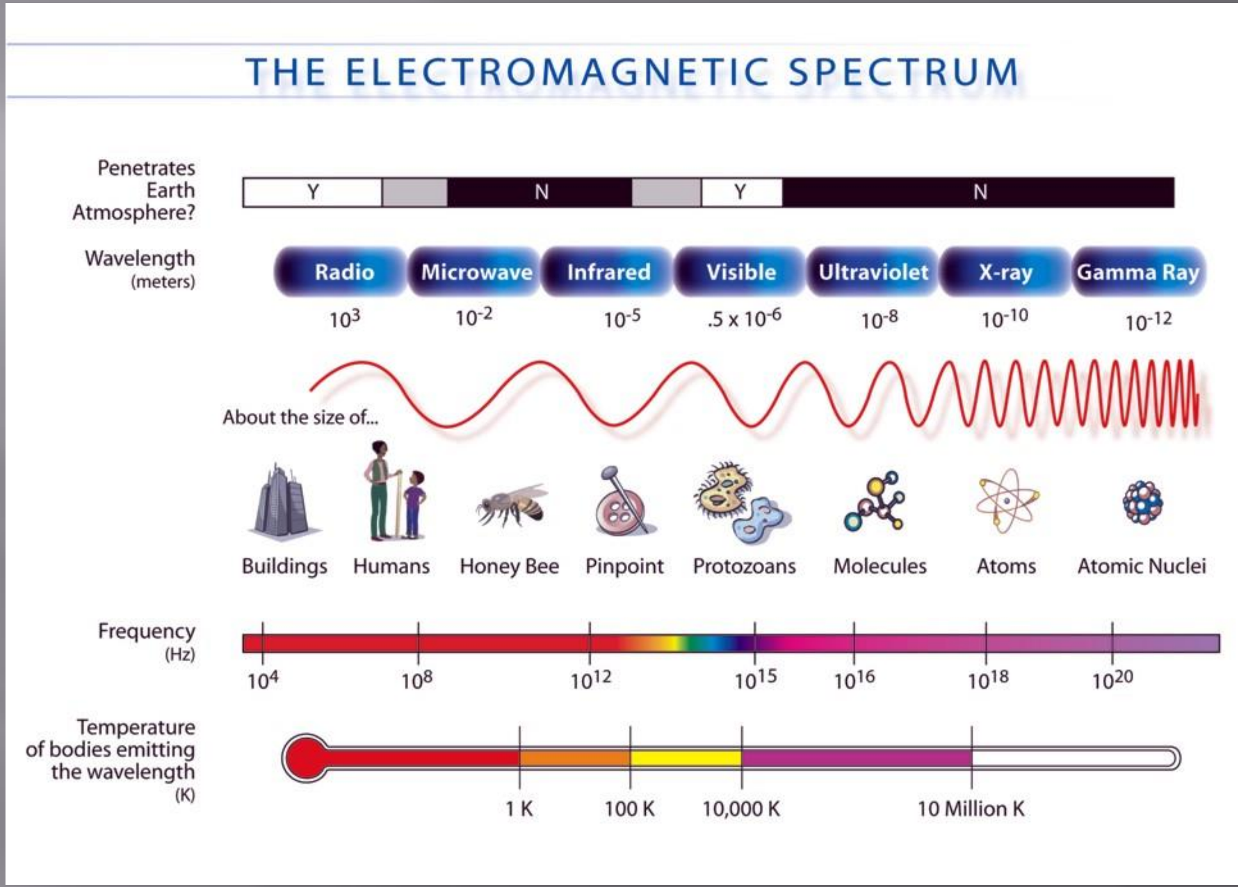
ELECTROMAGNETIC WAVES



Physics

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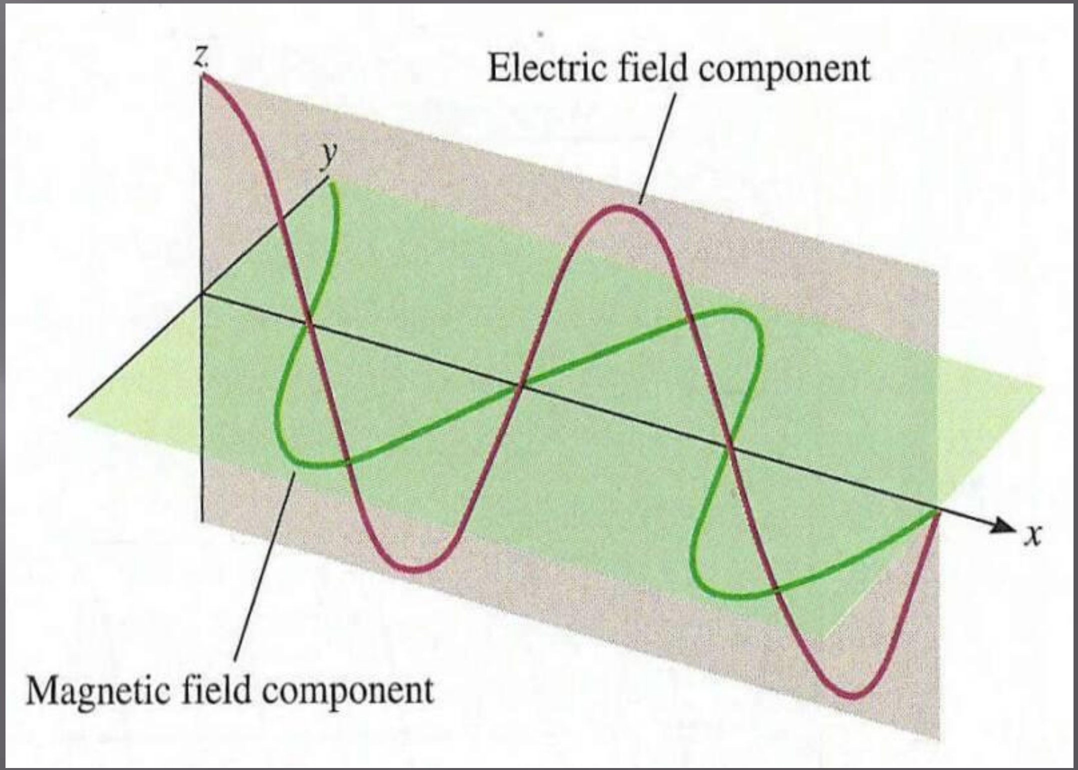
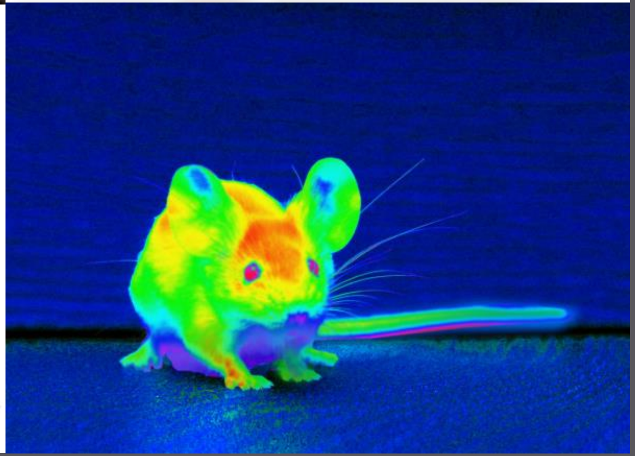
Complex Trans. Wave

- Electromagnetic waves are transverse waves with both a horizontal and vertical component.
  - Electric Field combined with a Magnetic Field.
  - EM waves can travel without a medium.
    - $v = 3.00 \times 10^8$-m/s



EM Breakdown by f

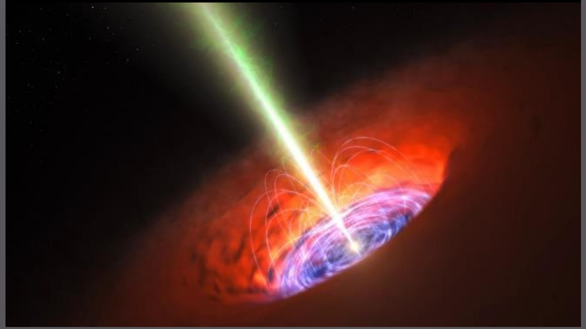
- Low Frequency (>1MHz): Power Lines
- Radio/TV (50MHz-1000MHz)
  - AM Radio (50-100 MHz)
  - TV/FM (100-1000MHz)
  - Cell Phone (900MHz)
- Wireless LAN (2.4-5.8 GHz)
- Microwaves (15-GHz)
- Infrared (10-THz)



EM Breakdown by f

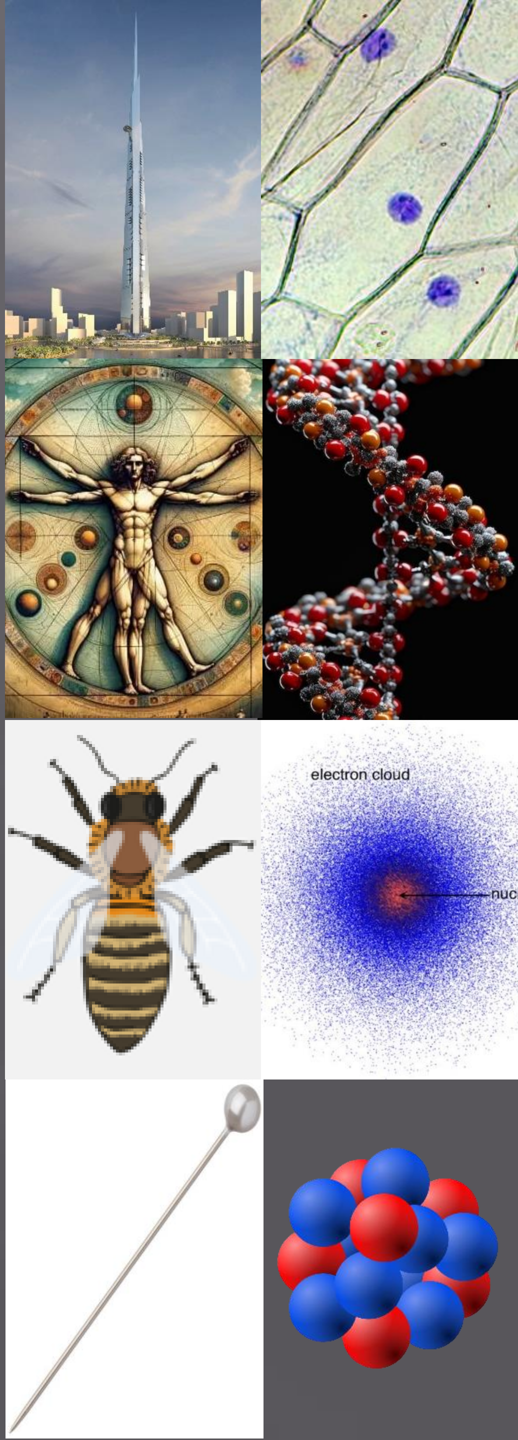
- Visible Light
  - Red: 400-484 THz
  - Orange: 484-508 THz
  - Yellow: 508-526 THz
  - Green: 526-606 THz
  - Blue: 606-668 THz
  - Violet: 668-789 THz
- Ultraviolet (10 PHz)
- X-Ray (1 EHz)
- Gamma/Cosmic Ray (10 EHz)



