Unit 9: Light-Reflection

And God said...

$$\frac{mv^2}{r} = \frac{Ze^2}{r^2}$$

$$mvr = \frac{nh}{2\pi}$$

$$r = \frac{r^2 h^2}{(2\pi)^2 m Z e^2}$$

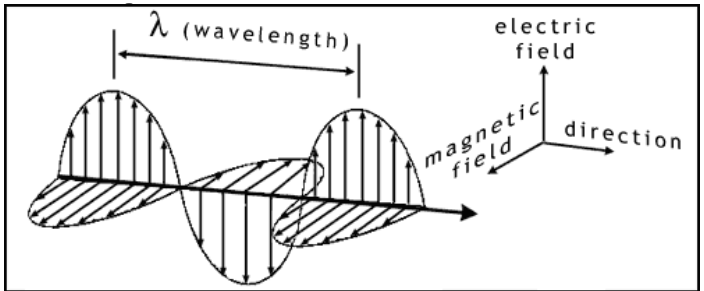
$$E = \frac{1}{2} mv^2 - Z\frac{e^2}{r}$$

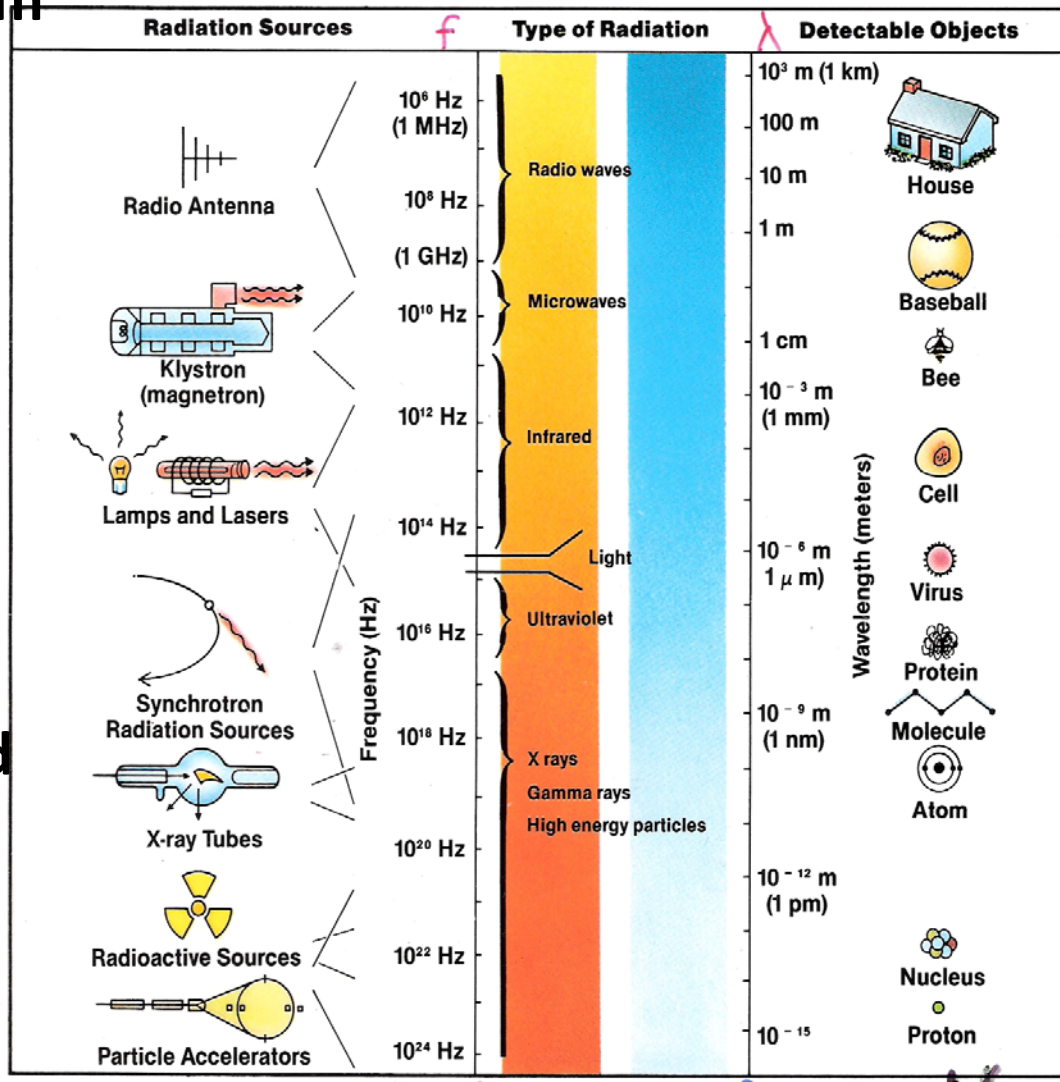
$$E = \frac{2\pi m Z^2 e^4}{n^2 h^2} = Ry$$

