the information and diagram below.

A ray of light ($f = 5.09 \times 10^{14}$ Hz) is incident on the boundary between air and an unknown material X at an angle of incidence of 55°, as shown. The absolute index of refraction of material X is 1.66.



17. Determine the speed of this ray of light in material X.

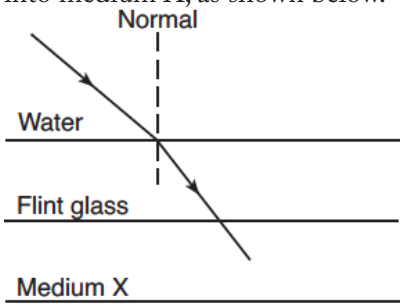
18. Calculate the angle of refraction of the ray of light in material X.

19. On the diagram above, use a straightedge and protractor to draw the refracted ray of light in material X.

Name: _____ Period: _____

Waves-Refraction

20. A ray of monochromatic light (f= 5.09 × 10^{14} Hz) passes from water through flint glass (n=1.66) and into medium X, as shown below.



The absolute index of refraction of medium X is
1. less than 1.33
2. greater than 1.33 and less than 1.52
3. greater than 1.52 and less than 1.66
4. equal to 1.66

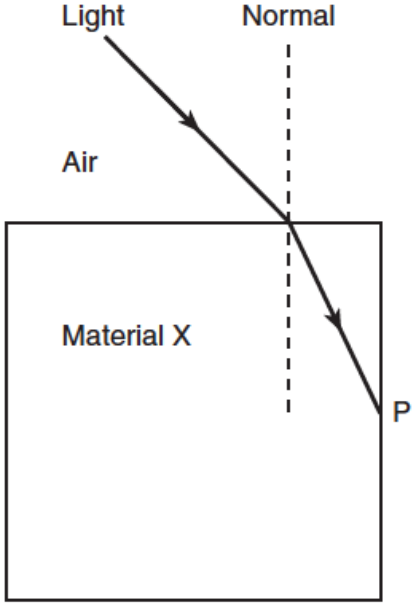
21. A beam of light travels through medium X with a speed of 1.80 × 10^{8} meters per second. Calculate the absolute index of refraction of medium X. [Show all work, including the equation and substitution with units.]

22. What happens to the speed and frequency of a light ray when it passes from air into water?
1. The speed decreases and the frequency increases.
2. The speed decreases and the frequency remains the same.
3. The speed increases and the frequency increases.
4. The speed increases and the frequency remains the same.

23. A ray of monochromatic light (f= 5.09 × 10^{14} Hz) in air is incident at an angle of 30° on a boundary with corn oil (n=1.47). What is the angle of refraction, to the nearest degree, for this light ray in the corn oil?
1. 6°
2. 20°
3. 30°
4. 47°

Base your answers to questions 24 through 26 on the information and diagram below.

A ray of light passes from air into a block of transparent material X as shown in the diagram below.



24. Measure the angles of incidence and refraction to the nearest degree for this light ray at the air into material X boundary.

θ_i= θ_r=

25. Calculate the absolute index of refraction of material X. [Show all work, including the equation and substitution with units.]

26. The refracted light ray is reflected from the material X–air boundary at point P. Using a protractor and straightedge, on the diagram in your answer booklet, draw the reflected ray from point P.