EM Breakdown by λ

- Low Frequency: Skyscrapers (10^3 m)
- Radio/TV: Human (2-m)
- Microwaves: Honeybee (cm)
- Infrared: Pinpoint (10-μm)
- Light: Cell (.5-μm)
- Ultraviolet: Molecule (10-nm)
- X-Ray: Atom (including e^- cloud) (.1-nm, Å)
- Gamma/Cosmic Ray: Atomic Nuclei (1-pm)



Example 1

Looking out your window on a stormy day a bolt of lightning appears off in the distance 10.00 seconds later a rumble is heard. How far away is the storm?

$$\boldsymbol{v = \frac{\Delta p}{\Delta t}}$$

$$\boldsymbol{343 - \frac{m}{s} = \frac{p}{10 - s}}$$

v = 343-m/s

p =

t =10-s

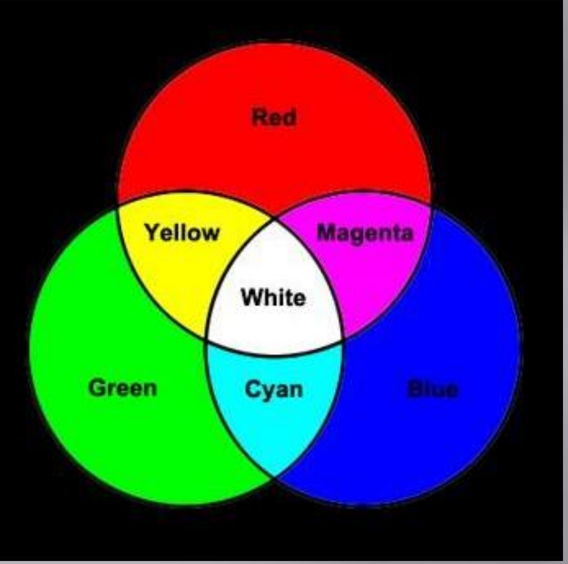
$$\boldsymbol{p = 3430.00 - m}$$

$$\boldsymbol{3430 - \mathrm{m} \approx 2 - mi}$$

Take the time to hear the thunder and divide by 5 you can tell how far a storm is away.

Special EM Section: Light

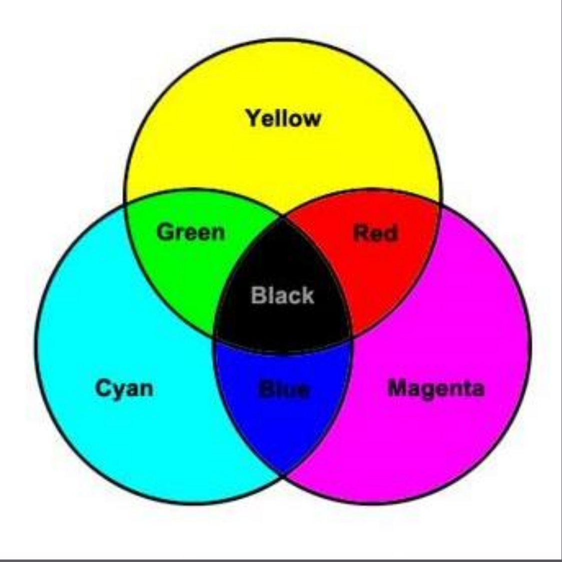
- Light is part of the Electromagnetic Spectrum
  - It is the only part we can collect with the eye.
  - Light is collected as color.
- Color theory is important to art. Three Parts:
  - Lightness: Light/Dark, White/Black, *Tint/Shade*
  - Saturation: Intense/Dull.
  - Hue: Specific Color: ROYGBV



