Optics

Sol PH. 11

What is light?

This question sparked a huge debate in physics.

- <u>Light is a **Stream of Particles**</u>.
- **Newton** called corpuscles
  - **Colors travel at different speeds.**
- **Einstein** called quanti

- <u>Light is a **wave.**</u>
- **Young** in 1700's showed light had wave properties.

Quantum Mechanics says that light is both a wave and a stream of particles (called a photon)! Electrons can be at different energy levels, when it goes from a high level to a low one a photon is released.

The Wave Nature of Light

- Light can be considered an electromagnetic transverse wave.
- $C = \lambda f$ where c=speed of light=$3x10^8$ m/s
- * *show glow strip w/ spectrum on it.*

http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=35

The Electromagnetic Spectrum

Note: $1x10^{-9}$ m = 1nm

	Small λ / Big Frequency
Gamma Rays	**$.1x10^{-9}$ m > λ > 10^{-14}**
X-Rays	**$60x10^{-9}$m > λ>0.1 x 10^{-9} m**
Ultra Violet light (UV)	**400 x 10^{-9} m > λ>60x 10^{-9} m**
Visible Light (ROY-G-BIV)	**700 x 10^{-9} m> λ > 400 x 10^{-9} m**
Infrared light (IR)	**.001m > λ > 700 x 10^{-9} m**
Micro Wave	**.3m > λ >.001m**
Radio/TV waves	**λ >.3 m**
	Big λ / Small Frequency

Spectral Analysis

- Every element has a unique spectrum emission or absorption. This allows us to identify what elements are in far away stars.

Visible light

- We use prism and diffraction grating to turn white light into colors.
- 400 nm (Violet) to 700 nm (Red)
- A continuous source gives all the colors. An incandescent light bulb will do this (heavy on reds.)
- Fluorescent light bulbs are heavy on blues
- LEDs give a very limited spectrum.

Why Objects have color

- An object absorbs all colors except for the one that it appears to be. The color we see gets reflected from the object.
- White objects reflect all colors, while black ones absorb all colors.
- This is why a white tee shirt feels cooler than a black one.

Polarized light

- Light has both a vertical and a horizontal component.   Polarized light has one of these missing.

- This is used in designer sunglasses and cameras.
- Also used in LCD monitors/TV's to make black spots.

- **Show polarized film*

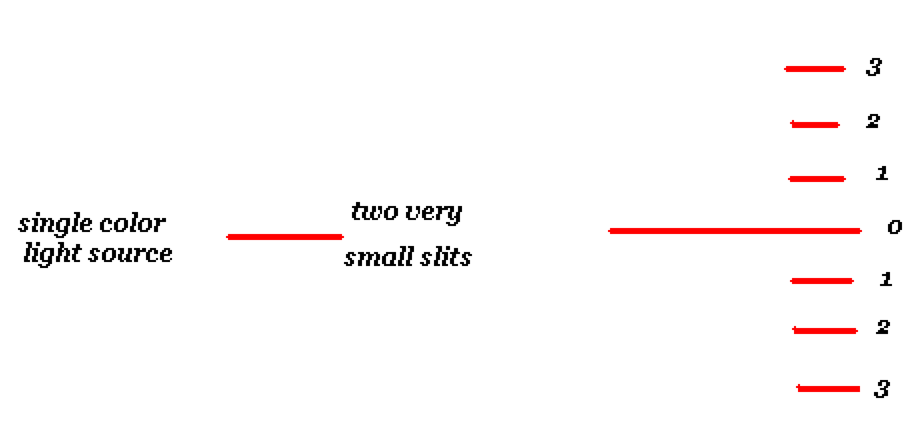
Diffraction

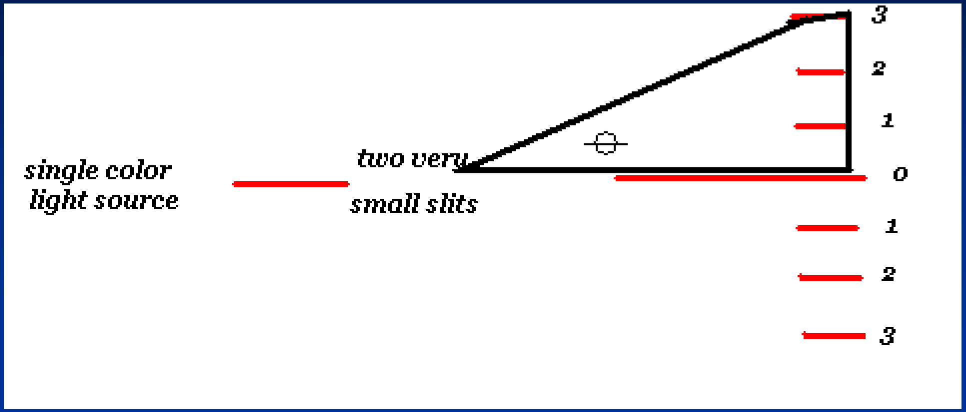
- Is the bending of light around a corner or object.
- Smaller wavelengths don't diffract as well as larger ones do.
- FM has a smaller wavelength than does AM, the radio people did this to get rid of FM, however they have a larger frequency range allowing it to come in clearer!

Thomas Young 1773-1829

- Was a genius – was said to have read the Bible twice by age four and could speak at least 7 languages.
- Was a doctor- but w/ poor bedside manner.
- Uncle died, leaving him independently wealthy.
- He had many discoveries, the most notable was his double slit experiment.
- Picture provided by Wikipedia.

- When light goes through two tiny holes next to each other, it creates a pattern of positive and negative interference. (bright and dark spots)
- We call the bright spots fringes.
- $n\lambda = d \sin\theta$





- The Fringes are numbered out from the center.
- Must use trig to get theta.

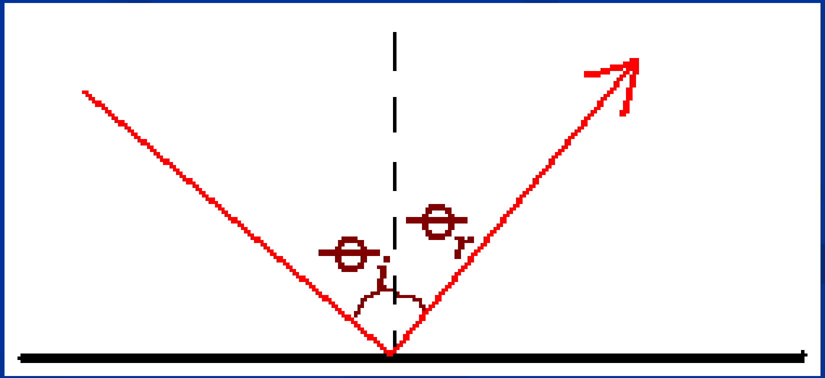
- *Example problems*

Particle Nature of Light

- Reflection- occurs when a light ray strikes a reflective surface and bounces back.

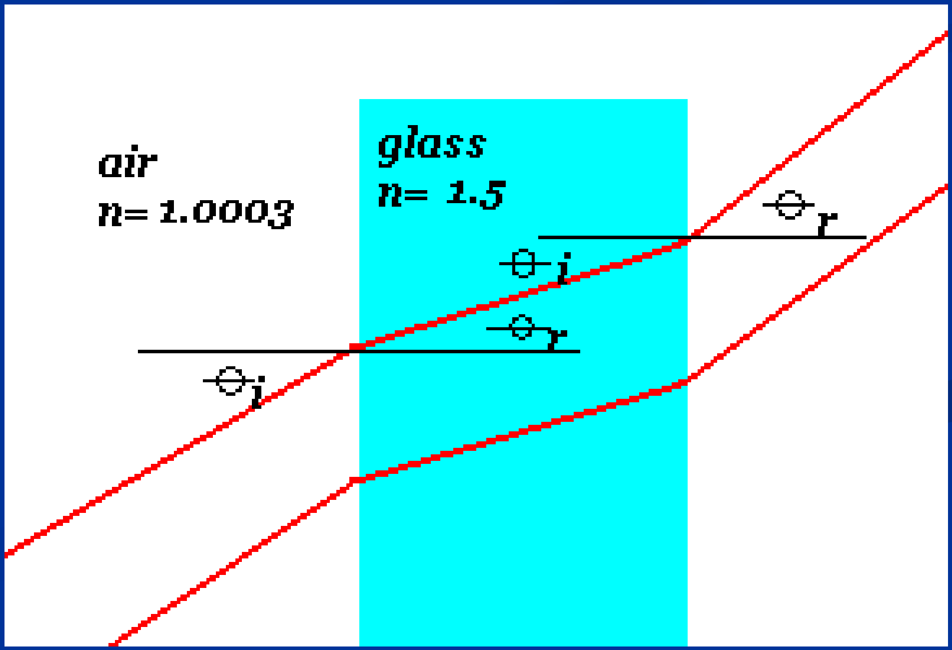
- The angle of incident ray measured from normal equals the angle of reflected ray also measure from the normal.
- θi=θr
- Mirrors are designed to

reflect light.

