Modern Physics - Waves, Optics

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March 27, 2014

Contents

Chapter 1

Geometric Optics

1.1 Reflection

1. Specular Reflection

   Reflection from a smooth surface that reflects rays parallel to each other. Occurs as long as the surface variations are much smaller than λ.

2. Diffuse Reflection

   Reflection from a rough surface that reflects rays in various directions.

In general, the angle of reflection will equal to angle of incidence, or

$$\theta_1' = \theta_1$$
$$\text{(Reflection Angle = Incident Angle)}$$

1.2 Refraction

1.2.1 Equations

1. Index of Refraction:

   $$n = \frac{c}{v_{\text{Medium}}} \text{ or } vn = c$$

   Defined as the ratio between the speed of light in a vaccum and in a medium. v is always less than c, so $n > 1$ for all substances. This also implies $\lambda_n < \lambda$, or that the wavelength of light in a medium is always lower than its wavelength in a vacuum.

2. Snell's Law of Refraction:

   $$n_1 \sin\theta_1 = n_2 \sin\theta_2$$
   $$\lambda_1 n_1 = \lambda_2 n_2$$

   As light travels from one medium to another, its frequency does not change, but its wavelength does.

3. Total internal reflection:

$$\sin\theta_{\text{crit}} = \frac{n_2}{n_1} \qquad\qquad (\text{for } n_1 > n_2)$$

Occurs when light travels from a medium with a high n to one with a lower n, so $n_2/n_1 \leq 1$. Can be in degrees or radians, just use the conversion

$$\frac{\text{radians}}{2\pi} = \frac{\text{degrees}}{360°}$$

1.3 Homework Review

The light beam in the figure below strikes surface 2 at the critical angle. Determine the angle of incidence θ_1. (Let θ_2 = 40.8°.)

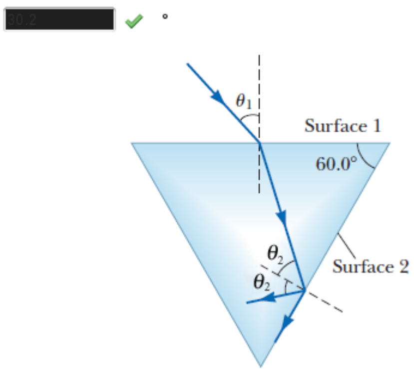


Figure 1.1: Determine angle of incidence, given the critical angle inside the prism.

Hints: The sum of interior angles is always 180°. Solve for ratio of indices of refraction. Use Snell's Law.
Solution: 30.2°.

Chapter 2

Image Formation: Mirrors, Lenses

2.1 Flat Mirrors

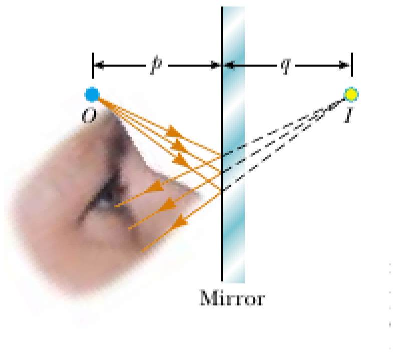


Figure 2.1: Conventions

Conventions

- O: Object
- I: Image of object
- p: Actual distance of object
- q: Distance of Image

2.2 Conic Mirrors

To determine image location, only three principle rays are essential:

1. From the top of the object, parallel to the principal axis.
   (Reflected along line with F. Concave: Towards, Convex: Away)
2. From the top of the object, through the focal point f.
   (Always reflected parallel to principal axis.)
3. From the top of the object, through the center of curvature C.
   (Always reflected back upon itself)

The intersection of these rays locates the image.

2.2.1 Concave Mirrors

The center of curvature C is located on the principle axis. All paraxial rays (ones that diverge from the principle axis by only a small angle) converge on I, so objects placed farther away than C (on the principle axis) produce a **real** image in front of the mirror. If rays emanating from O instead tend to diverge from the principal axis, spherical aberration is introduced and the image becomes blurred.
Always has a **positive** focal length – that is, F is in front of the mirror.
If object is *farther* than C, image is **real, inverted,** and **reduced** in size.
If the object is *between* C and the mirror, the image is **virtual, upright,** and **enlarged**.

2.2.2 Convex Mirrors

Always has **negative** focal length, where F is located behind the mirror. Images are always **virtual, upright,** and **reduced** in size.

Table 36.1

Sign Conventions for Mirrors

Quantity	Positive When	Negative When
Object location (p)	Object is in front of mirror (real object)	Object is in back of mirror (virtual object)
Image location (q)	Image is in front of mirror (real image)	Image is in back of mirror (virtual image)
Image height (h')	Image is upright	Image is inverted
Focal length (f) and radius (R)	Mirror is concave	Mirror is convex
Magnification (M)	Image is upright	Image is inverted

Figure 2.2: Sign Conventions for Mirrors

2.3 Equations

1. Definition of Magnification:

$$M = \frac{h'}{h}$$

2. Magnification in a Concave Mirror:

$$M = \frac{-q}{p}$$

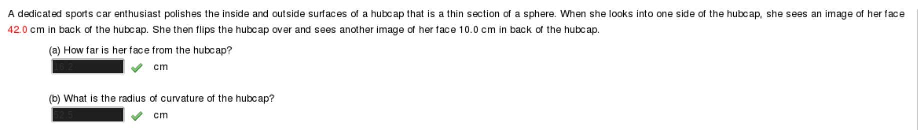
   $M < 1$ indicates that the image is smaller than the object. $-M$ indicates image is inverted.

3. The Mirror Equation:

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} (\text{ where} f = \frac{R}{2})$$

   Depends only on the curvature of the mirror, and not its material. $+q$ denotes an image on the front side of the mirror (real), and vice-versa.

2.4 Homework / Review



A dedicated sports car enthusiast polishes the inside and outside surfaces of a hubcap that is a thin section of a sphere. When she looks into one side of the hubcap, she sees an image of her face 42.0 cm in back of the hubcap. She then flips the hubcap over and sees another image of her face 10.0 cm in back of the hubcap.

(a) How far is her face from the hubcap?

[redacted] cm

(b) What is the radius of curvature of the hubcap?

[redacted] cm

Figure 2.3: Convex/Concave Mirrors

Hints: Results in two equations in two unknowns. Near image is convex, far image is concave. F is negative for convex mirrors.

Solutions: 16.2 cm, 52,5 cm.