Color Theory

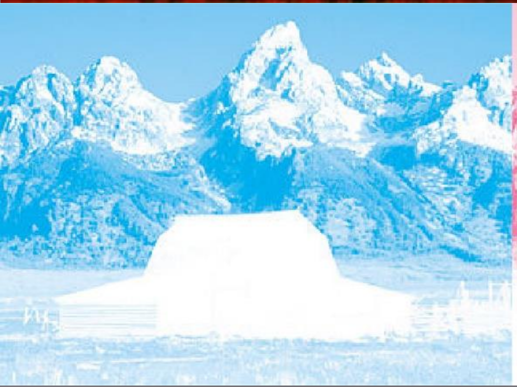
Additive Color: Light Mixing

Subtractive Color: Pigment Mixing

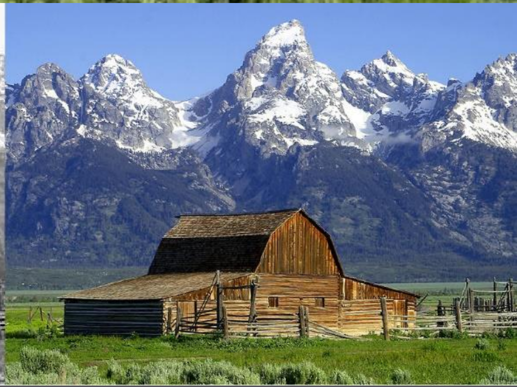








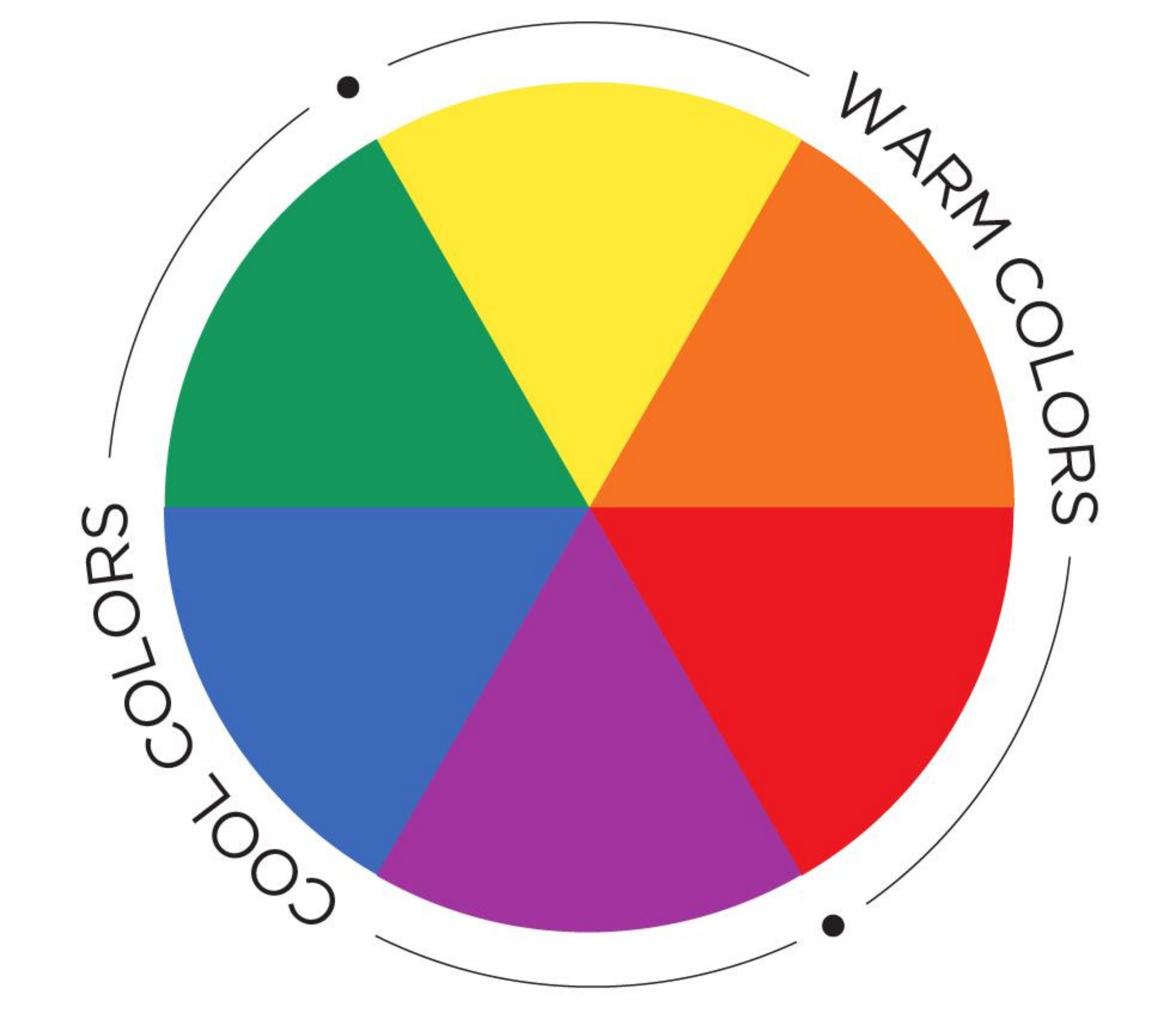




Color Theory

Cool

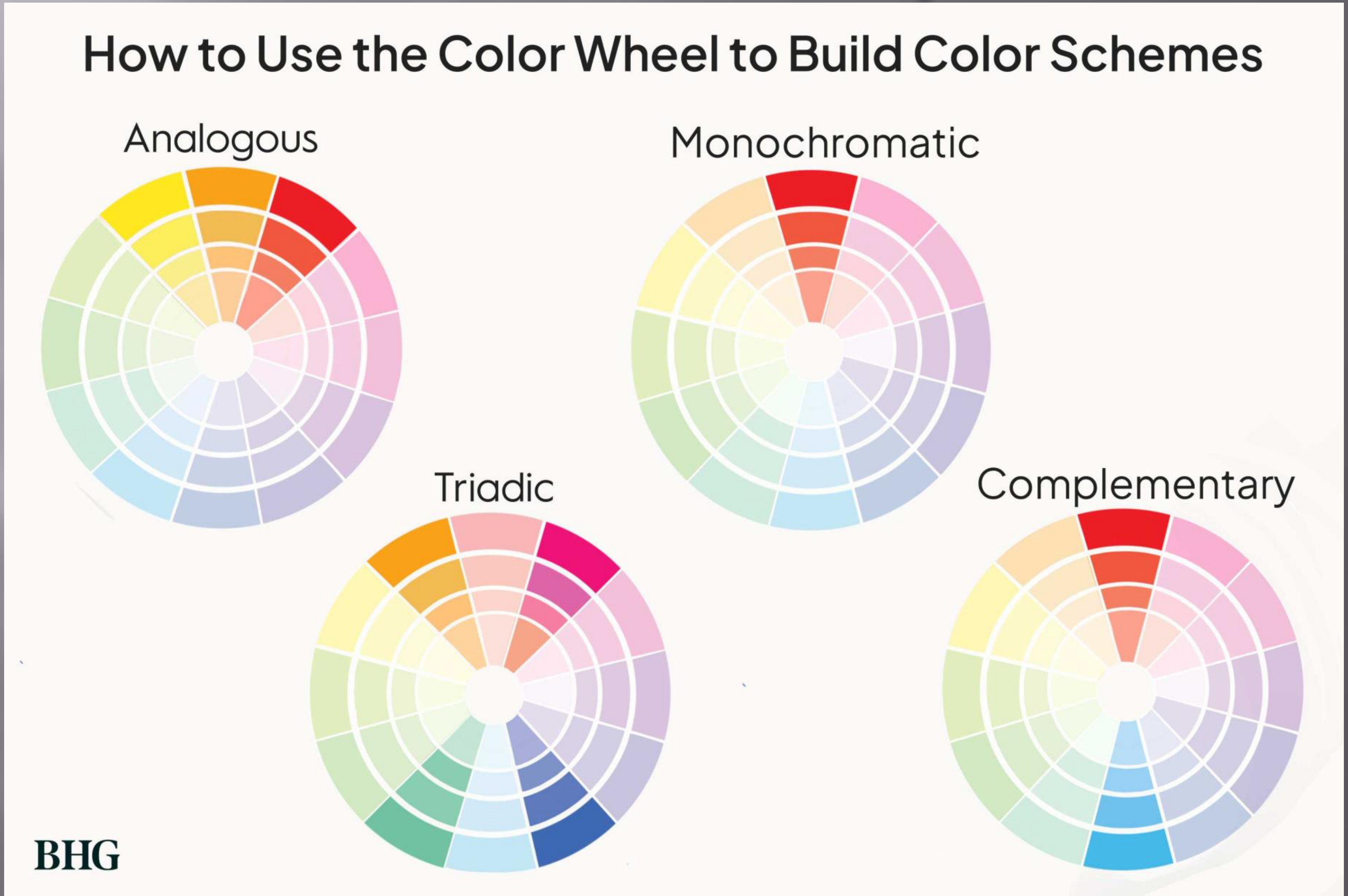
Colors that are often associated with water, grass, and sky



Warm

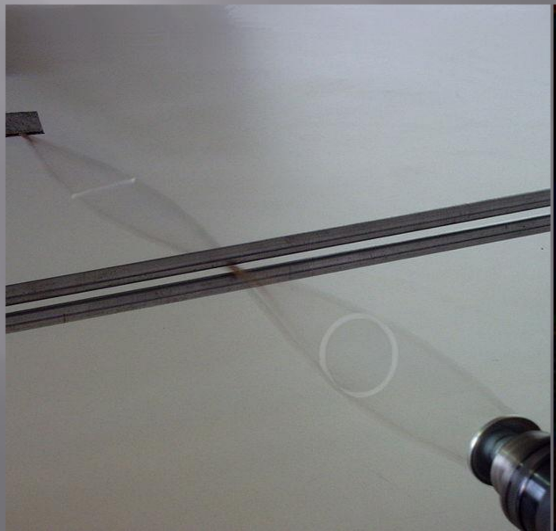
Colors that are often associated with fire, the sun, and heat

Color Theory

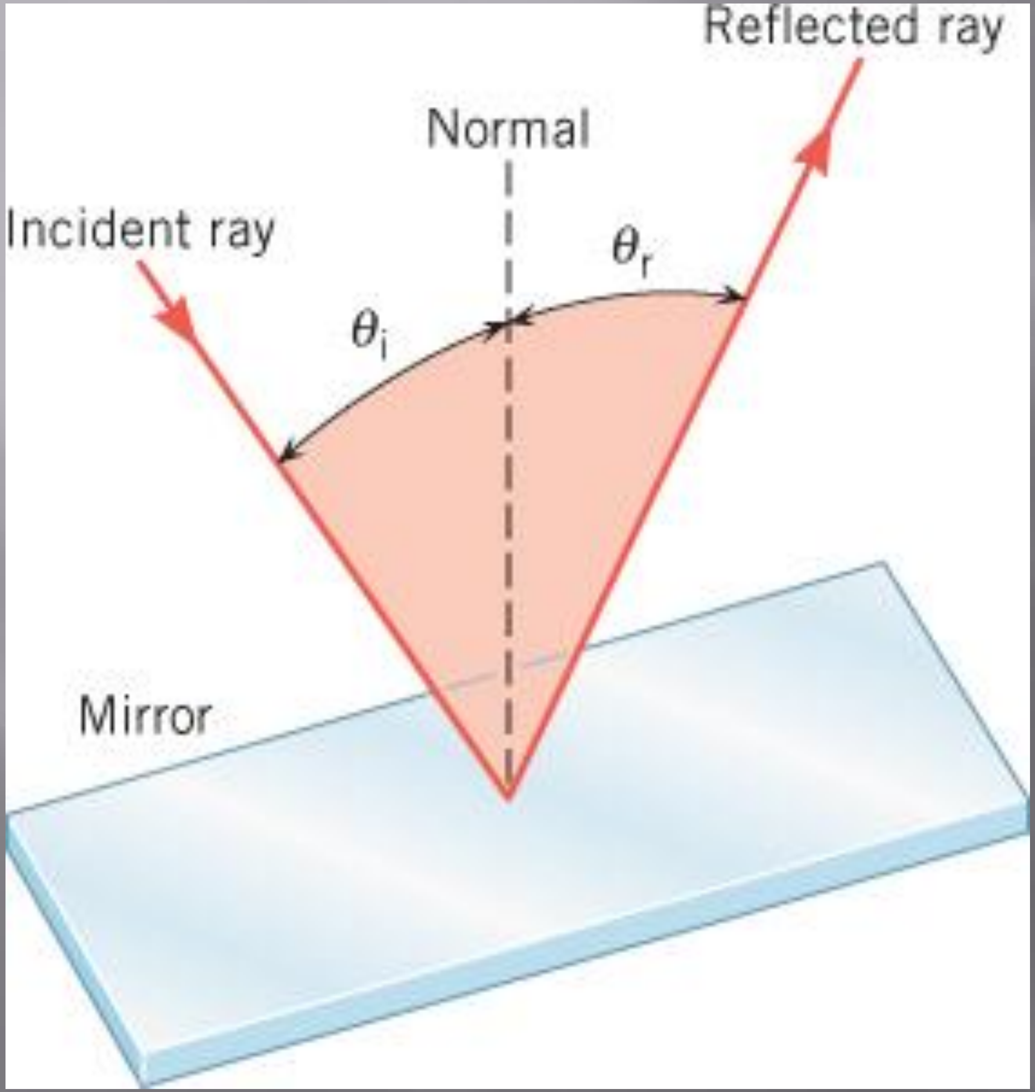


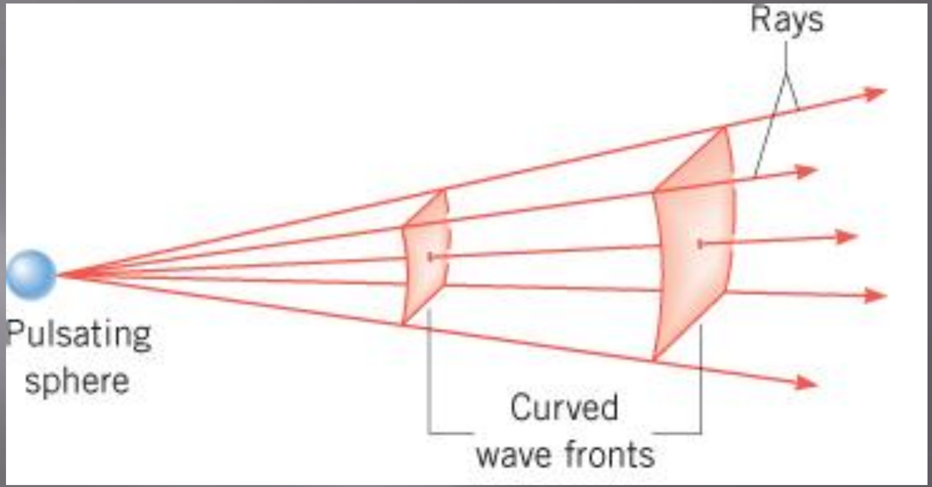
Special EM Section: Light

- Polarization: waves of light or other radiation are restricted in direction of vibration.
  - Does not work on waves that start in one direction.
- Benefits include reducing glare, brightness and harmful wavelengths.