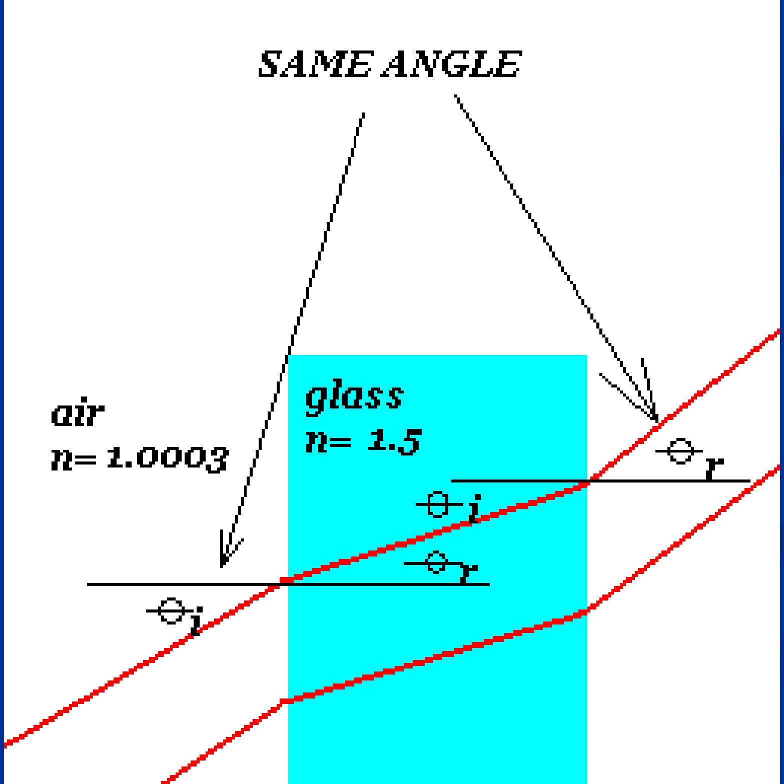


Refraction – is the bending of light as it changes medium.

- This follows Snell's Law
  - $n_i \sin\theta_i = n_r \sin\theta_r$ -measure θ from normal
- "n" is the index of Refraction (unitless)
- n(vacuum) = 1.0
- n(air) = 1.0003
- n(water) = 1.33
- n(glass) = 1.5
- n(diamond) = 2.42



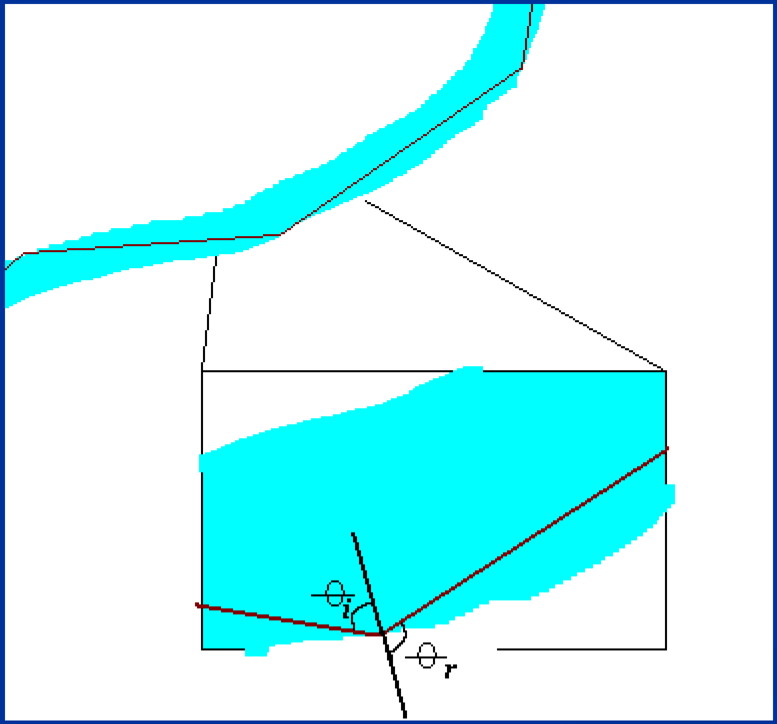
- If a beam comes out of the material, it will leave with the same angle it had at incidence, if the sides of the medium are parallel.
- **Show*

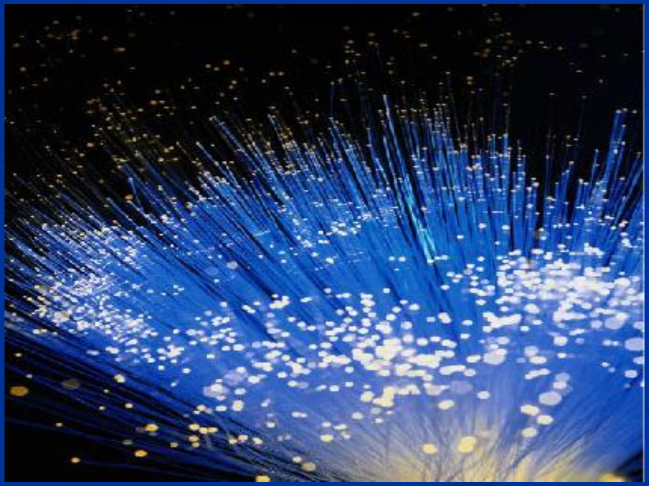


Total Internal Reflection

- Occurs when the refraction is so big, that the beam does not leave the material.
- Principle used in fiber optics and diamond cutting.
- The critical angle is the minimum angle where total internal reflection will occur. This is equivalent to a refracted angle of 90º. Any incident angle greater than the critical angle will also exhibit total internal reflection.
- **show flashlight w/ water*

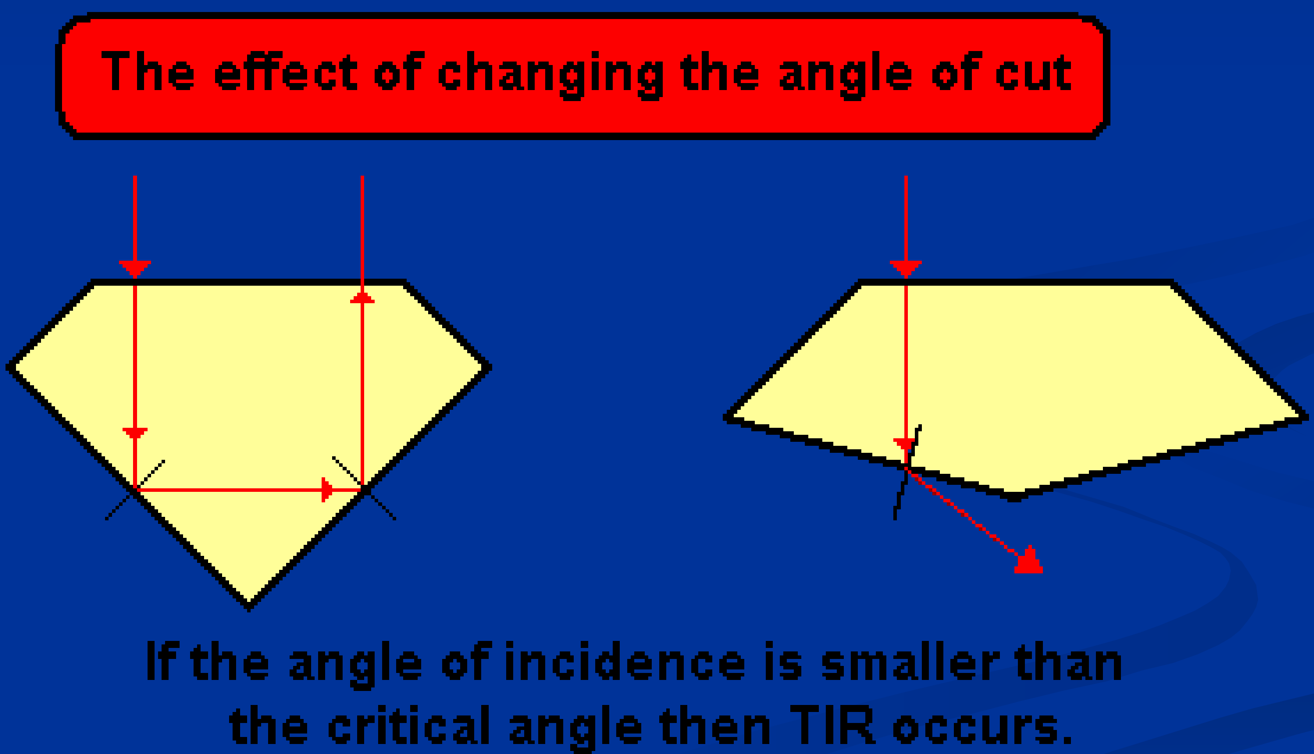
- Photo obtained at http://www.atp.nist.gov/atp/brochure.htm





TIR for diamond

- Obtained from http://www.cyberphysics.pwp.blueyonder.co.uk/topics/physics/light/TIR.htm



Formula

- Sin $\theta_c = n_r/n_i$

- must be going from larger index of refraction into smaller one.