...and there was Light.

LIGHT

- ► Transverse EM wave
- ► Speed = 3 x 10^8 m/s in vacuum
- ► Can only be seen when scattered or reflected
  - See **BLUE** sky because ↓λ scatters more easily
- ► Wave (Huygens) vs. particle (Newton-Einstein)
  - Newton: particle = corpuscles
  - Einstein: particle = photon
- ► Travels straight path
  - Electric field & Magnetic field travel ⊥ to each other thru vacuum & reinforce each





$c = \lambda f = 3 \times 10^8$ m/s

ROY G BIV

V = $f\lambda$ = 3 x 10^8 m/s

** f determines color of light-how fast vibrating is determined by source & doesn't change between different mediums

Demo Laser through air & water

Light slows down($\downarrow v$) as travels thru more dense medium because $\downarrow\lambda$ so if λ caused color then the laser would change color but IT DOESN'T!!

If yellow light has a wavelength of 586 nm what is its frequency?

$$f = \frac{3 \times 10^8 \text{ m/s}}{5.86 \times 10^{-7} \text{ m}} = \textbf{5.1 x } \mathbf{10^{14}} \textbf{ Hz}$$

Plane Mirrors

Activity: Use plane mirror & look at words

How do they appear?

RANT
1481

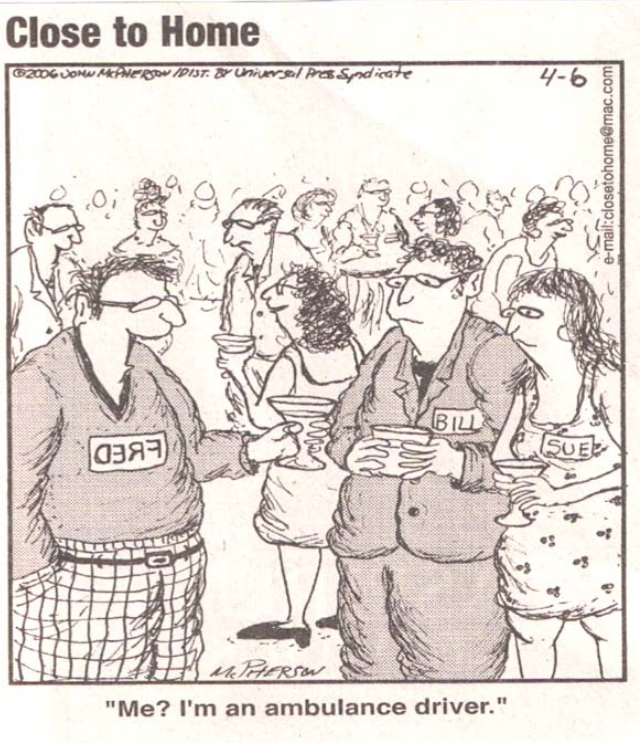
THE RORRIM

THE FINAL ISSUE

SH prom theme announced

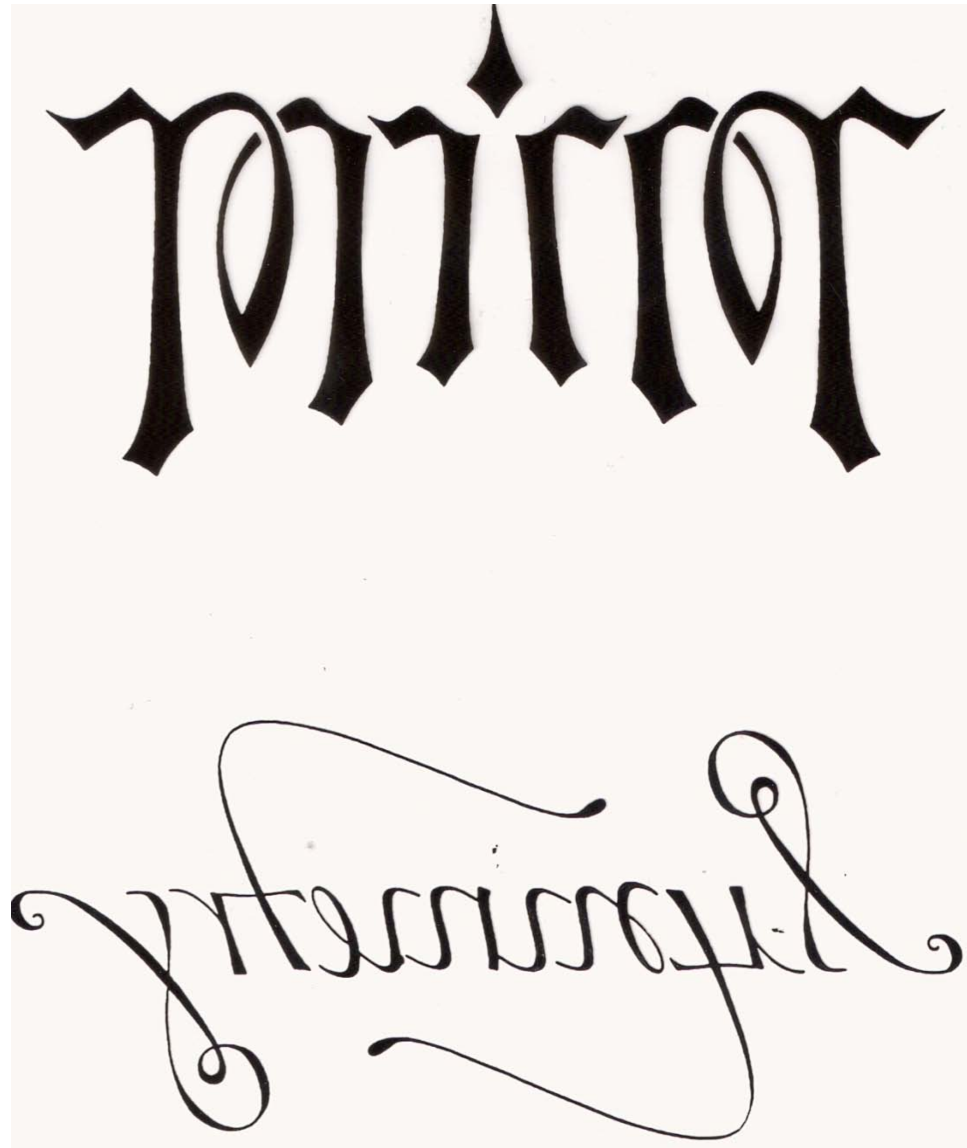
ittee announced this week that the theme for
tar Wars." The committee chose this feeling, it
e.
are just getting old. Our parents did it, and now
the whole idea of the junior prom," said Jane
committee