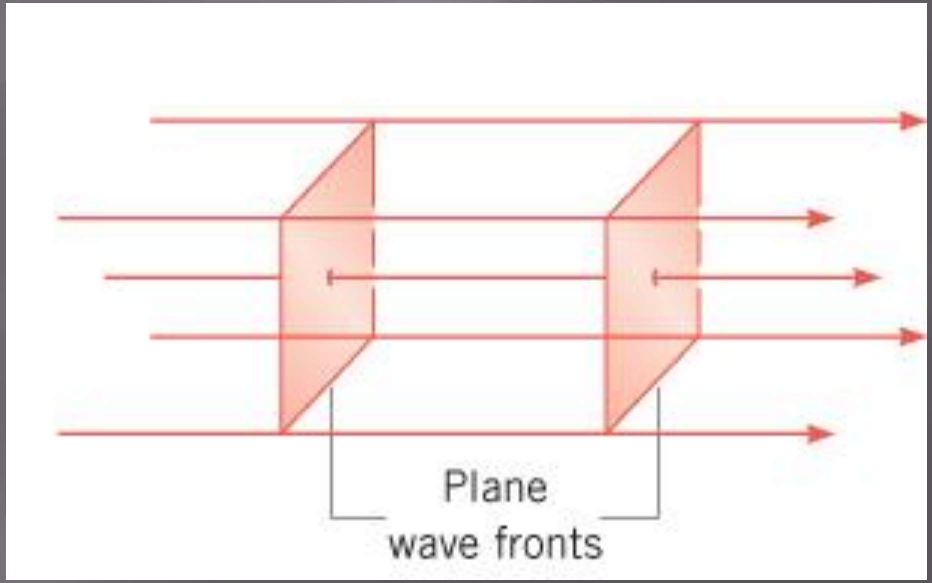


Optics Basics





Light radiates from a source in all directions



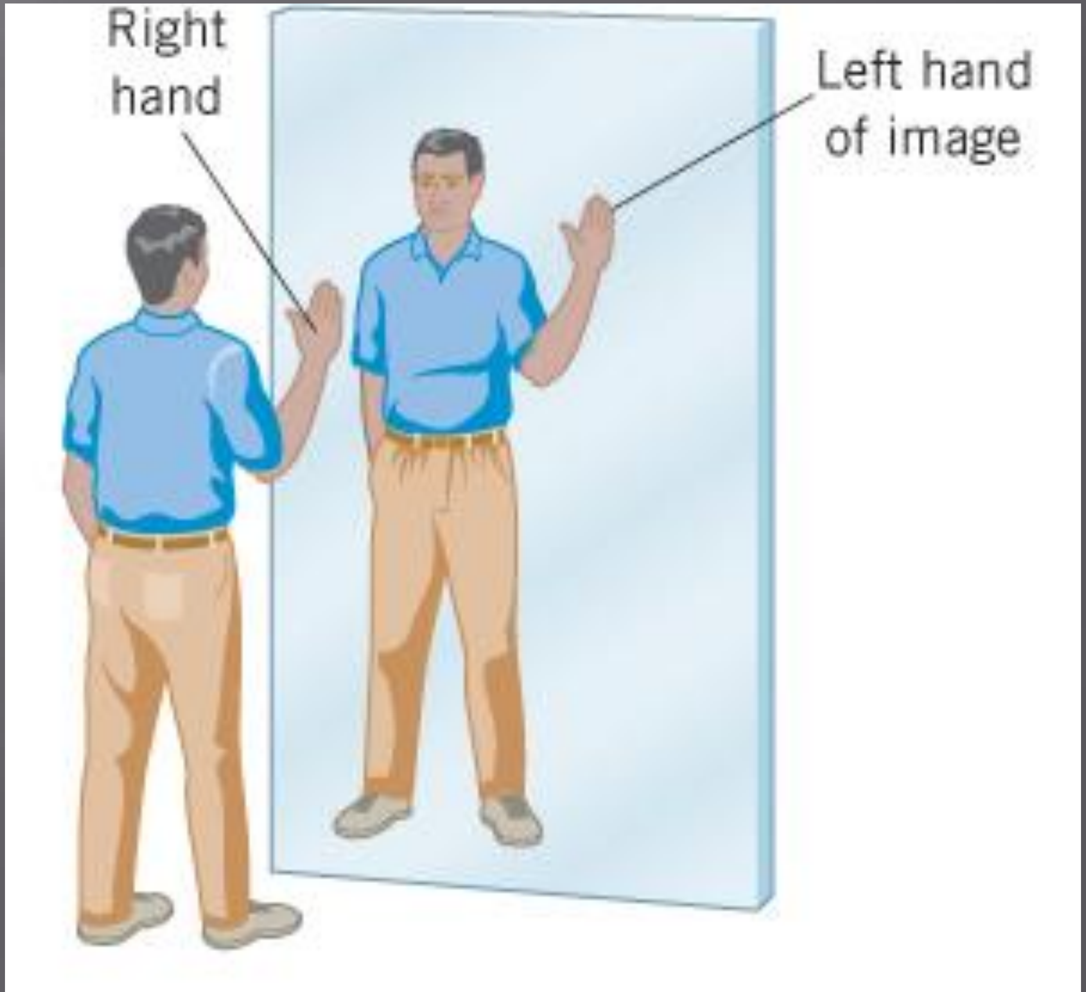
From far enough away the rays are assumed to travel in parallel rays.

Optics Basics

- When an object is formed it has the following properties:
  - Distance: How far from the mirror/lens.
  - Erection: Is the object upright or inverted.
  - Magnification: smaller ($m<1$), same ($m=1$), larger ($m>1$)
  - Construction: Real or Virtual
    - Real: Object becomes focused in real space.
    - Virtual: Object seems to diverge in real space.

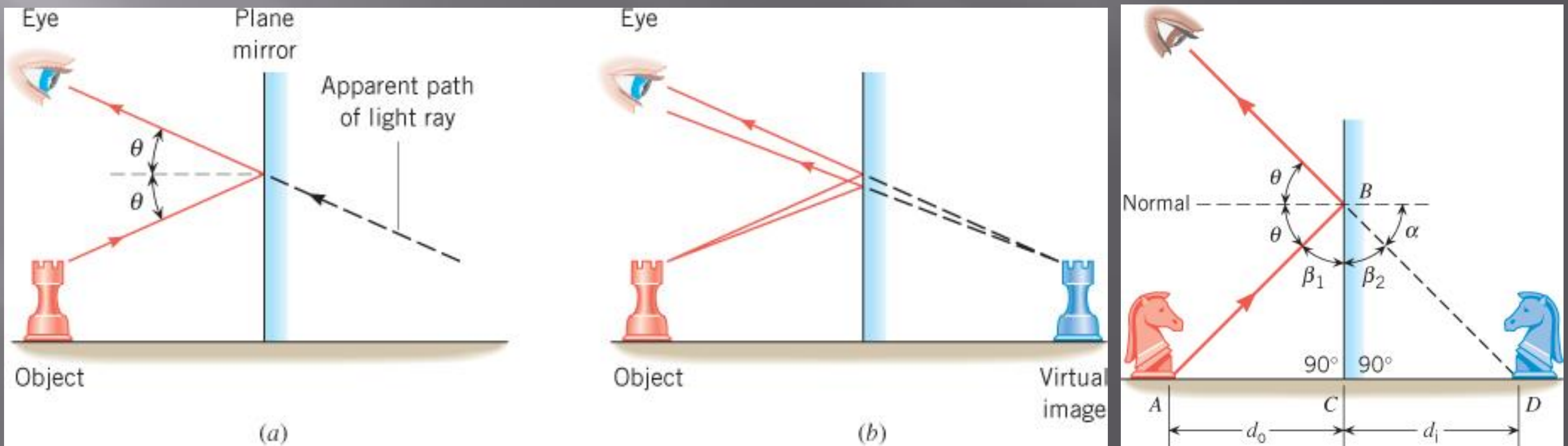
Light: Reflection

- Plane Mirrors have three properties.
  - The image is upright.
  - The image is the same size as the object.
  - The image is as far behind the mirror as the object is in front.



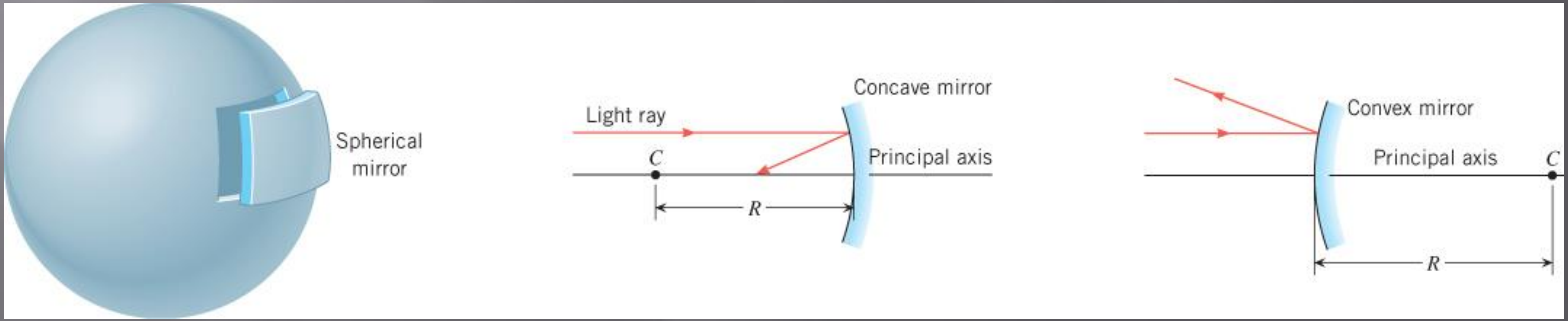
Plane Mirrors: Virtual v Real

- When an object is viewed through a mirror by an observer, a virtual image is seen.
- The distance of the object (d_o) will be as far as the distance of the image (d_i).