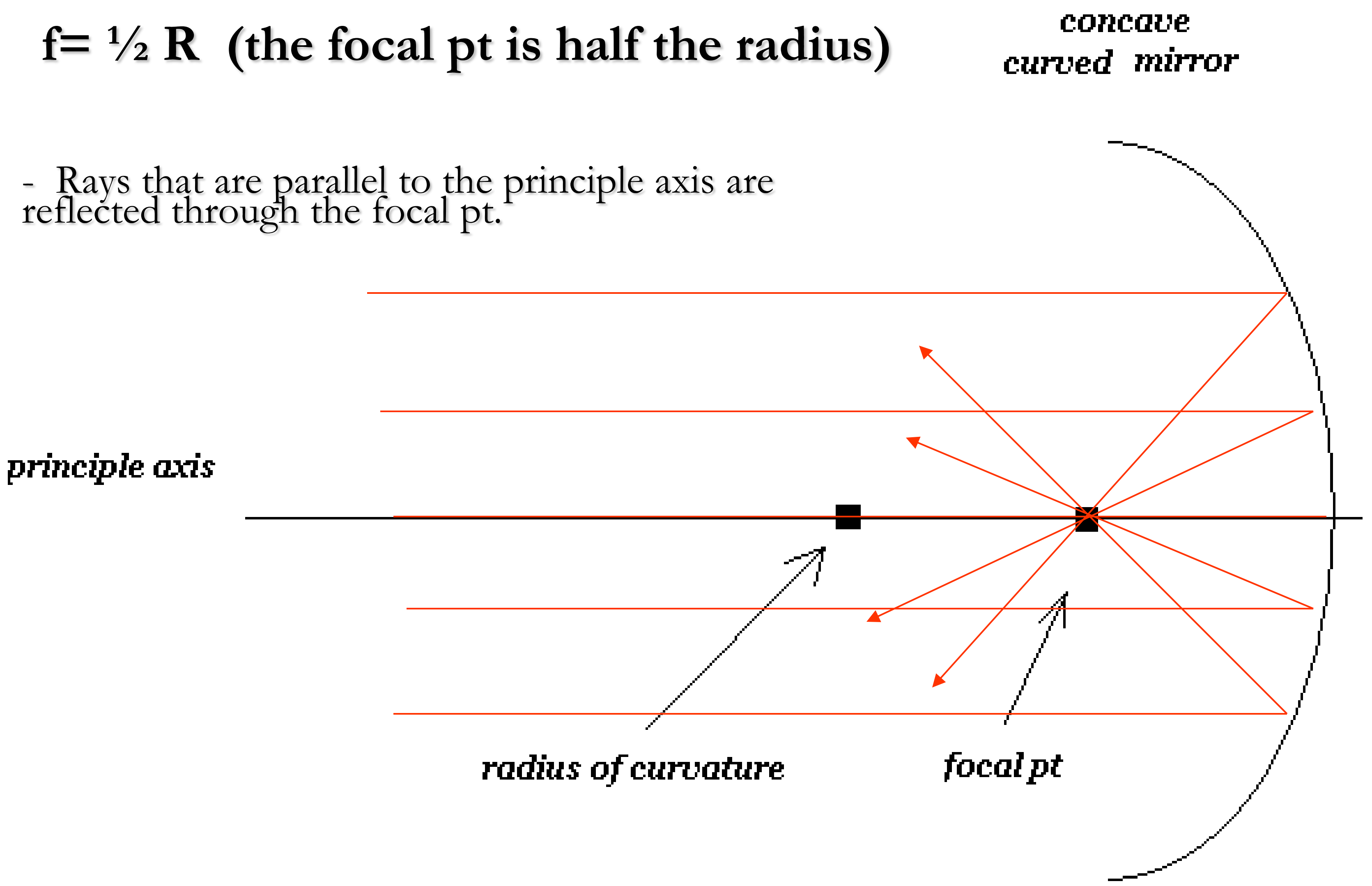
Curved Mirrors

- What does this mirror reflect?

- Obtained athttp://www.catholic.net/you_and_your_kids/print.phtml?article_id=555

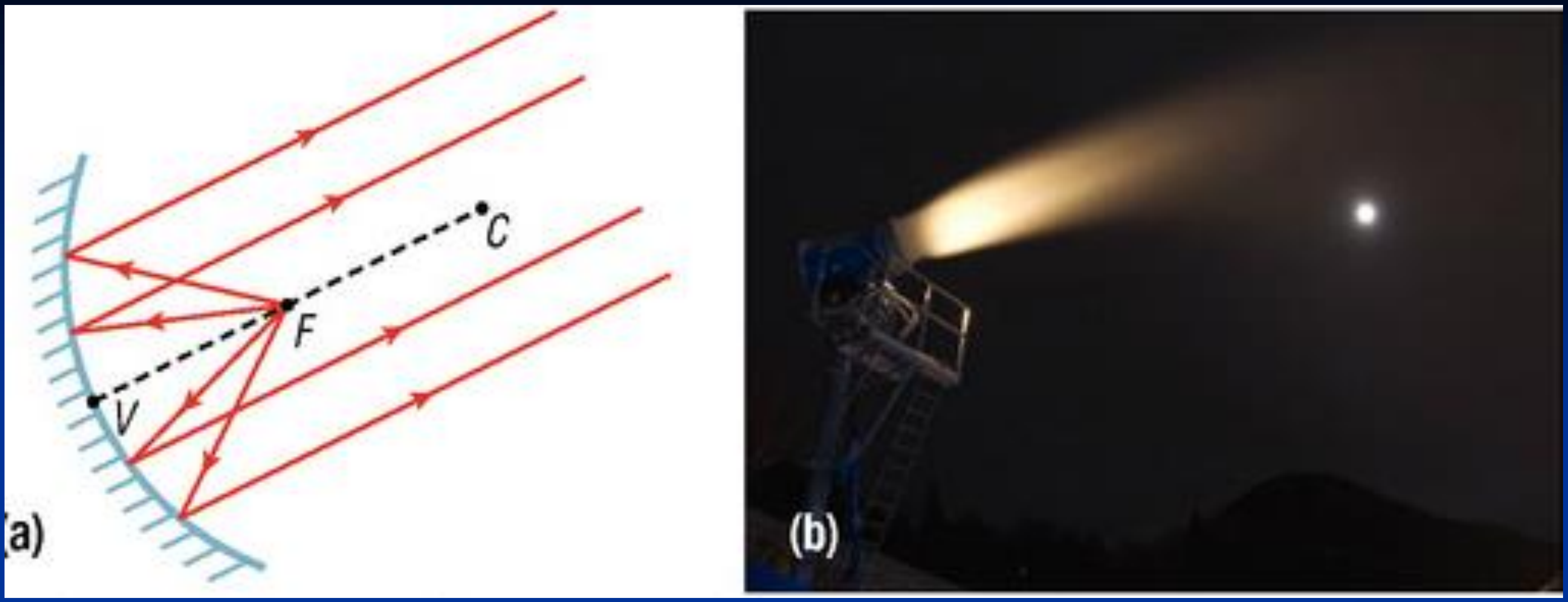
f= ½ R (the focal pt is half the radius)

- - Rays that are parallel to the principle axis are reflected through the focal pt.



- Satellite dishes are intended to be concave mirrors with an antenna at the focus.

- The Vdara hotel, in Las Vegas acts like concave mirror unintentionally, causing burns.



- Concave mirror can also be used as reflectors. Used in flashlights, car head lights, and other places.