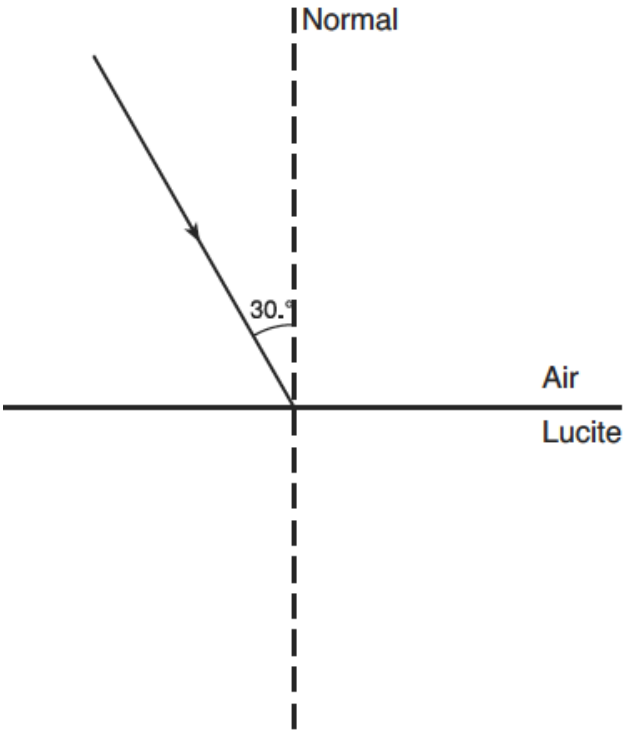
27. If the speed of a wave doubles as it passes from shallow water into deeper water, its wavelength will be
1. unchanged
2. doubled
3. halved
4. quadrupled

Name: _____ Period: _____

Waves-Refraction

Base your answers to questions 28 and 29 on the information and diagram below.

A ray of monochromatic light (f= 5.09×10^{14} Hz) passes from air into Lucite at an angle of incidence of 30°.

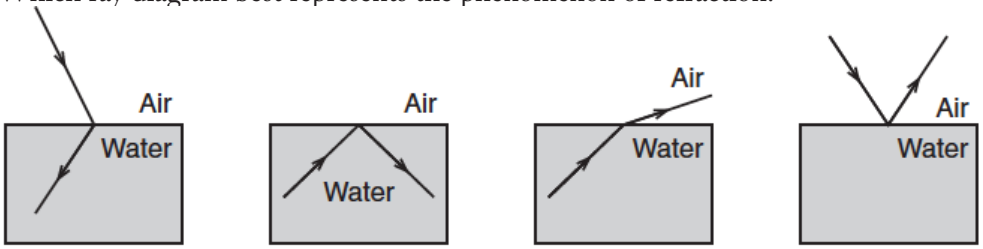


28. Calculate the angle of refraction in the Lucite. [Show all work, including the equation and substitution with units.]

29. Using a protractor and straightedge, on the diagram draw the refracted ray in the Lucite.

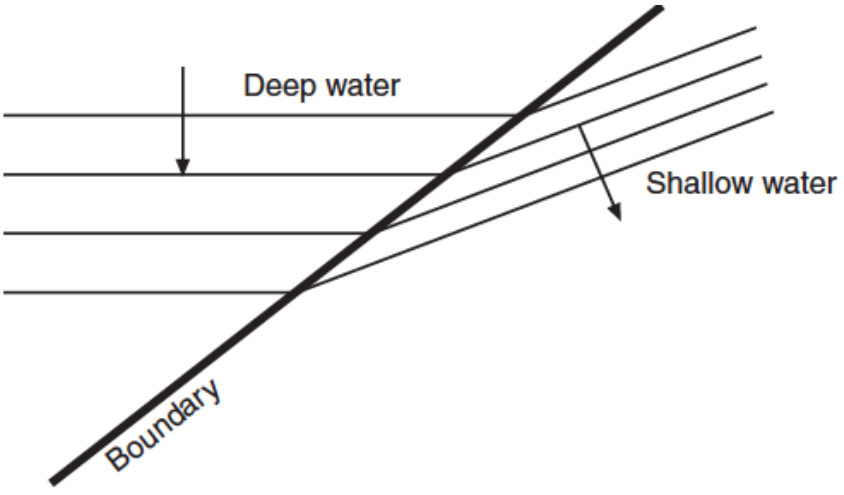
---

30. Which ray diagram best represents the phenomenon of refraction?



---

31. The diagram at right represents straight wave fronts passing from deep water into shallow water, with a change in speed and direction.



Which phenomenon is illustrated in the diagram?

