### Physics 222 Quiz Questions (Week #12)

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Section 222-26 meets Tu 7-10 p.m. in Room 32. (Abram) **Any one of the above**

**Note:** Quiz problems #5 is not all in sequence.
Quiz Questions for 4/8

1. Consider a light ray passing from vacuum into glass \( n=1.5 \) at an angle of 30 degrees to the surface of the glass. (a) What is the angle between the surface of the glass and the reflected ray? (b) What is the angle between the surface of the glass and the refracted ray? (c) What is the Brewster angle for this interface?

![Diagram of light ray passing from vacuum into glass at an angle of 30 degrees]

Solution:

(a) By the law of reflection, the angle of incidence (60°) must be equal to the angle of reflection. So, the reflected ray must make an angle of 30° with the interface.

(b) By the law of refraction, \( n_1 \sin(\theta_1) = n_2 \sin(\theta_2) \). So, we have:

\[
\sin(60°) = 1.5 \times \sin(\theta_2) \Rightarrow \theta_2 = \sin^{-1}\left(\frac{\sin(60°)}{1.5}\right) = 35.3°
\]

Therefore, the refracted ray makes an angle of 90-35.3 = 54.7° with the surface of the glass.

(c) The Brewster angle is given by \( \tan(\theta_B) = n_2/n_1 \).

\[
\theta_B = \tan^{-1}(1.5) = 56.3°
\]
A 3 cm tall object is placed 50 cm from a concave spherical mirror with a radius of curvature of 25 cm. (a) Where is the image located? (b) How tall is the image?

Solution:

(a) By convention, s and R are both negative in this case, so:

\[ \frac{1}{s} + \frac{1}{s'} = \frac{2}{R} \Rightarrow \frac{1}{s} + \frac{1}{s'} = \frac{2}{-50cm} \Rightarrow s' = \frac{-50}{3} = -16.66\text{cm} \]

Therefore, the image is located 16.66 cm in front of the mirror, and is real.

(b) \[ m = \frac{-s'}{s} = -16.66 \cdot \frac{1}{-50} = \frac{1}{3} \]

So, the image’s height is 1/3 of the object’s, or 1 cm.

A 5 cm tall object is placed 50 cm from a convex spherical mirror with a radius of curvature of 25 cm. (a) Where is the image located? (b) How tall is the image?

Solution:

(a) By convention, s is negative and R is positive in this case, so:

\[ \frac{1}{s} + \frac{1}{s'} = \frac{2}{R} \Rightarrow \frac{1}{s} + \frac{1}{s'} = \frac{2}{-50cm} \Rightarrow s' = 10\text{cm} \]

Therefore, the image is located 10 cm behind the mirror, and is virtual.

(b) \[ m = \frac{-s'}{s} = \frac{10}{-50} = -\frac{1}{5} \]

So, the image’s height is 1/5 of the object’s, or 1 cm. Also note that the image is inverted.
A 10 cm tall object is placed 50 cm from a single convex spherical glass (n=1.5) surface with a radius of curvature of 25 cm. Assume the index of refraction of air is 1. 

(a) Where is the image located? (b) How tall is the image?

![Diagram](image.png)

Solution:

(a) Recall that as shown, R is positive and s is negative.

\[-\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R} \Rightarrow -\frac{1}{-50cm} + \frac{1.5}{s'} = \frac{1.5 - 1}{25cm} \Rightarrow s' = 37.5cm\]

So, the image is located 37.5 cm to the right of the surface.

(b) \[
m = \frac{n_1 s'}{n_2 s} = \frac{37.5cm}{1.5 \cdot -50cm} = \frac{1}{2}
\]

So, the image's height is 1/2 of the object's, or 5 cm.
Consider a light ray passing from glass \((n=1.5)\) into vacuum at an angle of 60 degrees to the surface of the glass. (a) What is the angle between the surface of the glass and the reflected ray? (b) What is the angle between the surface of the glass and the refracted ray? (c) What is the critical angle for this interface?

\[
\begin{array}{c}
\text{glass} \\
\downarrow 60^\circ \\
\text{vacuum}
\end{array}
\]

Solution:

(a) By the law of reflection, the angle of incidence \((30^\circ)\) must be equal to the angle of reflection. So, the reflected ray must make an angle of 60° with the interface.

(b) By the law of refraction, \(n_1 \cdot \sin(\theta_1) = n_2 \cdot \sin(\theta_2)\). So, we have:

\[
1.5 \cdot \sin(30) = \sin(\theta_2) \implies \theta_2 = \sin^{-1}(1.5 \cdot \sin(30)) = 48.6^\circ
\]

Therefore, the refracted ray makes an angle of 90-48.6 = 41.4° with the surface of the glass.

(c) The critical angle is given by \(\sin(\theta_c) = \frac{n_2}{n_1}\).

\[
\theta_c = \sin^{-1}\left(\frac{1}{1.5}\right) = 41.8^\circ
\]
Consider a corner mirror, as shown below with two perpendicular mirrored surfaces, and an incident ray that is 50° from vertical. Once the light ray bounces off of both mirrored surfaces, what angle does the outgoing ray make with a vertical line?

\[ \text{Solution:} \]

A carefully drawn diagram shows that the outgoing ray will be antiparallel to the incoming ray.
7. In your bathroom, the mirror on the wall is a plane mirror, which is simply a spherical mirror with an infinite radius of curvature. Assume that you are standing 1 meter in front of such a plane mirror and looking at your reflection. (a) What is the object distance? (b) What is the image distance? (c) What is the magnification? (d) Is the image real or virtual?

Solution:

(a) By convention, the object distance is negative, so \( s = -1 \text{ m} \).

(b) The general mirror equation applies with \( R \) equal to infinity.

\[
\frac{1}{s} + \frac{1}{s'} = \frac{2}{\infty} = 0 \Rightarrow s' = -s = 1 \text{ m}
\]

(c) The general magnification equation applies as well.

\[ m = -\frac{s'}{s} = 1 \]

(d) Since \( s' \) is greater than zero, the image is located behind the mirror. No light from the object passes through the mirror, so this must be a virtual image.

8. In the diagram below, the arrow on the left could be a person standing in front of a mirror, and the arrow on the right his image. If he is 6 feet tall, how tall must the mirror be in order to allow him to see both his feet and his head? (Hint: Consider where on the mirror rays from his head and from his feet must strike to be reflected to his eyes.)

Solution:

Since light from his feet will reflect off of a waist-high point on the mirror to get to his eyes, the mirror only needs to be 3 feet long.
9. Consider two mirrors that make an angle of 75° with one another, as shown. Assume that a light ray 50° from horizontal is incident on the horizontal mirror. After reflecting off the horizontal mirror, what angle does the reflected ray make with the second mirror?

Solution:

A carefully drawn diagram shows that the answer is 55°.