Things in a concave mirror look distorted

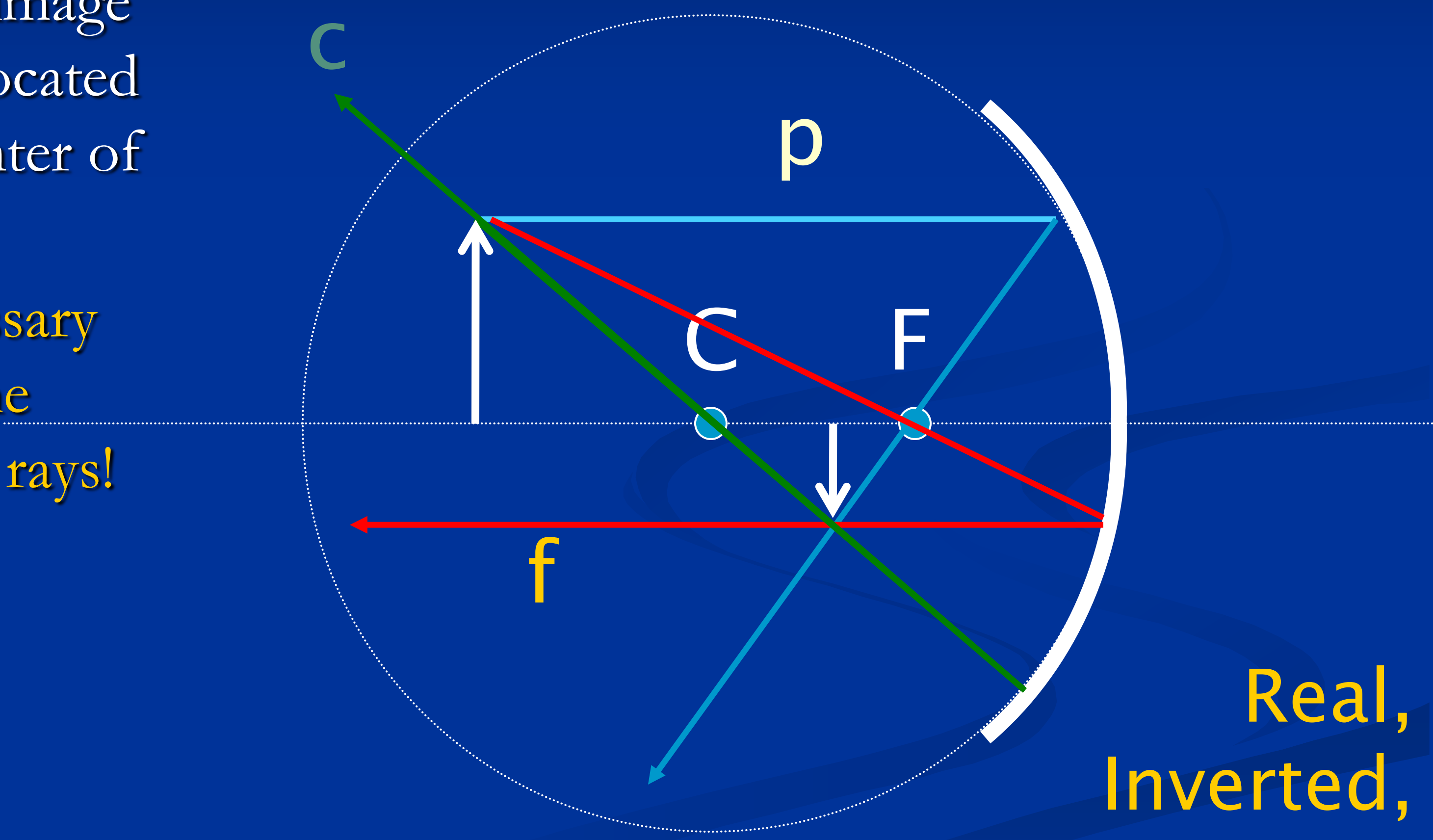
- If the object is closer than the focal point, the image will appear enlarged. (Make-up mirror)
- If the object is further than the focal point the image will appear inverted (upside-down).
- If the object is at the focal point no image will appear.

Ray Tracing- is used to determine what image will be visible.

- Certain Rays can be drawn to locate the position of an image. At least two rays must be drawn to see image.
- Ray 1, parallel to the principle, reflects/refracts through the focal point.
- Ray 2, through the focal point, reflects/refracts parallel to the principle axis
- Ray 3, straight through the center of a lens, or straight from object to radius of mirror.

Ray tracing: spherical concave mirror

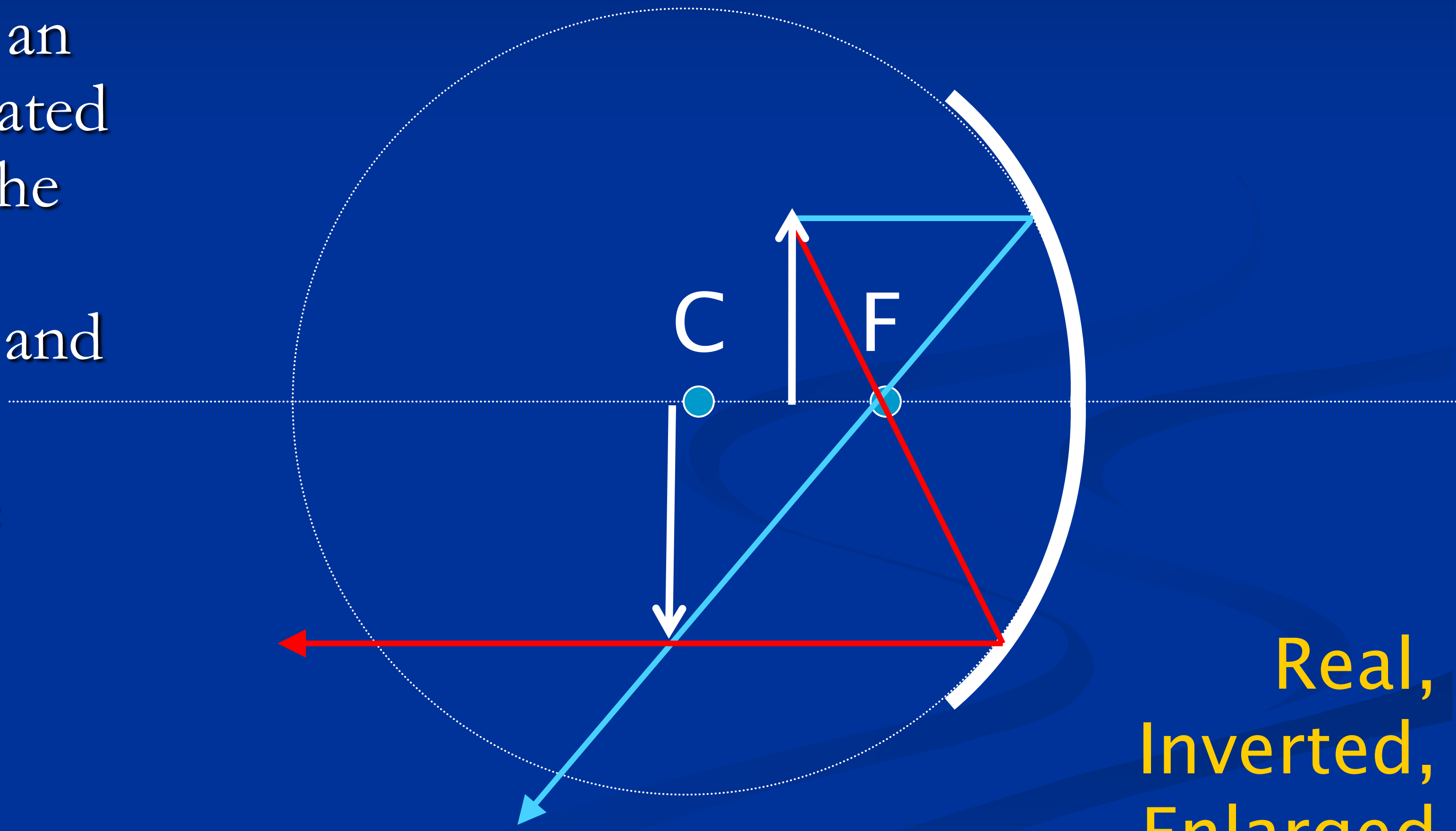
- Construct the image for an object located outside the center of curvature.
- It is only necessary to draw 2 of the three principal rays!