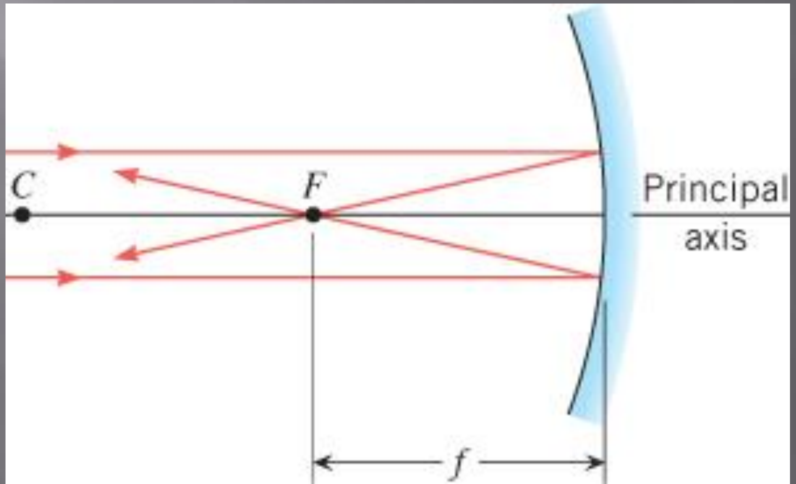
Curved Mirrors

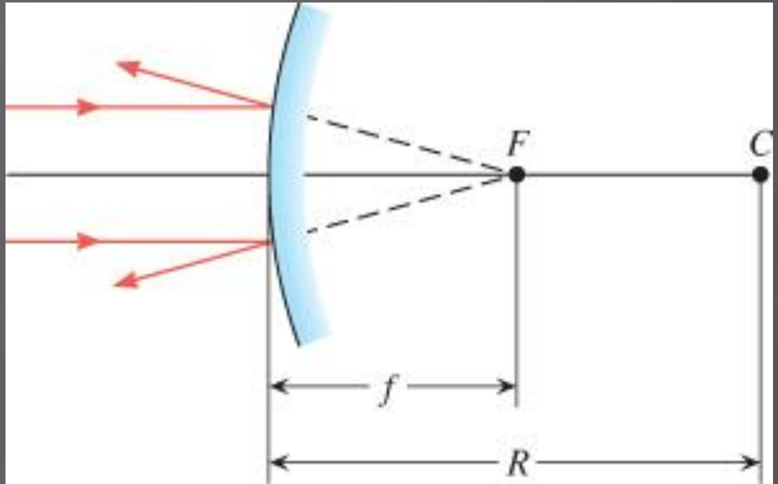
- A curved mirror is made from a sphere.
- A mirror cut out from the sphere creates two reflectors:
  - Convex: Looking at the outer surface.
  - Concave: Looking at the inner surface.



Curved Mirrors: Terms

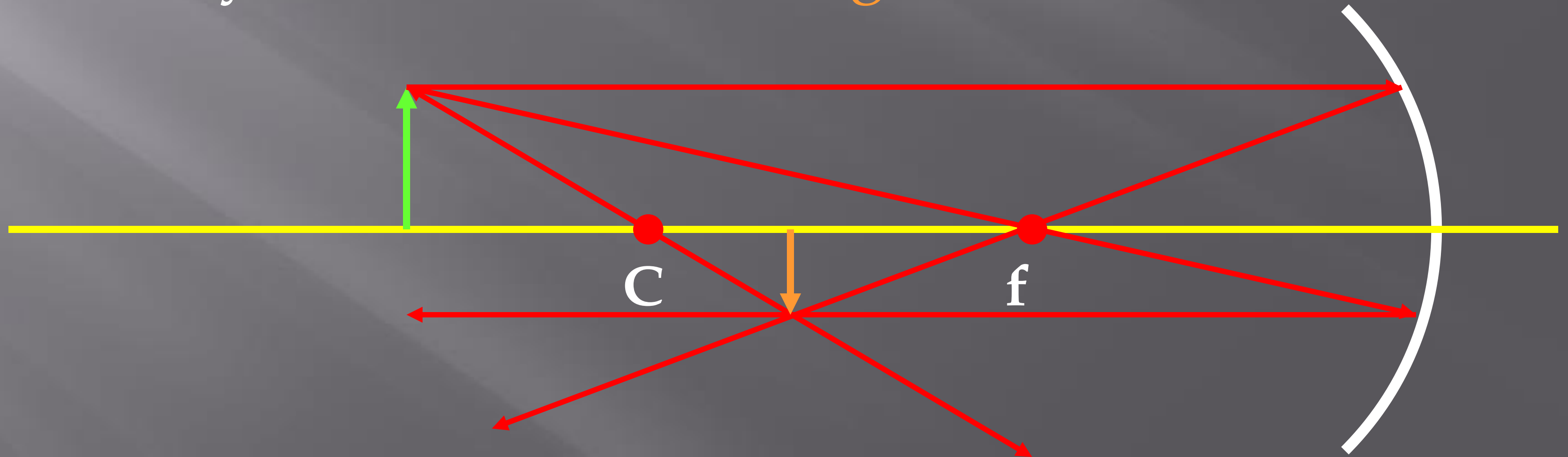
- Center of Curvature (C): Radius of the Sphere
- Principle Axis: Line connecting C and the midpoint of the mirror.
- Focal Length (f): Point at which rays parallel and near to the Principle Axis will intersect.
  - Concave Mirror: $f = 1/2$ C
  - Convex Mirror: $f = -1/2$ C





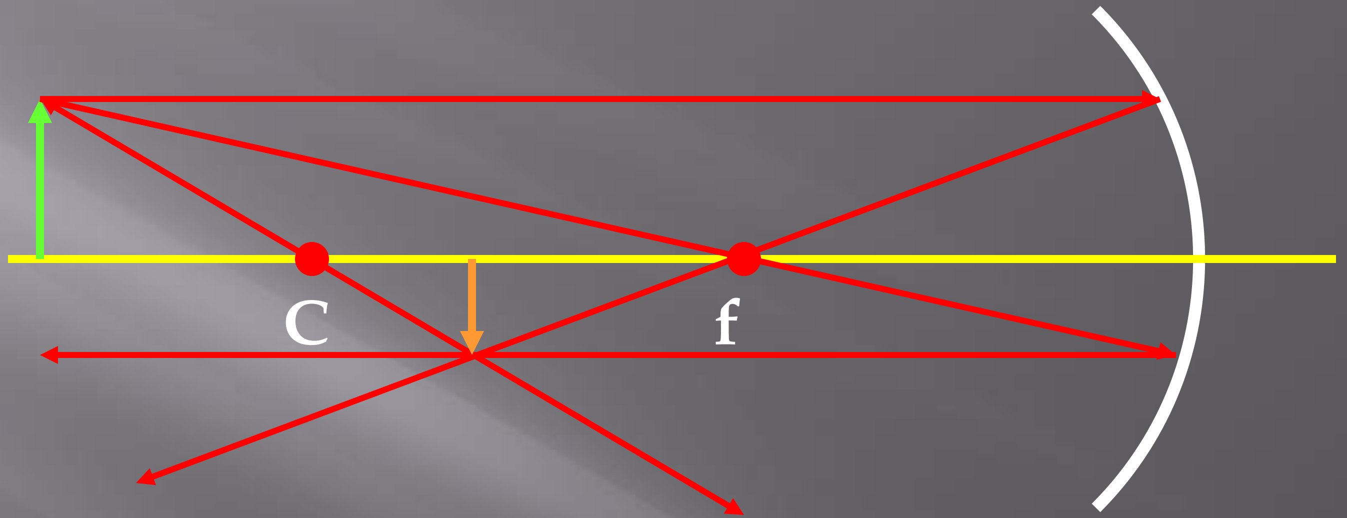
Concave Mirrors: Images

- To form an image draw object:
  1. Ray initially parallel to the P Axis and then intersects the f point.
  2. Ray initially passes to the f point and then runs parallel to the P Axis.
  3. Ray travels through C and perpendicularly back on itself.
  - Where all rays intersect is the image.