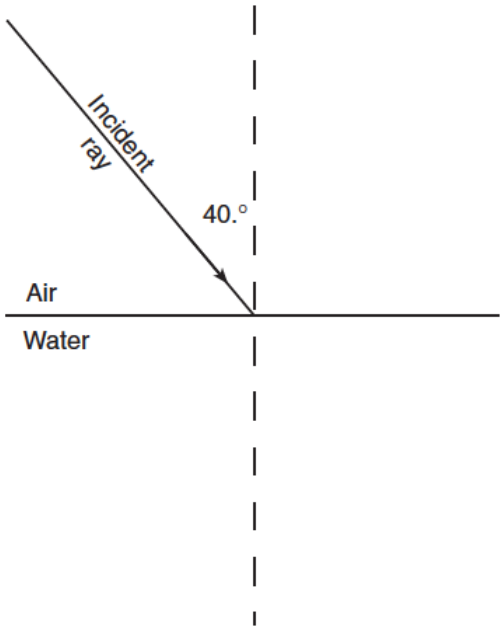
1. reflection
2. refraction
3. diffraction
4. interference

Name: _____ Period: _____

Waves-Refraction

Base your answers to questions 32 through 34 on the information and diagram below.

A light ray with a frequency of 5.09×10^{14} hertz traveling in air is incident at an angle of 40° on an air-water interface as shown. At the interface, part of the ray is refracted as it enters the water and part of the ray is reflected from the interface.



32. Calculate the angle of refraction of the light ray as it enters the water. [Show all work, including the equation and substitution with units.]

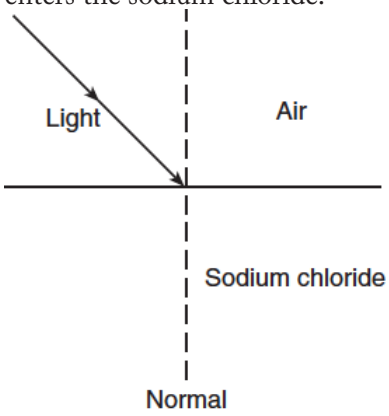
33. On the diagram above, using a protractor and straightedge, draw the refracted ray. Label this ray "Refracted ray."

34. On the diagram above, using a protractor and straightedge, draw the reflected ray. Label this ray "Reflected ray."

35. An electromagnetic wave of wavelength 5.89×10^{-7} meter traveling through air is incident on an interface with corn oil (n=1.47). Calculate the wavelength of the EM wave in corn oil.

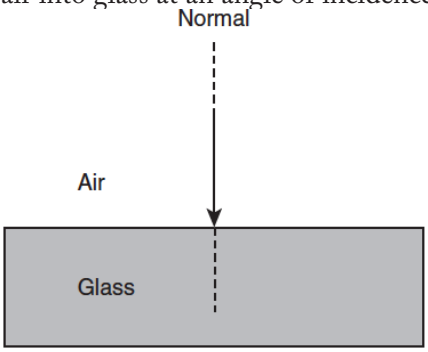
36. The speed of light in a piece of plastic is 2.00×10^{8} meters per second. What is the absolute index of refraction of this plastic?
    1. 1.00
    2. 0.67
    3. 1.33
    4. 1.50

37. A ray of monochromatic light is incident on an air-sodium chloride (n=1.54) boundary as shown in the diagram below. At the boundary, part of the ray is reflected back into the air and part is refracted as it enters the sodium chloride.