Real,
Inverted,
Reduced
Image

Ray tracing: spherical concave mirror

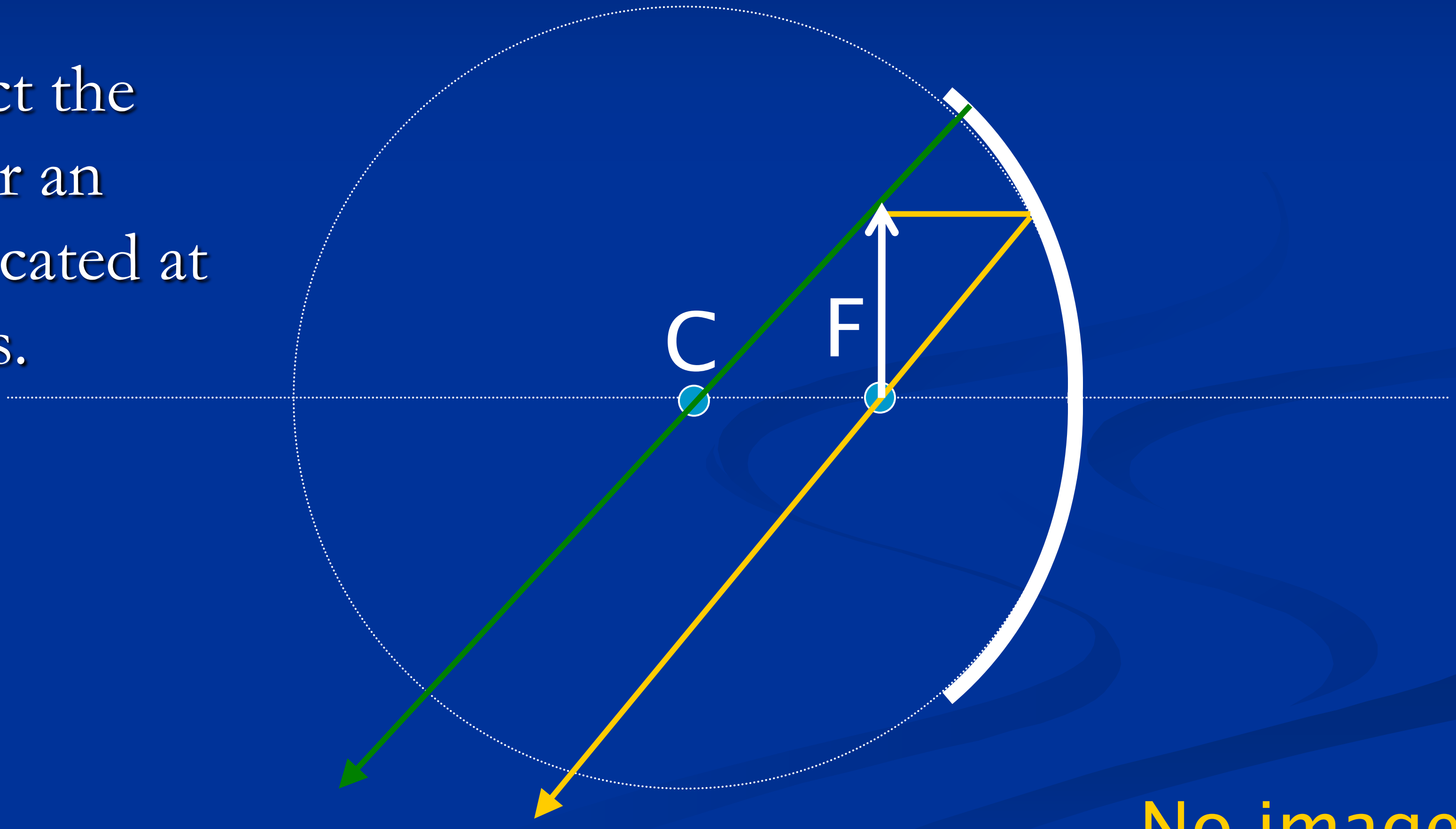
- Construct the image for an object located between the center of curvature and the focus.
- Name the image.



Real,
Inverted,
Enlarged
Image

Ray tracing: spherical concave mirror

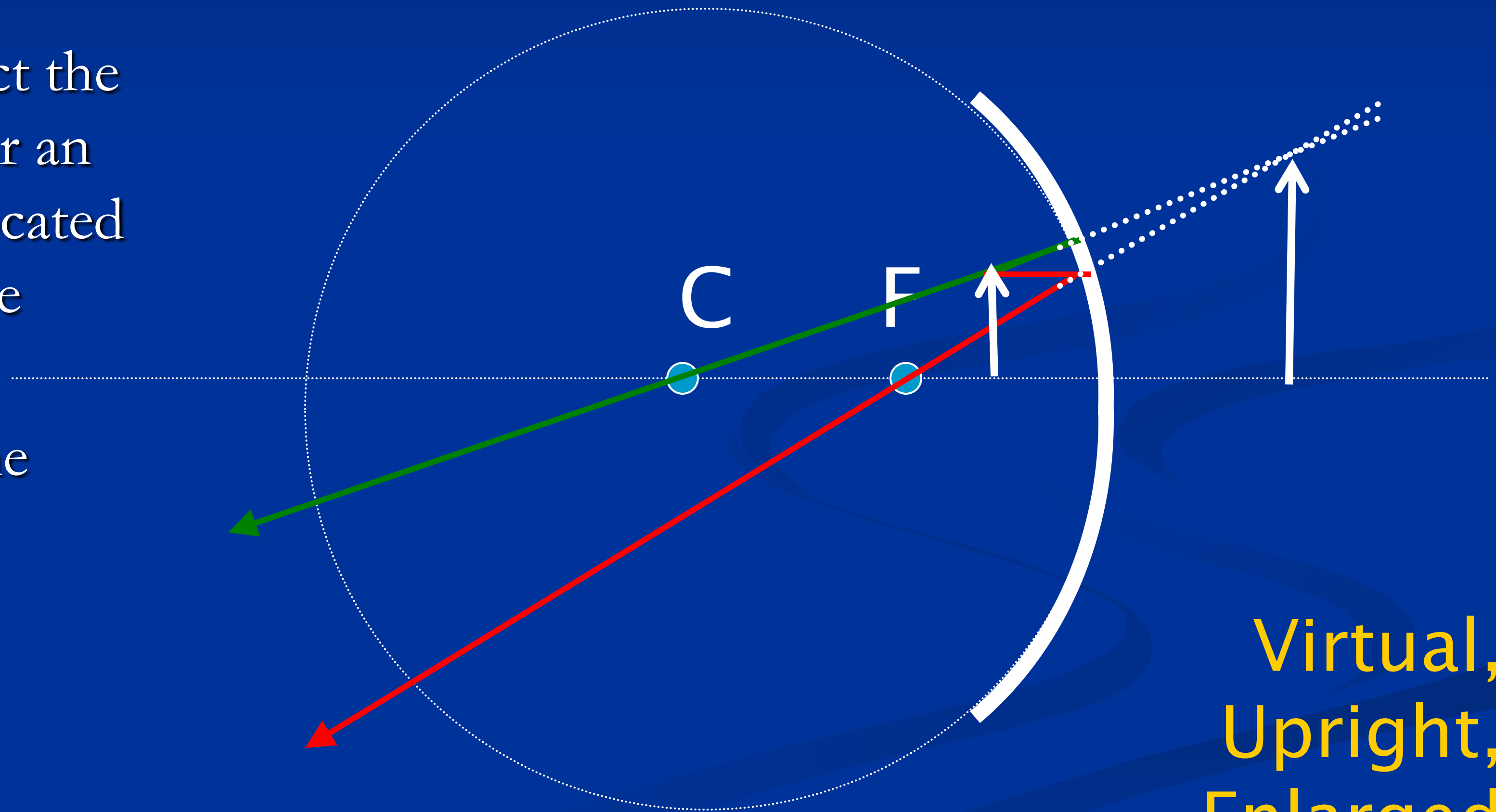
- Construct the image for an object located at the focus.



No image is formed.

Ray tracing: spherical concave mirror

- Construct the image for an object located inside the focus.
- Name the image.



Virtual,
Upright,
Enlarged
Image

The Lens Makers Formula

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \qquad m = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$$

Sign Convention:

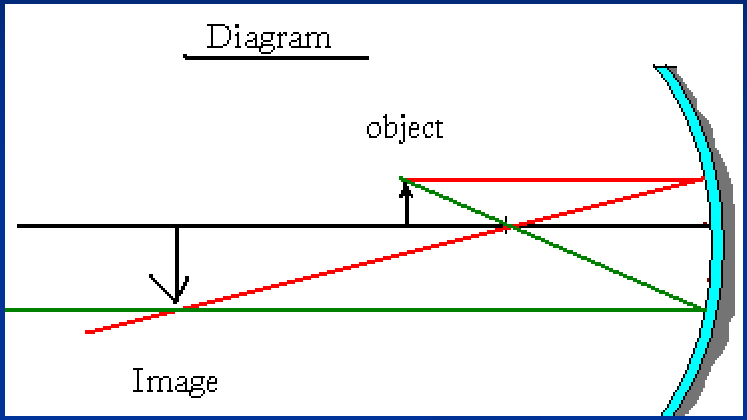
Focal length (f) mirrors
(+) Positive for CONCAVE mirrors
(-) Negative for CONVEX mirrors

Focal length (f) lenses
(+) Positive for Convex lenses
(-) Negative for Concave lenses

Magnification (M) and (h_i)
(+) Positive for UPRIGHT images
(-) Negative for INVERTED images

Image Distance
d_i is (+) POSITIVE for real images
d_i is (-) NEGATIVE for virtual images

A spherical concave mirror, focal length 20 cm, has a 5-cm high object placed 30 cm from it. Calculate the position, magnification, and size of the image.