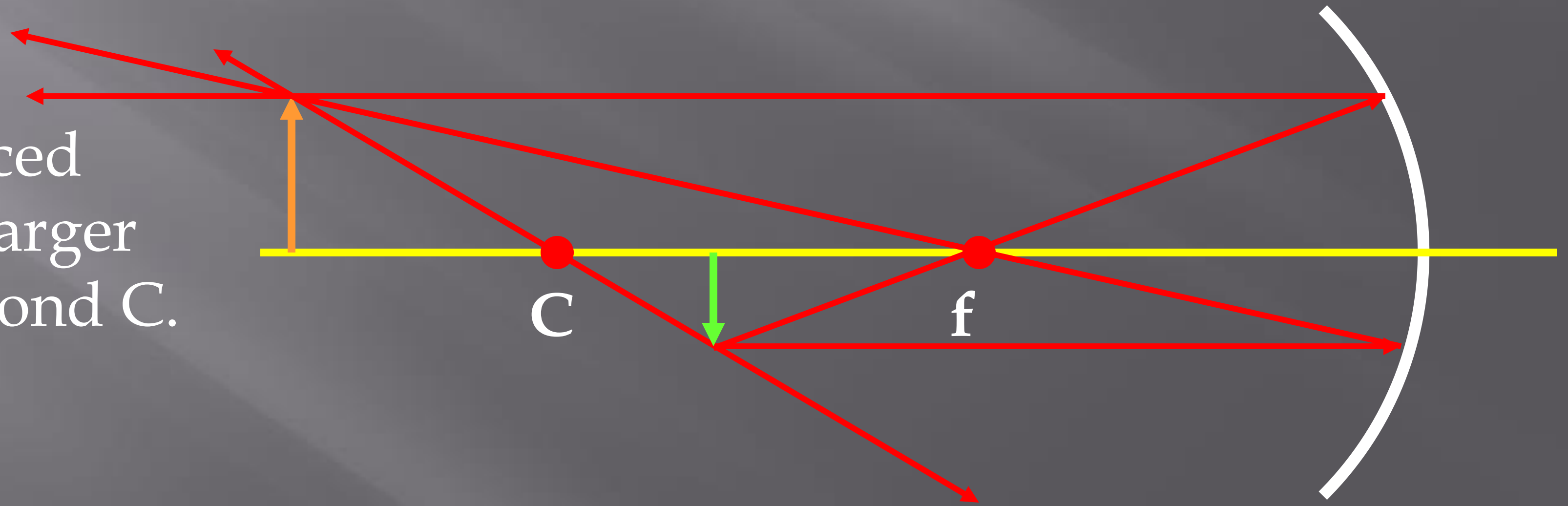


Concave Mirrors: Images

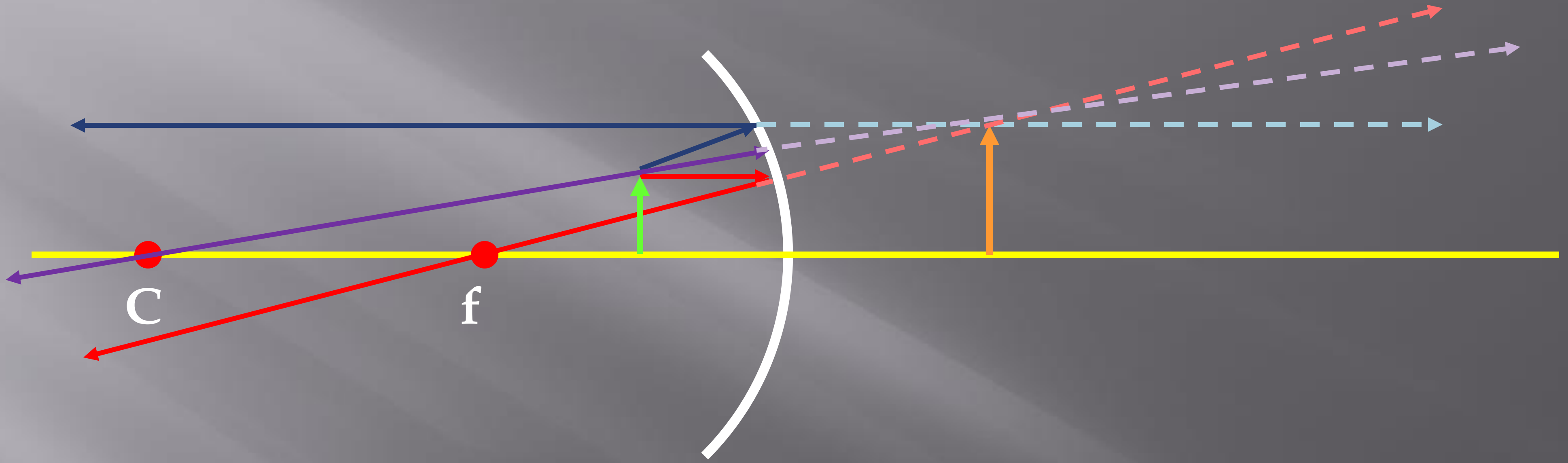
For Objects placed behind C: Smaller Real Image between C-f.



For Objects placed between C-f : Larger Real Image beyond C.

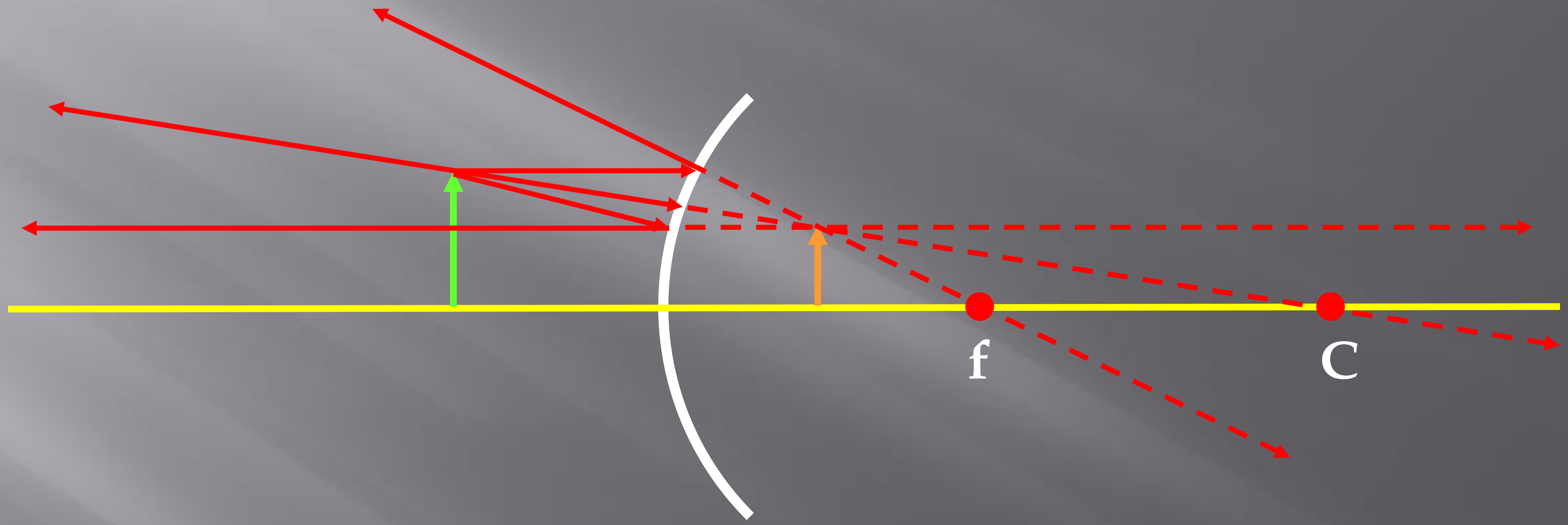


Concave Mirrors: Images



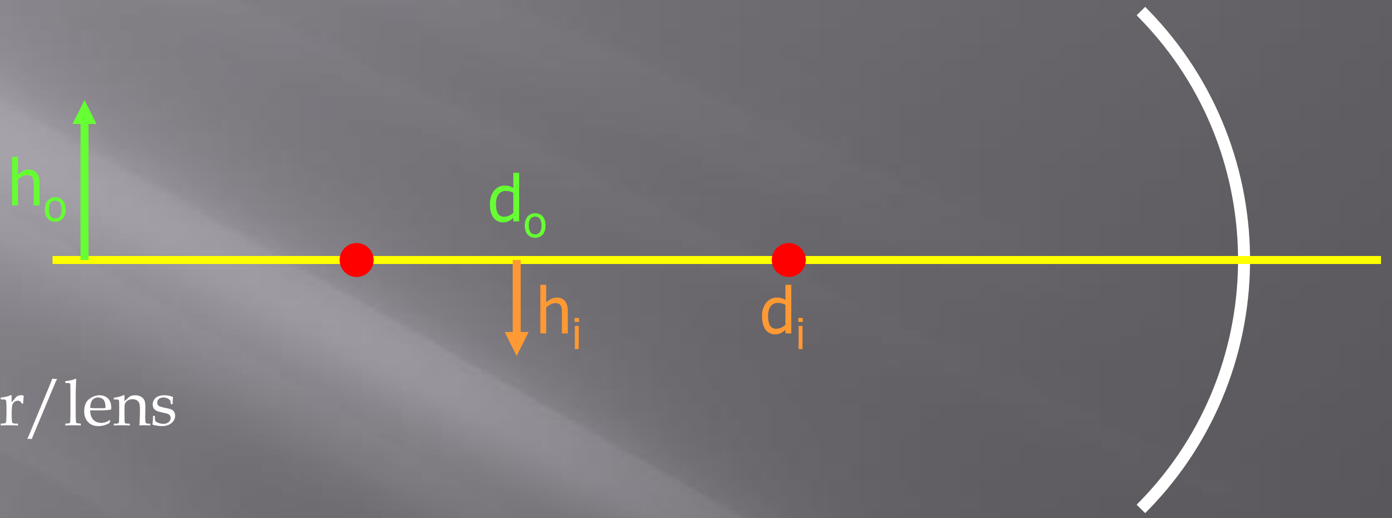
For Objects placed within f: Larger virtual Image beyond the mirror.

Convex Mirrors: Images



For Objects: Smaller virtual Image beyond the mirror.

Mirrors & Lenses: Math



f= focal Length of the mirror/lens

h_o= height of object

h_i= height of image

d_o= Distance of object (from m/l)

d_i= Distance of image (from m/l)

m= magnification

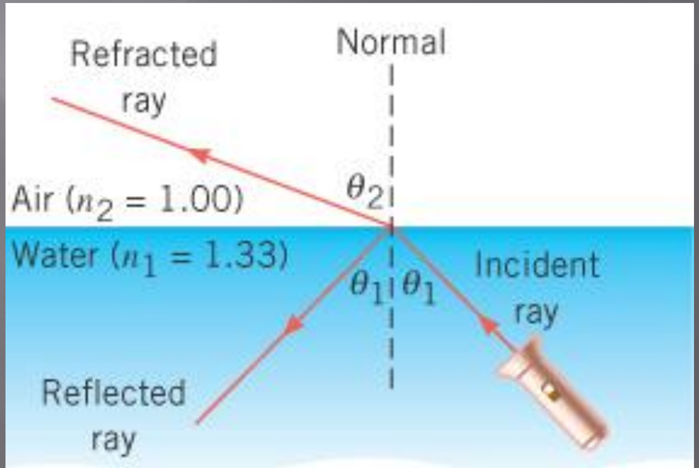
Remember for Convex mirrors: f is a negative number.

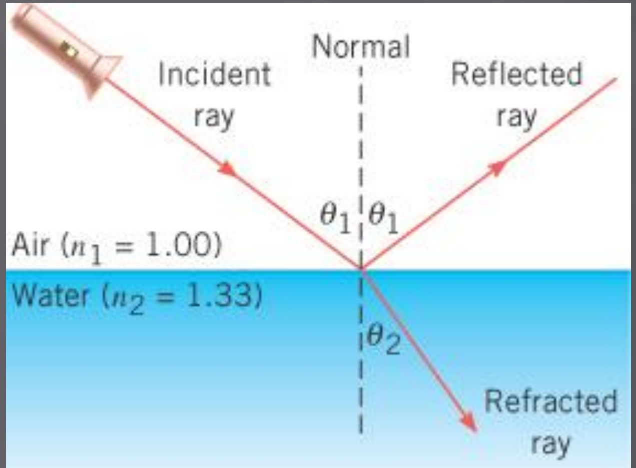
$$\frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f}$$

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

Light: Refraction

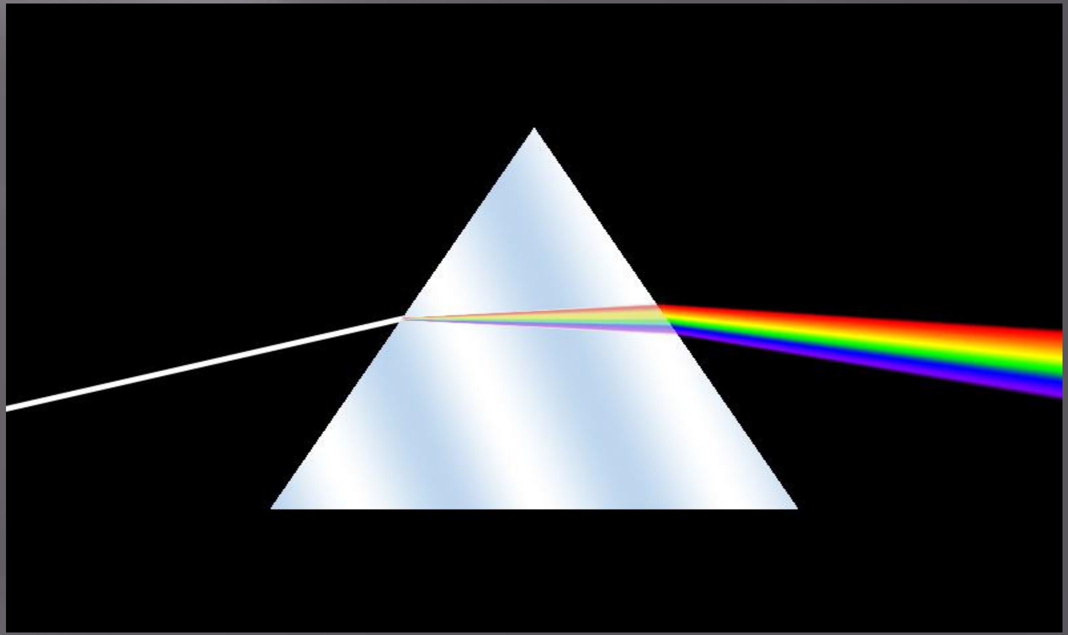
- When light passes through a different medium, it bends and slows down (v_m).
- The ratio for this is called the index of refraction (n).
  - $n = \frac{c}{v_m}$
- Snell's law states the refraction: $n_1 \sin\theta_1 = n_2 \sin\theta_2$.