Compared to the ray's angle of refraction in the sodium chloride, the ray's angle of reflection in the air is
    1. smaller
    2. larger
    3. the same

38. The diagram below shows a ray of light passing from air into glass at an angle of incidence of 0°.

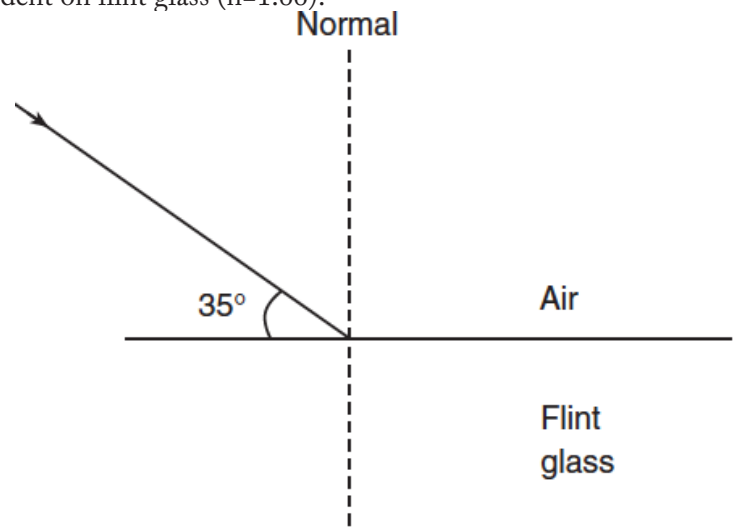


Which statement best describes the speed and direction of the light ray as it passes into the glass?
    1. Only speed changes.
    2. Only direction changes.
    3. Both speed and direction change.
    4. Neither speed nor direction changes.

Name: _____ Period: _____

Waves-Refraction

Base your answers to questions 39 through 42 on the diagram below, which represents a ray of monochromatic light (5.09×10^{14} Hz) in air incident on flint glass (n=1.66).



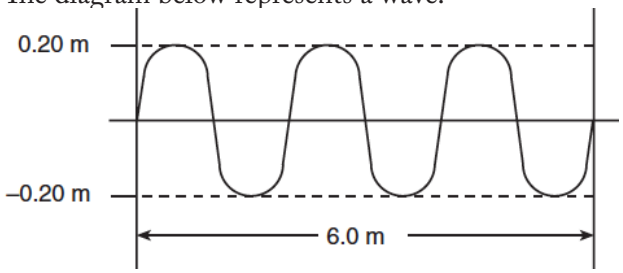
39. Determine the angle of incidence of the light ray in air.

40. Calculate the angle of refraction of the light ray in the flint glass. [Show all work, including the equation and substitution with units.]

41. Using a protractor and straightedge, draw the refracted ray on the diagram.

42. What happens to the light from the incident ray that is *not* refracted or absorbed?

43. The diagram below represents a wave.



What is the speed of the wave if its frequency is 8.0 hertz?

1. 48 m/s
2. 16 m/s
3. 3.2 m/s
4. 1.6 m/s

44. What is the wavelength of a light ray with frequency 5.09×10^{14} hertz as it travels through Lucite (n=1.50)?

1. 3.93×10^{-7} m
2. 5.89×10^{-7} m
3. 3.39×10^{14} m
4. 7.64×10^{14} m

45. The speed of light (f=5.09×10^{14} Hz) in a transparent material is 0.75 times its speed in air. The absolute index of refraction of the material is approximately

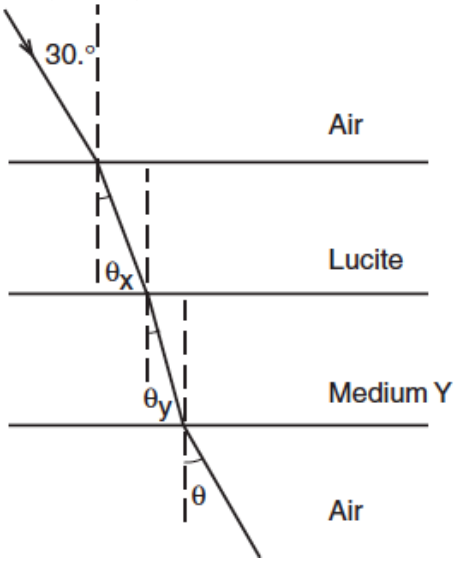
1. 0.75
2. 1.3
3. 2.3
4. 4.0

Name: _____ Period: _____

Waves-Refraction

46. A light ray traveling in air enters a second medium and its speed slows to 1.71×10^8 meters per second. What is the absolute index of refraction of the second medium?
    1. 1.00
    2. 0.570
    3. 1.75
    4. 1.94

Base your answers to questions 47 and 48 on the diagram below, which represents a light ray traveling from air to Lucite (n=1.50) to medium Y and back into air.