List

$f = 20cm$

$ho = 5cm$

$do = 30cm$

$di = ?$

$m = ?$

$hi = ?$

$1/f = 1/di + 1/do$

$20^{-1}cm = d_i^{-1} + 30^{-1}$

$di = (20^{-1}cm - 30^{-1}cm)^{-1}$

$di = 60\ cm$

$m = -di/do$

$m = -\ 60\ cm / 30\ cm$

$m = -\ 2$

$m = hi/ho$

$-\ 2 = hi/5cm$

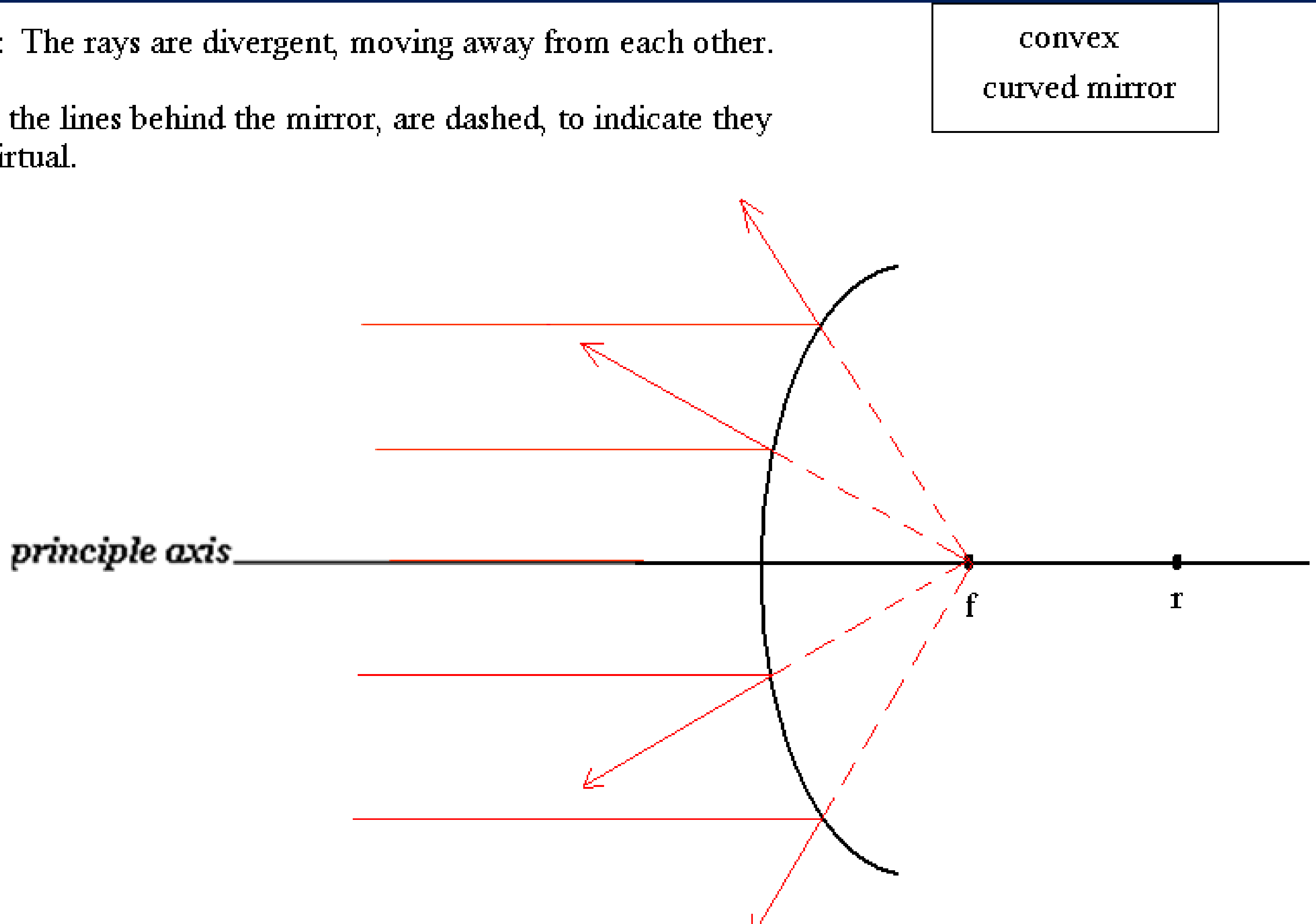
$hi = -\ 2\ (5\ cm)$

$hi = -\ 10\ cm$

Convex mirror:

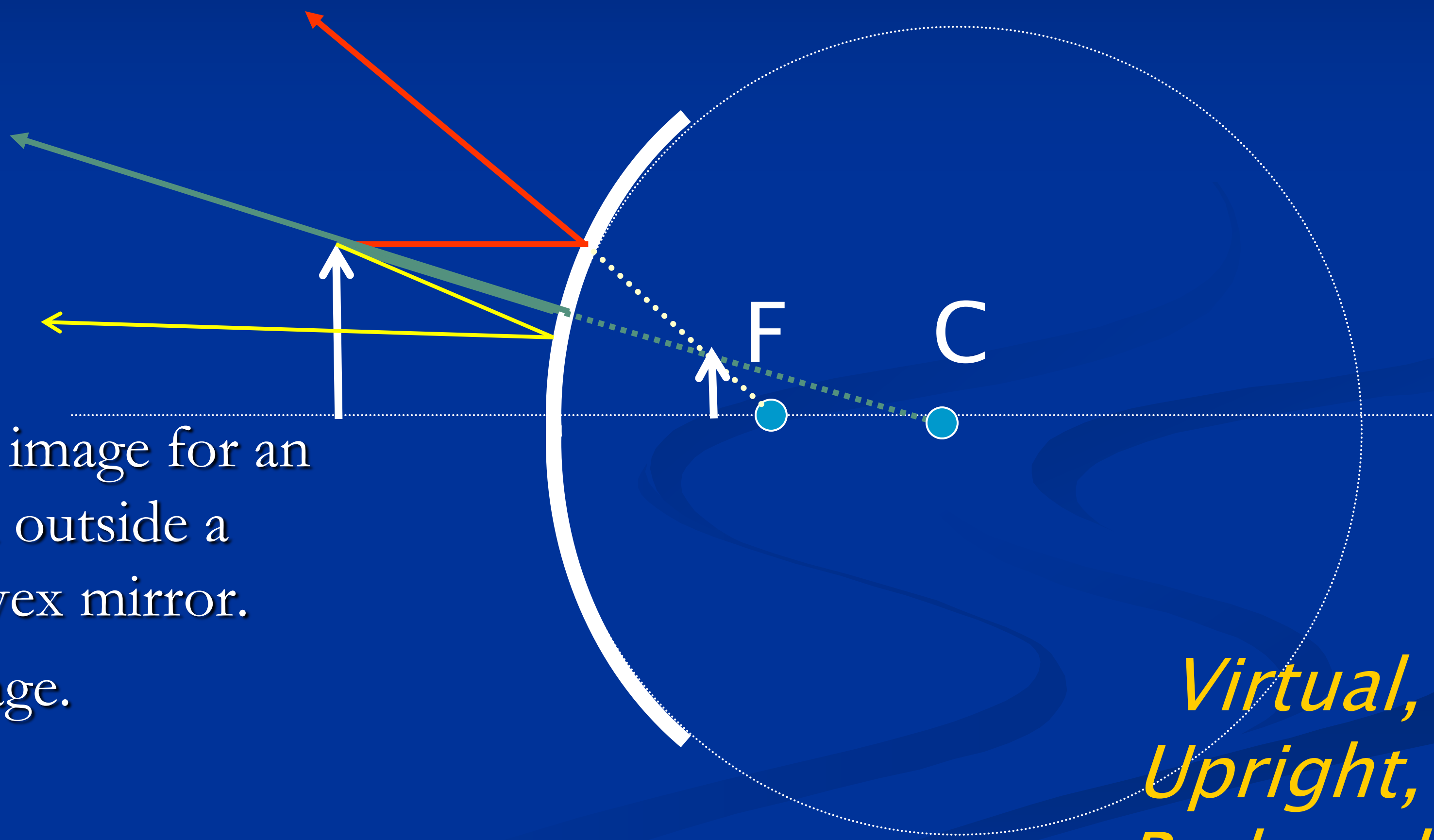
Note: The rays are divergent, moving away from each other.

Also, the lines behind the mirror, are dashed, to indicate they are virtual.



- Convex mirrors allow you to see a larger area.
- Used as a side mirror in car or security mirrors.

