

# Nature of Light

Ancient times & Middle Ages: light consist of stream of particles *corpuscles* 

19th century: light is a wave (EM wave)

20<sup>th</sup> century: several effects associated with the emission and absorption of light revel that it also has a particle aspect and that the energy carried by light waves is packaged in discrete bundles called *photons*.

Quantum electrodynamics – a comprehensive theory that includes both wave and particle properties.

The *propagation* of light is best described by a wave model The *emission and absorption* by atoms and nuclei requires a particle approach

### Wave Fronts

Wave Front – a convenient concept to describe wave propagation

A wave front is the locus of all adjacent points at which the phase of vibration of the wave is the same



### Rays

It is very convenient to represent a light wave by rays rather than by wave fronts

A ray is an imaginary line along the direction of travel of the wave

The branch of optics for which the ray description is adequate is called geometric optics

The branch dealing specifically with wave behavior is called physical optics



Part 1
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### Types of Reflection

If the surface from which the light is reflected is smooth, then the light undergoes specular reflection (parallel rays will all be reflected in the same directions).

If, on the other hand, the surface is rough, then the light will undergo diffuse reflection (parallel rays will be reflected in a variety of directions)





Eduard Manet – A Bar at the Foleis-Bergère (1882)

### Types of Images for Mirrors and Lenses

A real image is one in which light actually passes through the image point

Real images can be displayed on screens

A virtual image is one in which the light does not pass through the image point

The light appears to diverge from that point *Virtual images cannot be displayed on screens* 





# <text>



# 2





### **Conceptual Checkpoint**

To save expenses, you would like to buy the shortest mirror that will allow you to see your entire body. Should the mirror be equal to your height?

Does the answer depend on how far away from the mirror you stand?













### **Focal Length**

The focal length *f* is the distance from the surface of the mirror to the focal point. It can be shown that the focal length is half the radius of curvature of the mirror.

Sign Convention: the focal length is negative if the focal point is behind the mirror.

For a concave mirror,  $f = \frac{l}{2}R$ 

For a convex mirror,  $f = -\frac{1}{2}R$  (R is always positive)





















Example 2	problem
An object is placed 3 cm in f 20 cm. Where is the image upright or inverted? What is	iront of a concave mirror of radius located? Is it real or virtual? Is it the magnification of the image?
$\frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{f} + \frac{1}{3} + \frac{1}{d_i} = \frac{1}{\left(\frac{20}{2}\right)}$ $\frac{1}{d_i} = \frac{1}{10} - \frac{1}{3}  or  d_i = -\frac{3 \times 10}{7} = -4.3 \text{ cm}$	$m = -\frac{d_i}{d_0} = \frac{4.3}{3} = 1.43$ Image is larger, virtual, and upright.



problemA concave mirror produces a virtual image that is three<br/>times as tall as the object. (a) If the object is 22 cm in<br/>front of the mirror, what is the image distance? (b) What<br/>is the focal length of this mirror?a.)  $m = -\frac{d_i}{d_0}$ b.)  $\frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{f}$  $\frac{1}{22} - \frac{1}{66} = \frac{1}{f}$  $3 = -\frac{d_i}{22}$  $d_i = -66$  cm $f = \frac{66 \times 22}{66 - 22} = 33$  cm



























### Question

Sometimes when looking at a window, one sees two reflected images, slightly displaced from each other. What causes this effect?

## Question

A student claims that, because of atmospheric refraction, the sun can be seen after it has set and that the day is therefore longer than it would be if the earth had no atmosphere.

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What does the student mean by saying the sun can be seen after it has set?

Does the same effect also occur at sunrise?



?













### Example 5

# problem

An object is placed 5 cm in front of a converging lens of focal length 10 cm. Where is the image? Is it upright or inverted? Real or virtual? What is the magnification of the image?

$$\frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{f} \qquad \frac{1}{5} + \frac{1}{d_i} = \frac{1}{10} \qquad \frac{1}{d_i} = \frac{1}{10} - \frac{1}{5}$$
$$d_i = \frac{10 \times 5}{5 - 10} = \boxed{-10 \text{ cm}}$$

Since  $d_i$  is negative, the image is virtual.

 $m = -\frac{d_i}{d_0} = \frac{10}{5} = 2$  Therefore the image in upright.

### Example 6

# problem

An object is placed 8 cm in front of a diverging lens of focal length 4 cm. Where is the image? Is it upright or inverted? Real or virtual? What is the magnification of the image?

$$\begin{aligned} \frac{1}{d_0} + \frac{1}{d_i} &= \frac{1}{f} & \frac{1}{8} + \frac{1}{d_i} = -\frac{1}{4} & \frac{1}{d_i} = -\frac{1}{4} - \frac{1}{8} = -\left(\frac{1}{4} + \frac{1}{8}\right) \\ d_i &= -\left(\frac{4 \times 8}{4 + 8}\right) = \boxed{-2.67 \text{ cm}} \end{aligned}$$

Since 
$$d_i$$
 is negative, the image is virtual.

$$m = -\frac{d_i}{d_0} = \frac{2.67}{8} = 0.33$$
 Therefore the image in upright and smaller











# Using Spectra to Identify Gases

All hot, low pressure gases emit their own characteristic spectra

The particular wavelengths emitted by a gas serve as "fingerprints" of that gas

Some uses of spectral analysis Identification of molecules Identification of elements in distant stars Identification of minerals



problem











Mirrors					
Convex Mirror Object location Arbitrary	Image orientation Upright	Image size Reduced	Image type Virtual		
Concave Mirror Object location Beyond C C Between F & C Just beyond F Just inside F Between F & mirror	Image orientation Inverted Inverted Inverted Upright Upright	Image size Reduced Same as object Enlarged Approaching Infinity Approaching Infinity Enlarged	Image type Real Real Real Real Virtual Virtual		

Lenses						
Concave Lens Object location Arbitrary	Image orientation Upright	Image size Reduced	Image type Virtual			
Convex Lens Object location Beyond F Just beyond F Just inside F Between F & lens	Image orientation Inverted Inverted Upright Upright	Image size Reduced or enlarg. Approaching Infinity Approaching Infinity Enlarged	Image type Real ( Real ( Virtual Virtual			



### Question

A concave mirror (sometimes surrounded by light) is often used as an aid for applying cosmetics to the face. Why is such a mirror always concave rather than convex? What considerations determine its radius of curvature?

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### Question

A person looks at her reflection in the concave side of a shiny spoon.

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Is this image right side up or inverted?

What does she see if she looks in the convex side?