47. The sine of angle θ_x is
    1. 0.333
    2. 0.500
    3. 0.707
    4. 0.886

48. Light travels *slowest* in
    1. air, only
    2. Lucite, only
    3. medium Y, only
    4. air, Lucite, and medium Y

---

49. Which quantity is equivalent to the product of the absolute index of refraction of water and the speed of light in water?
    1. wavelength of light in a vacuum
    2. frequency of light in water
    3. sine of the angle of incidence
    4. speed of light in a vacuum

50. What is the speed of light ($f=5.09 \times 10^{14}$ Hz) in flint glass?
    1. 1.81×10^8 m/s
    2. 1.97×10^8 m/s
    3. 3.00×10^8 m/s
    4. 4.98×10^8 m/s

51. What happens to the frequency and the speed of an electromagnetic wave as it passes from air into glass?
    1. The frequency decreases and the speed increases.
    2. The frequency increases and the speed decreases.
    3. The frequency remains the same and the speed increases.
    4. The frequency remains the same and the speed decreases.

52. When a light wave enters a new medium and is refracted, there must be a change in the light wave's
    1. color
    2. frequency
    3. period
    4. speed

53. As a sound wave passes from water, where the speed is 1.49×10^3 meters per second, into air, the wave's speed
    1. decreases and its frequency remains the same
    2. increases and its frequency remains the same
    3. remains the same and its frequency decreases
    4. remains the same and its frequency increases

54. In a certain material, a beam of monochromatic light ($f=5.09 \times 10^{14}$ Hz) has a speed of 2.25×10^8 meters per second. The material could be
    1. crown glass (n=1.52)
    2. flint glass (n=1.66)
    3. glycerol (n=1.47)
    4. water (n=1.33)

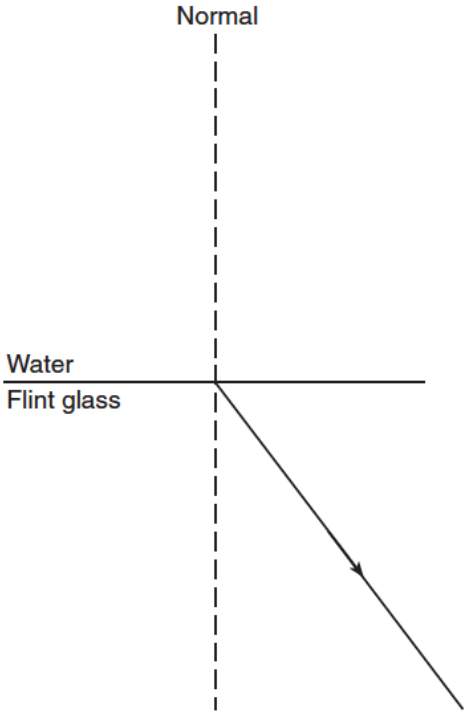
55. A ray of monochromatic light with frequency 5.09×10^{14} Hz is transmitted through four different media: corn oil, ethyl alcohol, flint glass, and water. Rank the four media from the one through which the light travels at the slowest speed to the one through which light travels at the fastest speed.

Name: _____ Period: _____

Waves-Refraction

Base your answers to questions 56 through 59 on the information below.

A light ray ($f=5.09 \times 10^{14}$ Hz) is refracted as it travels from water into flint glass. The path of the light ray in the flint glass is shown in the diagram.



