Foundations of Physics: Optics

Week 12 & 13 Content

Name: _____

Date: _____

1 Summary

1.1 Mirror Equation

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

- f = focal length of the mirror (positive for concave, negative for convex)
- d_o = object distance (positive if object is in front of the mirror)
- d_i = image distance (positive if image is real and in front of mirror)

1.2 Magnification

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

- m = magnification (dimensionless)
- h_i = image height (negative if inverted)
- h_o = object height
- d_i = image distance
- d_o = object distance

1.3 Relationship Between Radius of Curvature and Focal Length

$$f = \frac{R}{2}$$

- R = radius of curvature of the mirror

1.4 Sign Conventions for Mirrors

- Distances measured **toward** the mirror along the incident light direction are **positive**.
- For a **concave mirror**: $f > 0$, $d_i > 0$ for real images.
- For a **convex mirror**: $f < 0$, $d_i < 0$ for virtual images.
- Heights above the principal axis are **positive**, below are **negative**.

1.5 Snell's Law (Refraction at a Boundary)

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

- n_1, n_2 = refractive indices of the two media
- θ_1, θ_2 = angles of incidence and refraction (measured from the normal)

1.6 Refractive Index and Speed of Light

$$n = \frac{c}{v}$$

- n = refractive index
- c = speed of light in vacuum (3.00×10^8 m/s)
- v = speed of light in the medium

1.7 Lens Makers' Equation (for comparison)

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

- Same form as mirror equation, but with opposite sign conventions:
  - **Converging lens:** $f > 0$
  - **Diverging lens:** $f < 0$

1.8 Power of Lens

This value is in SI units.

$$P(\text{Dioptres}) = \frac{1}{f}$$

1.9 Total Internal Reflection

Occurs when light attempts to move from a higher-index medium to a lower-index medium ($n_1 > n_2$) and the angle of incidence exceeds the critical angle θ_c:

$$\sin\theta_c = \frac{n_2}{n_1}$$

- θ_c = critical angle

1.10 Difference Between Real and Virtual Images

Property	Real Image	Virtual Image
Orientation	Real images are inverted.	Virtual images are erect.
Lens Formation	A real image is always formed by a convex lens.	Virtual images can be formed by concave, convex, or plane mirrors.
Screen Formation	Real images are formed on the screen.	Virtual images appear to be on the lens or mirror itself.
Mirror Formation	Real images are always formed by a concave mirror.	Convex mirrors form virtual images.
Ray Behavior	Formed due to actual intersection of light rays.	Formed due to imaginary intersection of light rays.

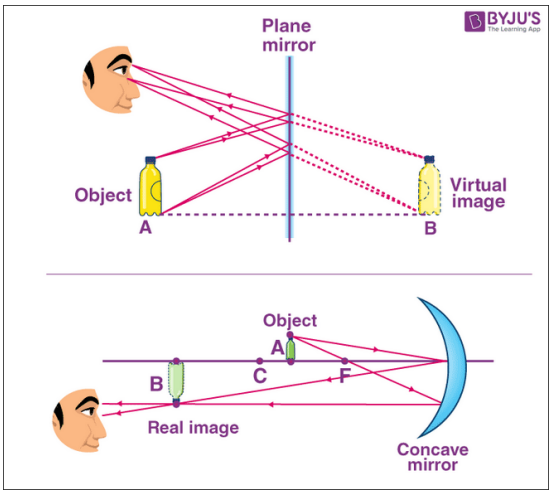

Figure 1

2 Questions

1. The speed of light in ice is 2.29×10^8 m/s. What is the index of refraction of ice?

2. The speed of light in a certain substance is 82% of its value in water. What is the index of refraction of that substance?

3. Flashlight beam strikes surface of a pane of glass ($n = 1.56$) at an angle of 67 degrees to the normal. Wha tis the angle of refraction?

4. Glass block with index of refraction 1.5 is immersed in water whose index of refraction is 1.33. What is the critical angle at the glass-water interface?

5. Diver shines flashlight upward from beneath the water at an angle of 35.2 degrees to the vertical. What is the angle at which light leaves water?

6. A beam of light in air strikes a slab of glass and is partially reflected and partially refracted. Determine the angle of incidence if the angle of reflection is twice the angle of refraction. ($n = 1.51$)
Hint: $\sin 2x = 2 \sin x \cos x$

7. A solar cooker, really a concave mirror pointed at the Sun, focuses the Sun's rays 18.8 cm in front of the mirror. What is the radius of the spherical surface from which the mirror was made?

8. How far from a concave mirror (radius 21.0 cm) must an object be placed if its image is to be at infinity?

9. A small candle is 38 cm from a concave mirror having a radius of curvature of 24 cm.
   (a) What is the focal length of the mirror?

   (b) (1 point) Where will the image of the candle be located?

   (c) What will the orientation of the image be?

10. A dentist wants a small mirror that, when 2.00 cm from a tooth, will produce a 4x upright image. What kind of mirror must be used and what must its radius of curvature be?

11. You are standing 3.4 m from a convex security mirror in a store. You estimate the height of your image to be half of your actual height. Estimate the radius of curvature of the mirror.

12. The image of a distant tree is virtual and very small when viewed in a curved mirror. The image appears to be 19.0 cm behind the mirror. What kind of mirror is it, and what is its radius of curvature?

13. You look at yourself in a shiny 8.8-cm-diameter Christ- mas tree ball. If your face is 25.0 cm away from the ball's front surface, where is your image? Is it real or virtual? Is it upright or inverted?

14. What is the critical angle for the interface between water and crown glass ($n = 1.52$) ? To be internally reflected, the light must start in which material?

15. A sharp image is located 391 mm behind a 215-mm- focal-length converging lens. Find the object distance

16. What is the power of a 32.5-cm-focal-length lens?

17. What is the focal length of a -6.75 D lens? Are these lenses converging or diverging?

18. A 1.50-cm-high object is placed 20.0 cm from a concave mirror with radius of curvature 30.0 cm. Determine
    (a) Position of the image

    (b) Its size