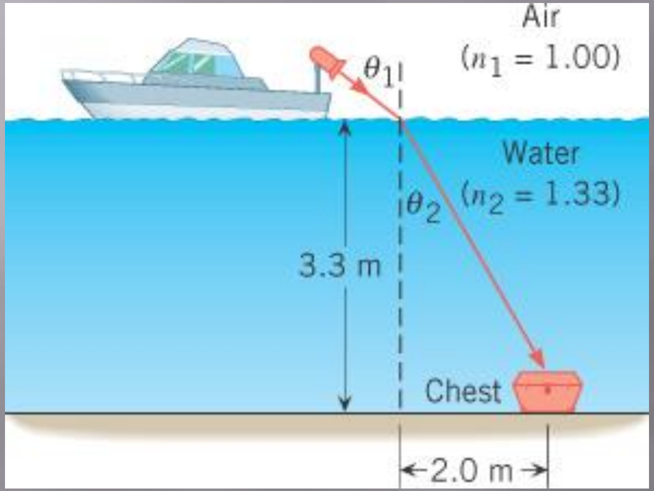
Light: What's Normal?

- To determine which way the light bends (towards or away from the normal) think of a car driving or either a road or in mud.
  - As a car on the road (low n) hits mud (high n) the first tire will slow down and pull the car away from the normal.
  - As a car in the mud hits the road the first tire will pull the car towards the normal.
- This effect is how rainbows and prisms work. The bigger wavelengths (red) bends less than the shorter (blue) ones.



Example 2

A search light is being used to find a chest under the water. At what angle must the spotlight be shined?



$n_1 = 1.00$ $\theta_1 =$

$n_2 = 1.33$ $\theta_2 = (\tan^{-1} 2/3.3)$

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

$$1 \cdot sin\theta_1 = 1.33 \cdot sin\,(31.218°)$$

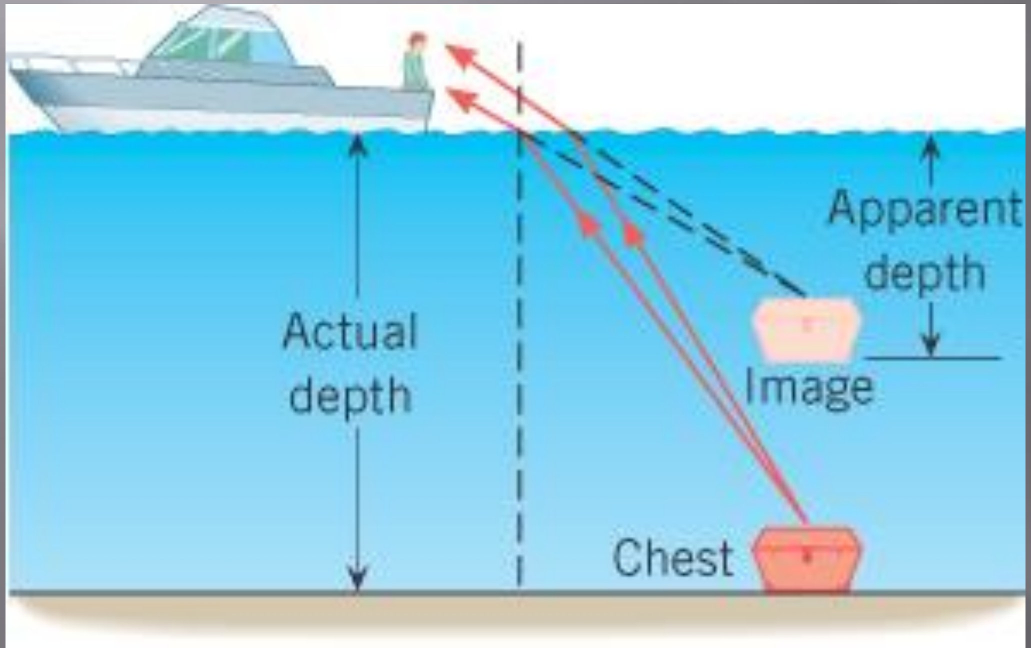
$$\theta_1 = sin^{-1}\,(.689)$$

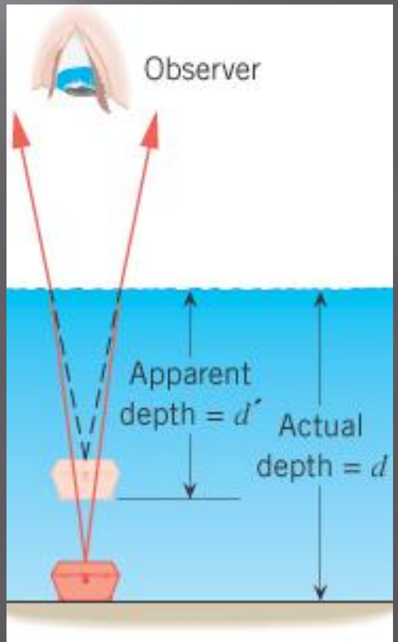
$$\theta_1 = 43.58°$$

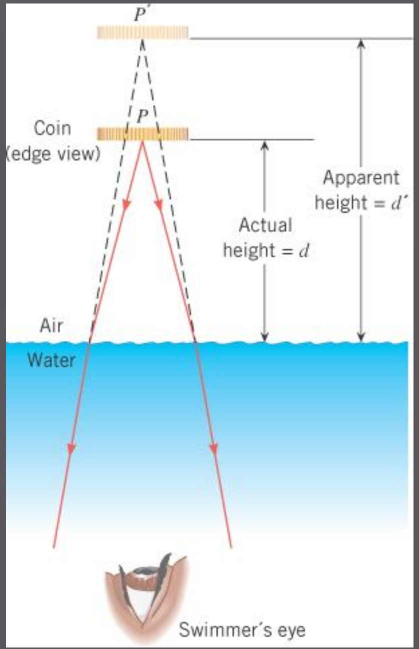
Light: Shrinking Sizes

- In the last problem the water bent the searchlight. Remember with the mirror when images are reconstructed the image is seen from straight rays.
- This also can affect the apparent depth.
- From directly overhead the apparent depth is defined as

$$d' = d\frac{n_2}{n_1}$$







Example 3

A swimmer kneels over the side of a pool and sees a coin at the bottom (3.00-m deep). How deep does the coin appear to be?