56. Using a protractor, measure the angle of refraction of the light ray in the flint glass.

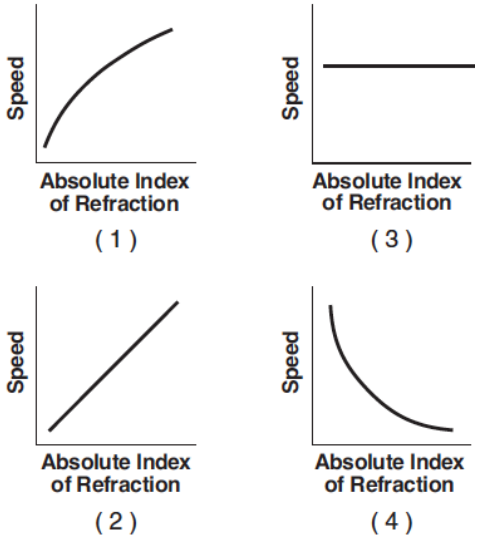
57. Calculate the angle of incidence for the light ray in water. [Show all work, including the equation and substitution with units.]

58. Using a protractor and straight edge, on the diagram draw the path of the incident light ray in the water.

59. Identify one physical event, other than transmission or refraction, that occurs as the light interacts with the water-flint glass boundary.

60. The wavelength of a wave doubles as it travels from medium A into medium B. Compared to the wave in medium A, the wave in medium B has
    1. half the speed
    2. twice the speed
    3. half the frequency
    4. twice the frequency

61. A ray of light ($f=5.09\times10^{14}$ Hz) travels through various substances. Which graph best represents the relationship between the absolute index of refraction of these substances and the corresponding speed of light in these substances?



62. What is the speed of light ($f=5.09\times10^{14}$ Hz) in ethyl alcohol?
    1. 4.53×10^{-9} m/s
    2. 2.43×10^{2} m/s
    3. 1.24×10^{8} m/s
    4. 2.21×10^{8} m/s

Name: _____ Period: _____

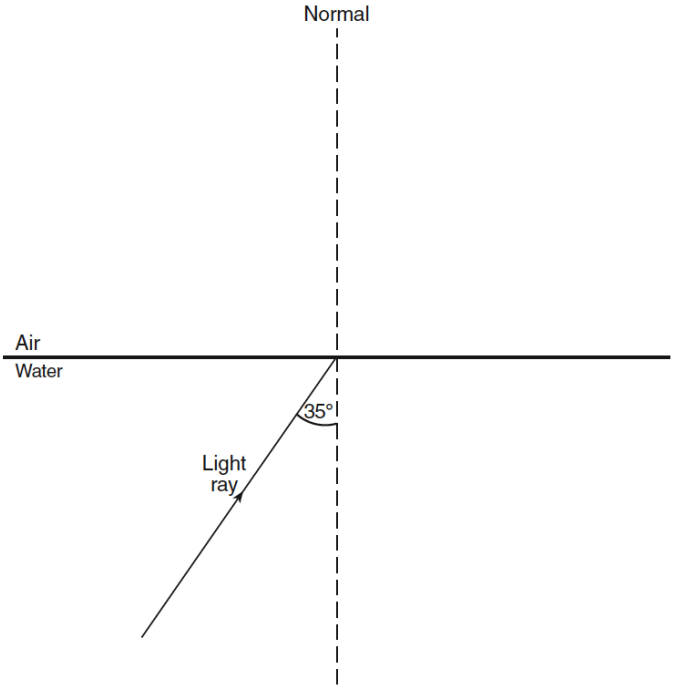
Waves-Refraction

Base your answers to questions 63 through 66 on the information below.

A light ray ($f=5.09 \times 10^{14}$ Hz) traveling in water has an angle of incidence of 35° on a water-air interface. At the interface, part of the ray is reflected from the interface and part of the ray is refracted as it enters the air.