Ray tracing: spherical convex mirror

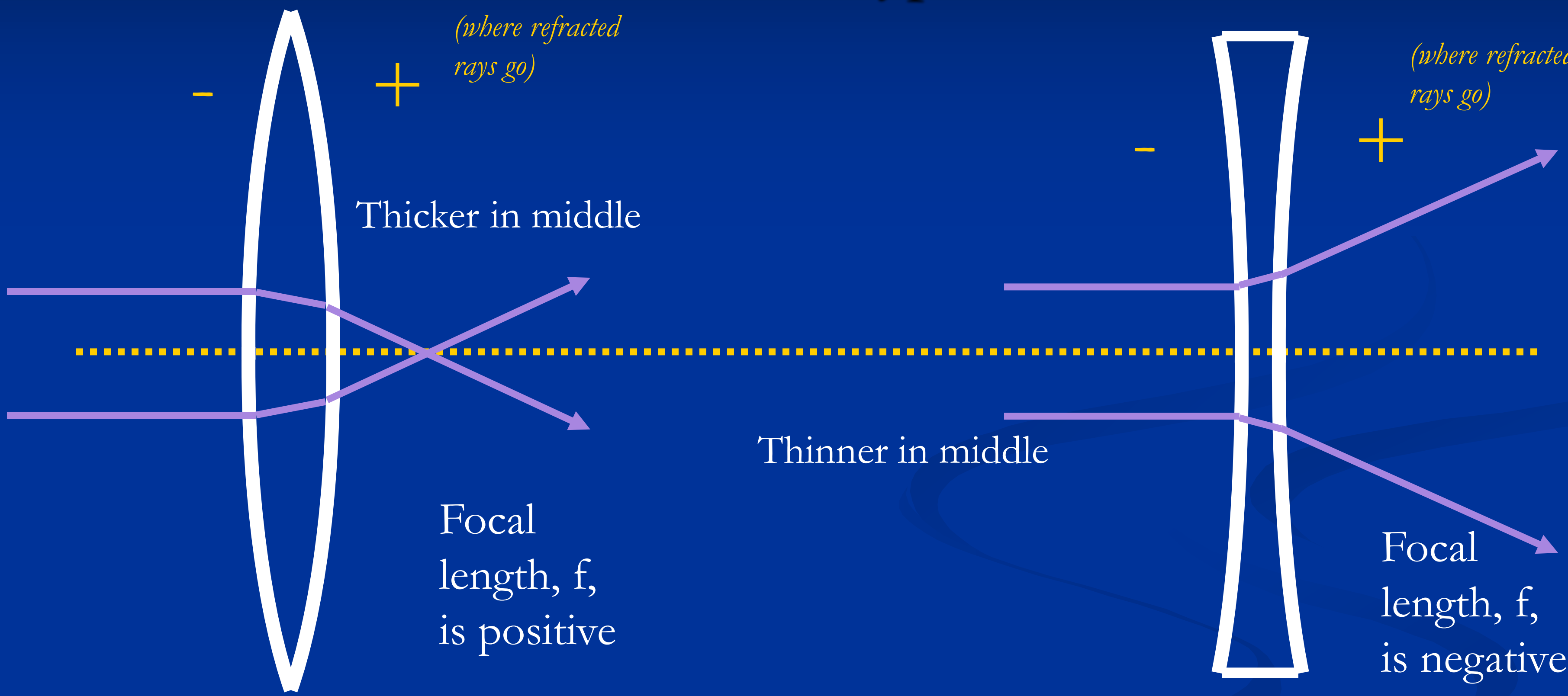


- Construct the image for an object located outside a spherical convex mirror.
- Name the image.

Virtual, Upright, Reduced Image

Lenses

- There are two types of lenses.

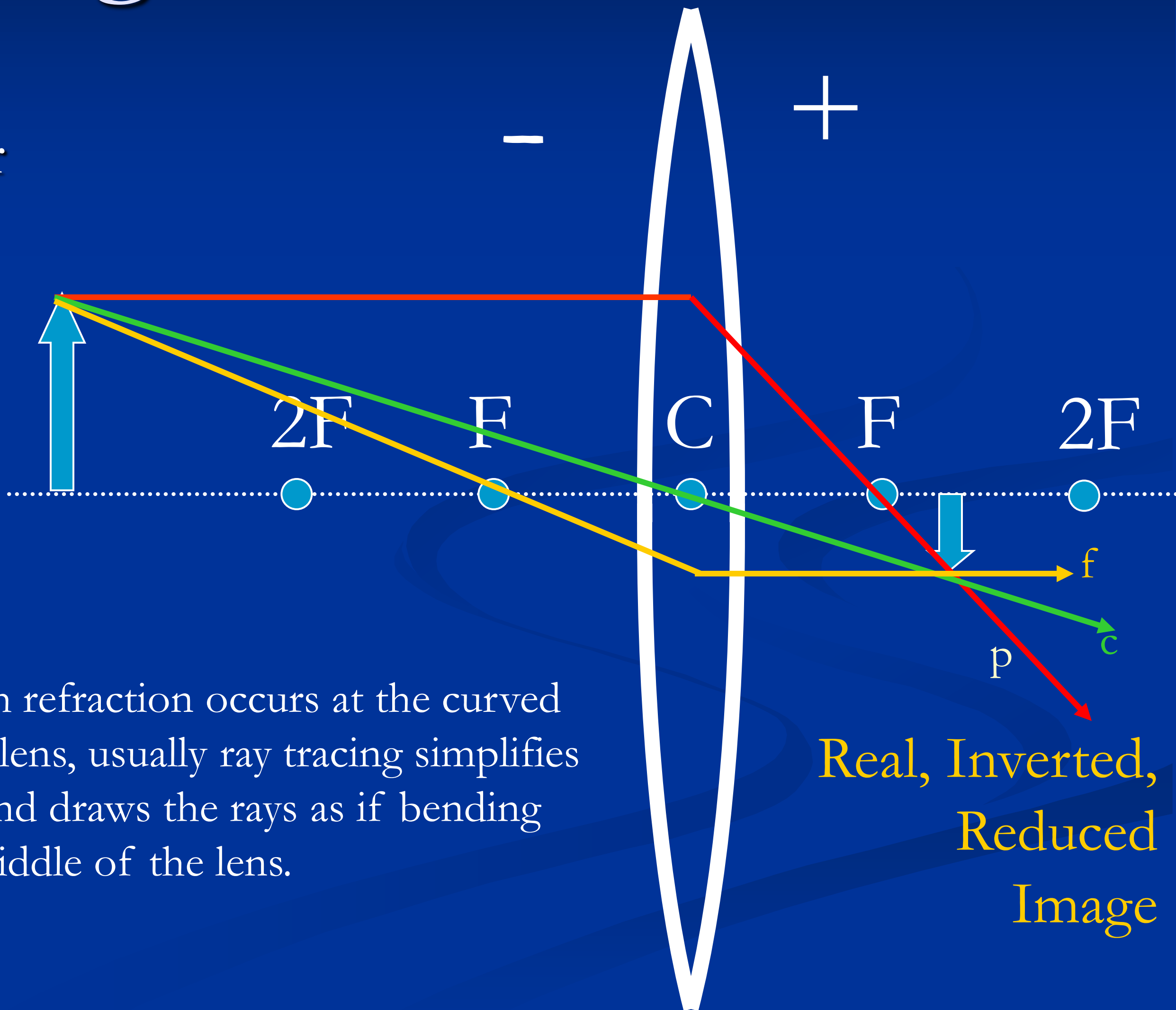


Converging
Called
CONVEX

Diverging
Called
CONCAVE

Same Rules for drawing rays and same sign convention.