$$d' = d\frac{n_2}{n_1}$$

$$d' = 3 - m\frac{1}{1.33}$$

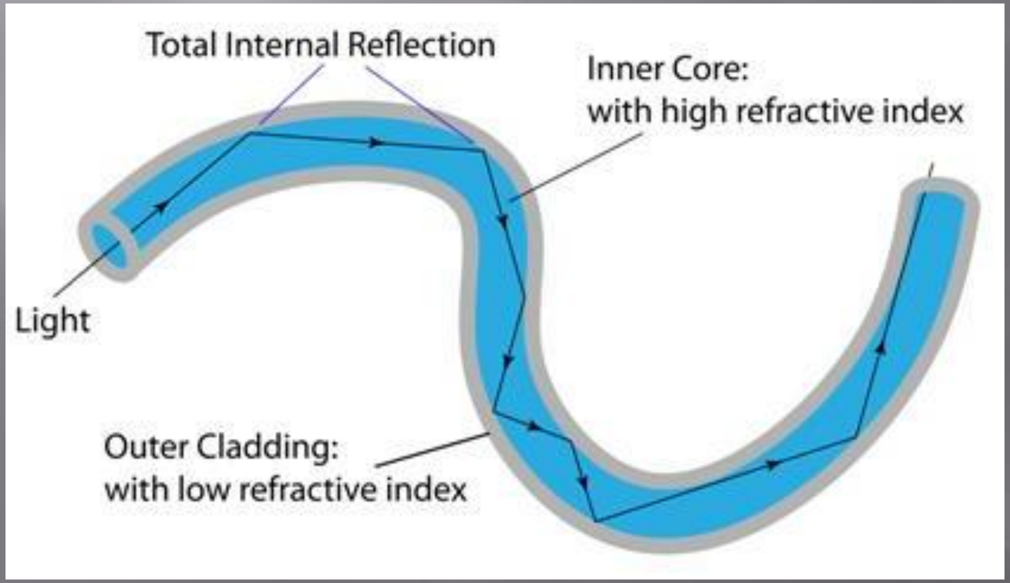
$$\boxed{d' = 2.26 - m}$$

d'= n_1 = 1.33

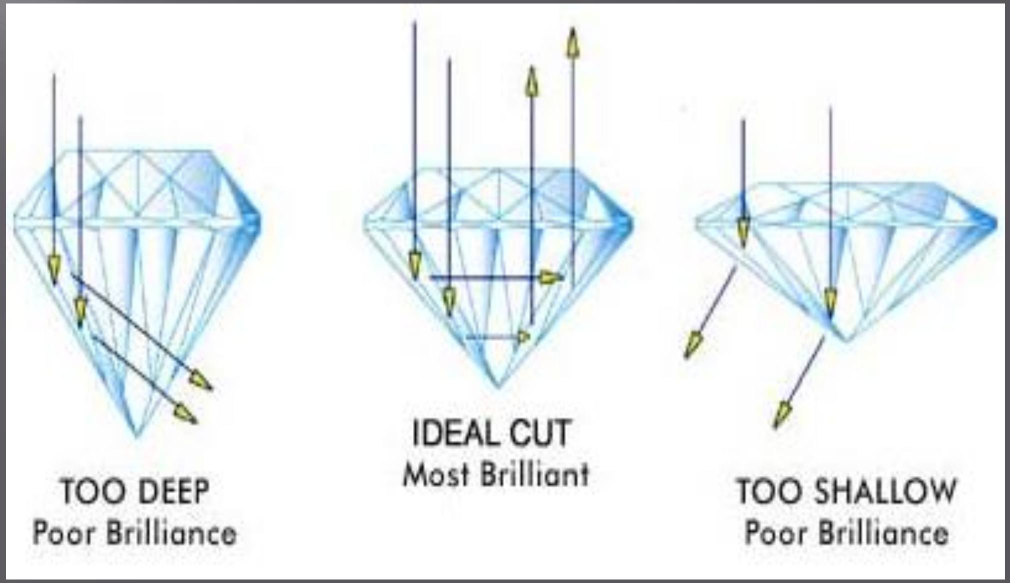
d = 3.00-m n_2 = 1.00

Refraction: Special Case

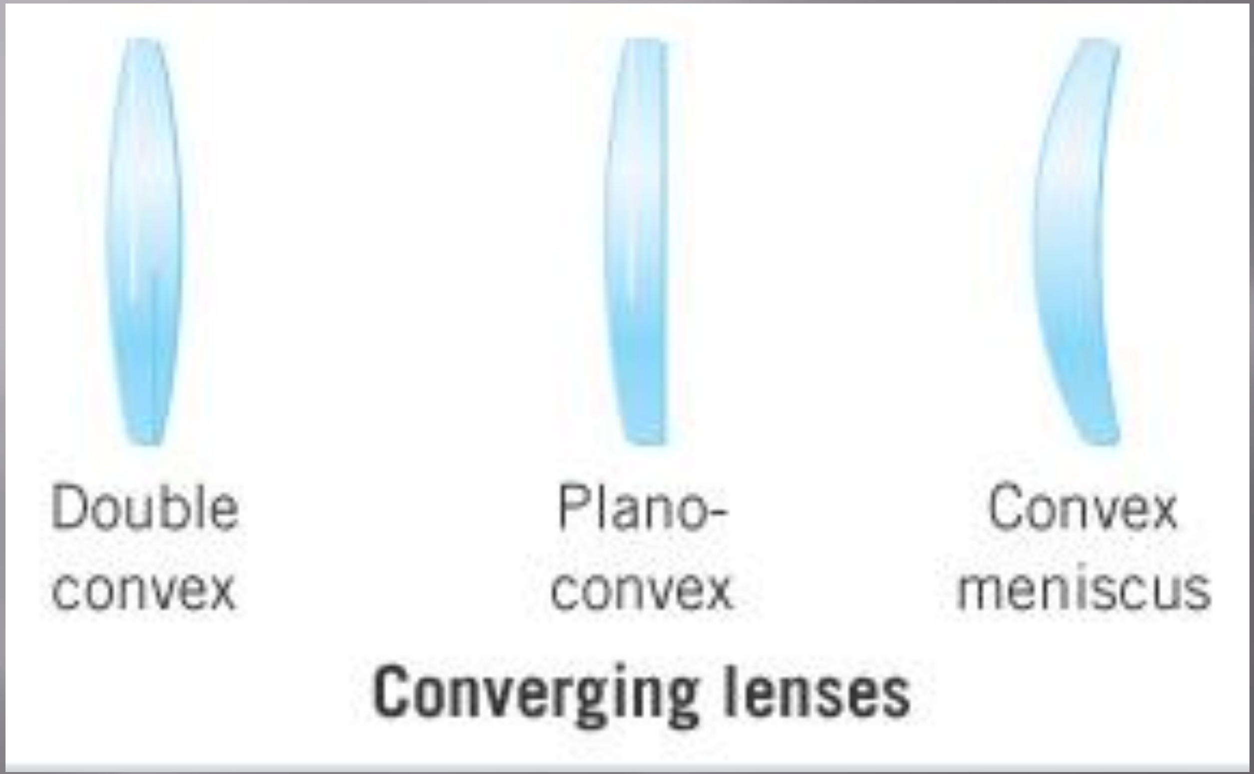
- When light in a denser medium (n_1) tries to pass into a thinner medium (n_2) if the angle is great enough the interface acts as a reflective surface (no light escapes).
  - This is called the critical angle ($n_1 > n_2$).

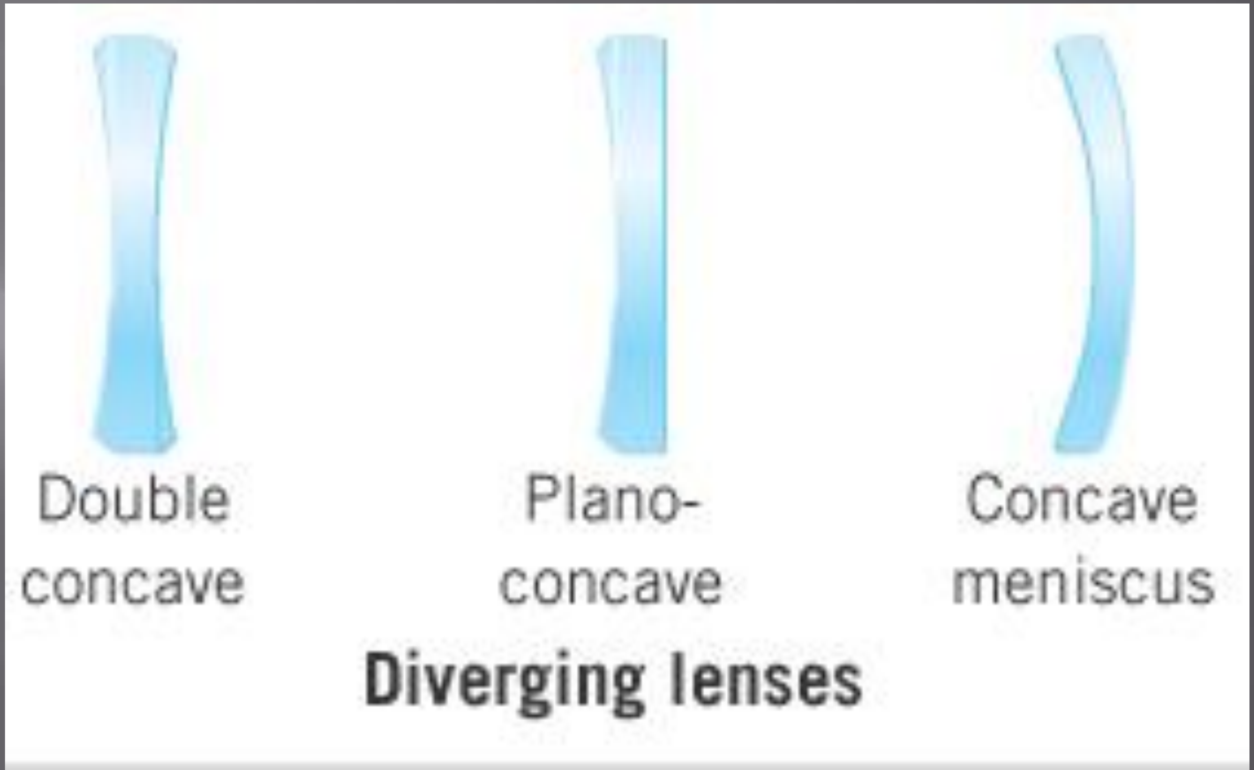


$$\sin\theta_c = \frac{n_2}{n_1}$$

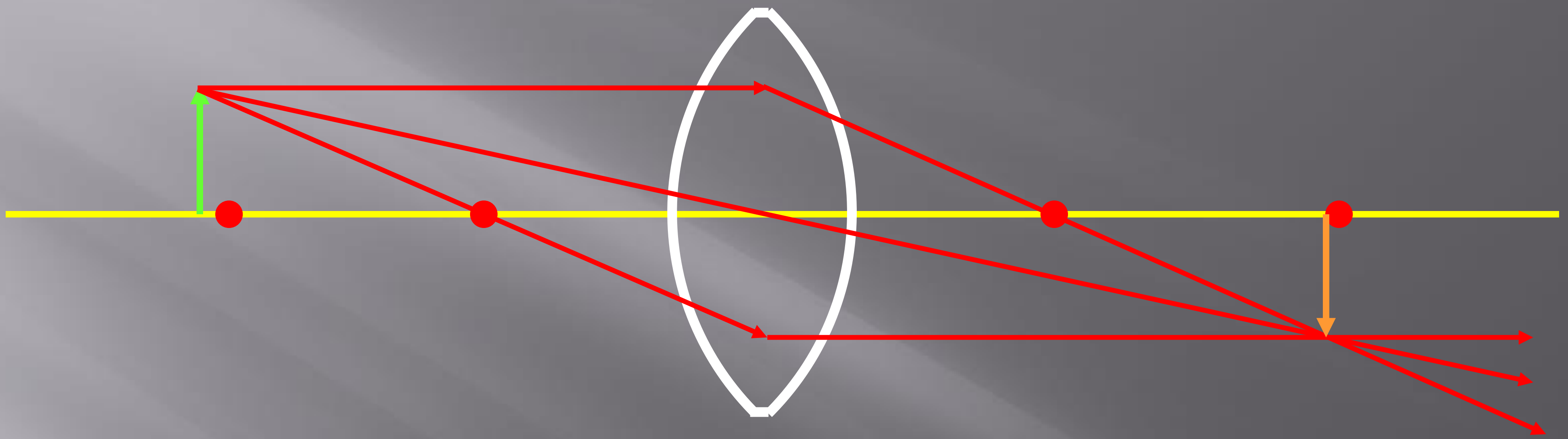


Types of Lenses





Drawing Lenses



1: Parallel to lens then through f.

2: Straight through the Principle Axis.

3: Through f to lens then parallel.

Object Infinite: Small Inverted Real Image at f

Object Beyond C: Small Inverted Real Image between f-C

Object Between f-C: Large Inverted Real Image beyond C

Object within f: Large Erect Virtual Image beyond C (same side as image: like magnifying text)