63. What is the angle of reflection of the light ray at the interface?

64. On the diagram below, using a protractor and a straightedge, draw the reflected ray.

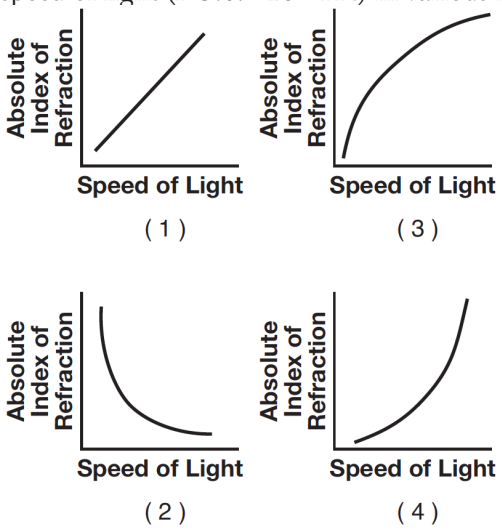


65. Calculate the angle of refraction of the light ray as it enters the air. [Show all work, including the equation and substitution with units.]

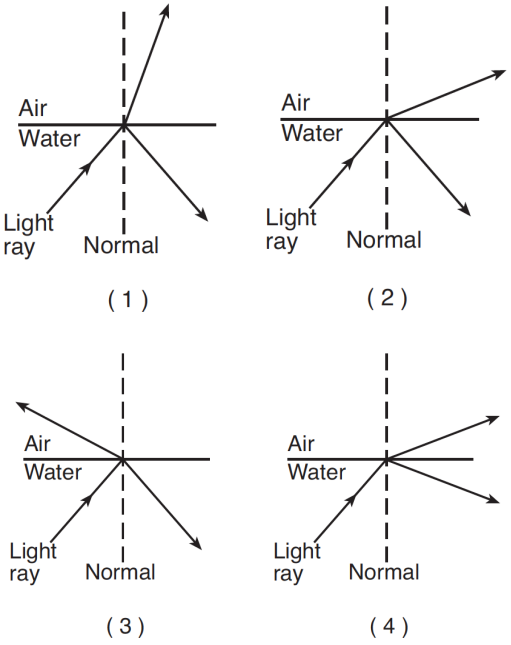
66. Identify one characteristic of this light ray that is the same in both the water and the air.

67. As a monochromatic light ray passes from air into water, two characteristics of the ray that will not change are
    1. wavelength and period
    2. frequency and period
    3. wavelength and speed
    4. frequency and speed

68. Which graph best represents the relationship between the absolute index of refraction and the speed of light ($f=5.09\times10^{14}$ Hz) in various media?



69. When a ray of light traveling in water reaches a boundary with air, part of the light ray is reflected and part is refracted. Which ray diagram best represents the paths of the reflected and refracted rays?



Name: _____ Period: _____

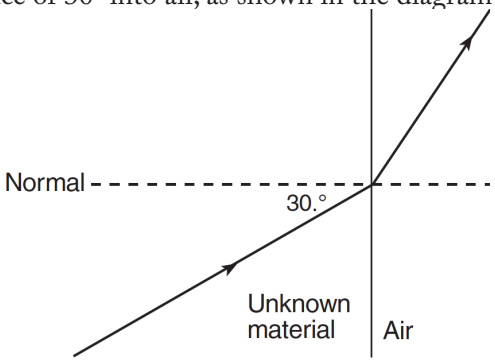
Waves-Refraction

70. Which characteristic of a light wave must increase as the light wave passes from glass into air?
    1. amplitude
    2. frequency
    3. period
    4. wavelength

71. A ray of yellow light ($f = 5.09 \times 10^{14}$ Hz) travels at a speed of 2.04×10^{8} meters per second in
    1. ethyl alcohol
    2. water
    3. Lucite
    4. glycerol

Base your answers to questions 72 and 73 on the information and diagram below.

A ray of light ($f=5.09 \times 10^{14}$ Hz) traveling through a block of an unknown material, passes at an angle of incidence of 30° into air, as shown in the diagram below.



72. Use a protractor to determine the angle of refraction of the light ray as it passes from the unknown material into air.

73. Calculate the index of refraction of the unknown material. [Show all work, including the equation and substitution with units.]