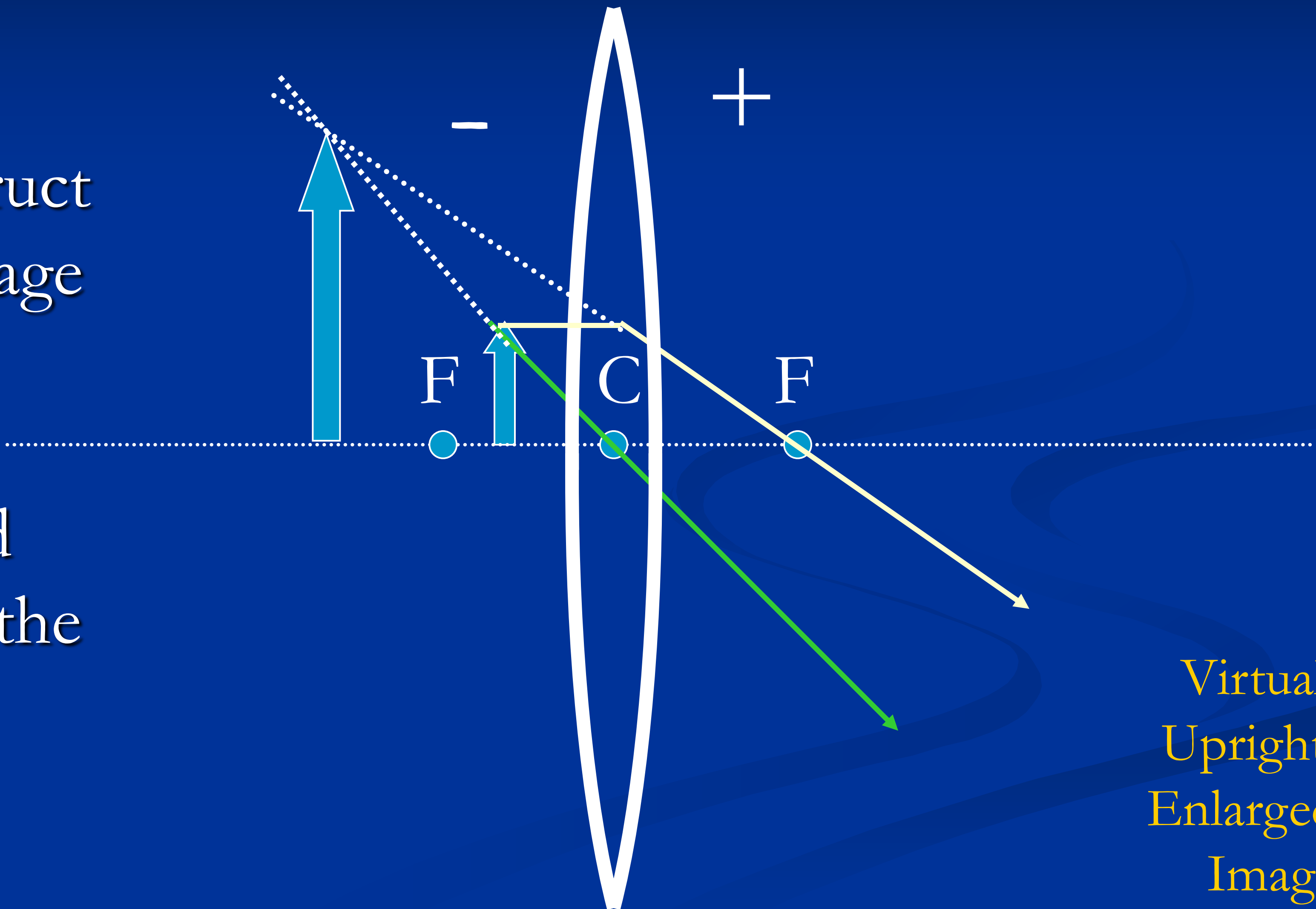
- Construct the image for an object located outside 2F.
- It is only necessary to draw 2 of the three principal rays!



Note: Although refraction occurs at the curved surfaces of the lens, usually ray tracing simplifies the technique and draws the rays as if bending occurs in the middle of the lens.

Ray tracing: converging lens

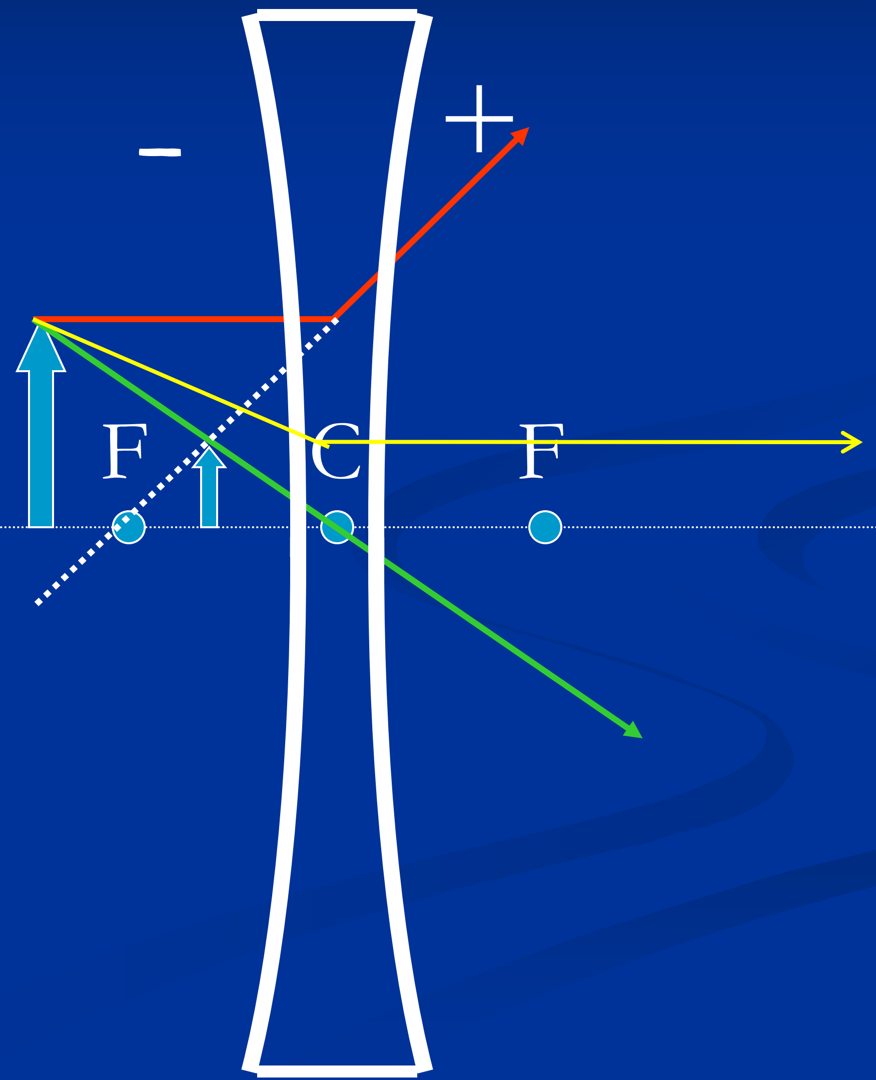
- Construct the image for an object located inside the focus.



Virtual, Upright, Enlarged Image

Diverging lens

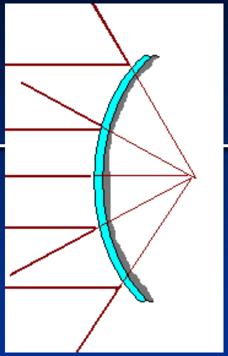
- Construct the image for an object located in front of a diverging lens.



Virtual, Upright, Reduced Image

Summary

- **Divergent** convex mirror



or concave lens

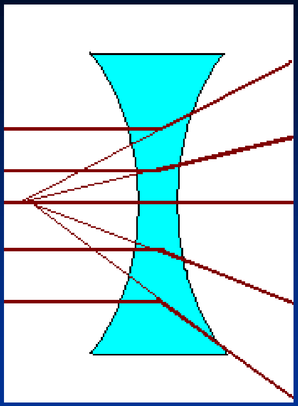
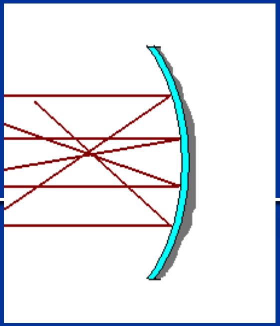
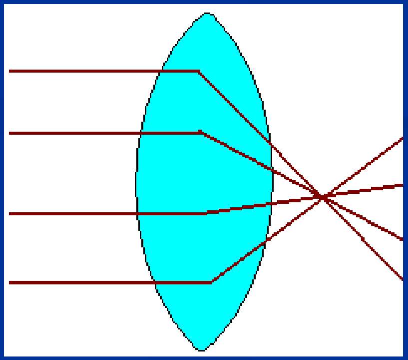


Image is always virtual, reduced, and upright

- **Convergent** concave mirror



oconvex lens



Imaginary is virtual, enlarged, and upright if object is in front of focal pt.

Image is real, inverted, if object is beyond focal pt.
enlarged between focal pt. and twice the focal pt.
actual size at twice the focal pt.
reduced in size beyond twice the focal pt.

Summary

Image is real and inverted
if object is beyond focal pt.

Imaginary, enlarged and
upright in front of focal pt.

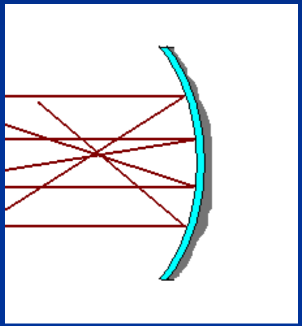


Image is always virtual,
reduced, and upright

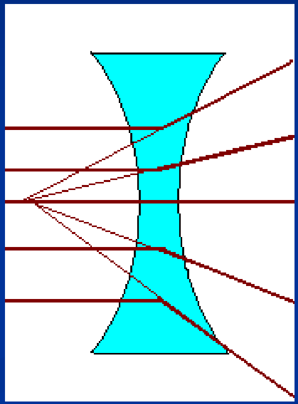


Image is always
imaginary, reduced, and
upright

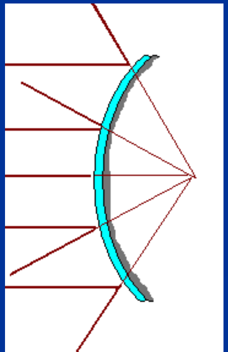


Image is real, inverted, if
object is beyond focal pt.

Imaginary is virtual enlarged,
and upright if object is in
front of focal pt.