Electromagnetic Waves: Practice Solutions

# Level 2: Reflection and Refraction

## Multiple Choice

1. 

A beam of light passes from medium 1 to medium 2 to medium 3as shown in the accompanying figure. What is true about the respective indices of refraction (n1, n2, and n3)

A) n1 > n2 > n3 B) n1 > n3 > n2 C) n2 > n3 > n1

**D) n2 > n1** > n3 E) n3 > n1 > n2

More–Less dense bend away, Less–More dense bend towards. The more the bend, the bigger the

difference in n’s.

 

1. A beam of light is directed toward point P on a boundary as shown to the right. Which segment best represents the refracted ray?

A) PA B) PB C) PC **D) PD** E) PE

Less–More bend towards. But it can’t be E because that would only happen if the incoming

angle was also 0.

1. Which diagram best represents what happens to a ray of light entering air from water? Air is at the top in all

diagrams.



Answer: C

Assuming total internal reflection didn’t happen, More–Less dense bend away

 

1. A beam of light passes from medium 1 to medium 2 to medium 3 as shown in the diagram. What may be

concluded about the speed of light in each medium?

**A) v3 > v1 > v2** B) v1 > v2 > v3 C) v1 > v3 < v2

D) v2 > v3 > v1 E) v2 > v1 > v3

More–Less dense bend away, Less–More dense bend towards. The more the bend, the bigger the

difference in n’s … this shows that n2 > n1 > n3. More n means less speed so v3 > v1 > v2

 

1. A beam of light travels through the air and strikes the surface of water at an angle of incidence of 45°. It continues through the water and then strikes the bottom of a glass aquarium. Which of the following would be closest to the angle of refraction after the beam enters the glass. The index of refraction of water is 1.3 and

that of glass is 1.5

A) 55° B) 45° C) 38° D) 33° E) 28°.

Use ni sin θi = nr sin θr, air to water and find θr. That θr is the θi for the second water to glass

interface. Then do ni sin θi = nr sin θr, water to glass and find θr

 

1. A light ray R in medium I strikes a sphere of medium II with angle of incidence θ, as shown above. The figure

shows five possible subsequent paths for the light ray.

1. Which path is possible if medium I is air and medium II is glass?

(A) A (B) B (C) C (D) D **(E) E**

Medium I (air) is surrounding the sphere on both sides. As it enters the sphere, it goes less–more

so bends towards the normal line (leaving D or E as the possibly answers). When the ray

reaches the far edge of the sphere, it goes from more–less so should bend away from the normal

line. Note the normal line drawn below.



1. Which path is possible if medium I is glass and medium II is air?

(A) A (B) B (C) C (D) D (E) E

 This should be the opposite of the scenario in the last question.

1. A wave moves from one medium to a second medium with a different index of refraction. Which of the

following wave properties would NEVER change?

**A) frequency** B) wavelength C) speed D) angle E) all will change

Fact for refraction problems.

1. When light passes from air into water, the frequency of the light remains the same. What happens to the speed

and the wavelength of light as it crosses the boundary in going from air into water?

Speed Wavelength

(A) Increases Remains the same

 (B) Remains the same Decreases

(C) Remains the same Remains the same

(D) Decreases Increases

**(E) Decreases Decreases**

When light goes in higher indices of refraction, it slows down. Since v = f λ and f remains

constant, when v decreases λ decrease with it.







## AP Free Response





### Solution



## Problem



 

(b) Calculate the index of refraction of the glass slab from your best-fit line.

(c) Describe how you could use the graph to determine the critical angle for the glass-air interface. Do not use

the answer to the part (b) for this purpose.

(d) On the graph in (a), sketch and label a line for a material of higher index of refraction.

### Solution





# Level 3: Mirrors

**Before moving on, make sure you have complete the assigned Ray Diagram Pages**

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1. **An object, slanted at an angle of 45°, is placed in front of a vertical plane mirror, as shown above. Which of the following shows the apparent position and orientation of the object's image?**

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**Answer: D**

**In a flat mirror, the image can be found by flipping the object to the other side, basically folding**

**it over the mirror onto the other side.**

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1. The spherical mirror shown has a center of curvature at point c. Which point is nearest

to the focal point?

(A) a (B) b (C) c (D) d (E) e

The focal point is half the center of curvature

1. A concave mirror with a radius of curvature of 1.0 m is used to collect light from a distant star. The distance

between the mirror and the image of the star is most nearly

(A) 0.25 m (B) 0.50 m (C) 0.75 m (D) 1.0 m (E) 2.0 m

Light from a distant star is assumed to be all horizontal. Horizontal light hitting a concave mirror

will all converge at the focal point to form an image of the star directly on the focal point. With a

radius of curvature = 1m, the focal point is 0.5 m.

## Free Response



1978B5. An object 6 centimeters high is placed 30 centimeters from a concave mirror of focal length

10 centimeters as shown above.

(a) On the diagram above, locate the image by tracing two rays that begin at point P and pass through the

focal point F. Is the image real or virtual? Is it located to the left or to the right of the mirror?

(b) Calculate the position of the image.

(c) Calculate the size of the image.

(d) Indicate on the diagram above how the ray from point P to point Q is reflected, if aberrations are

negligible.

#### Solution





# Snell’s Law Problem



1994B5. A point source S of monochromatic light is located on the bottom of a swimming pool filled with water to

a depth of 1.0 meter, as shown above. The index of refraction of water is 1.33 for this light. Point P is located on

the surface of the water directly above the light source. A person floats motionless on a raft so that the surface of

the water is undisturbed.

a. Determine the velocity of the source's light in water.

b. On the diagram above, draw the approximate path of a ray of light from the source S to the eye of the person. It

is not necessary to calculate any angles.

c. Determine the critical angle for the air-water interface.

Suppose that a converging lens with focal length 10 centimeters in water is placed 20 centimeters above the light

source, as shown in the diagram below. An image of the light source is formed by the lens.

## Solution

a) n = c/v … 1.33 = 3x108 / v … vwater = 2.26x108 m/s