New look will freshen up old tired tradition

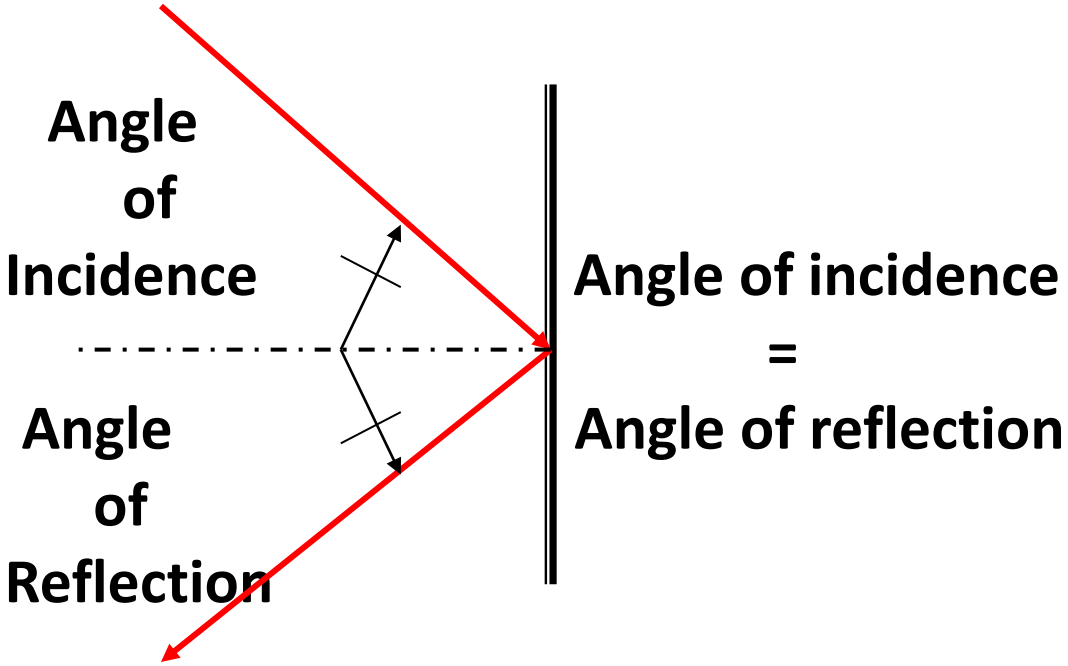


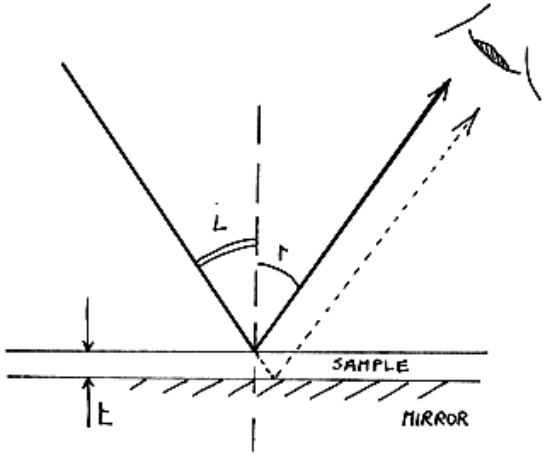
"Me? I'm an ambulance driver."


mirror
Symmetry


mirror
Symmetry

LAW OF REFLECTION

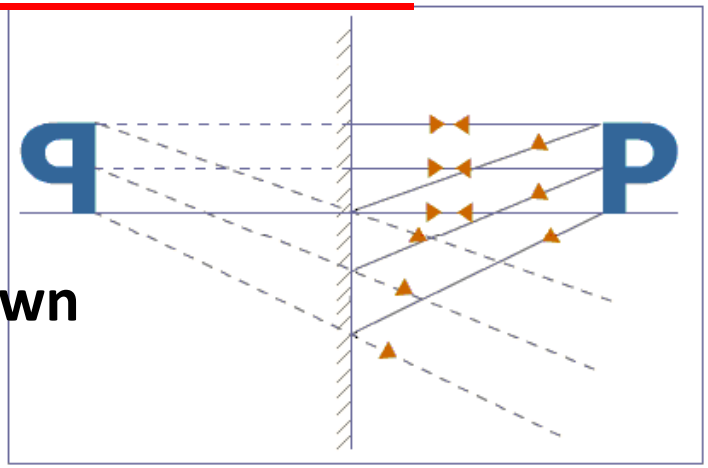




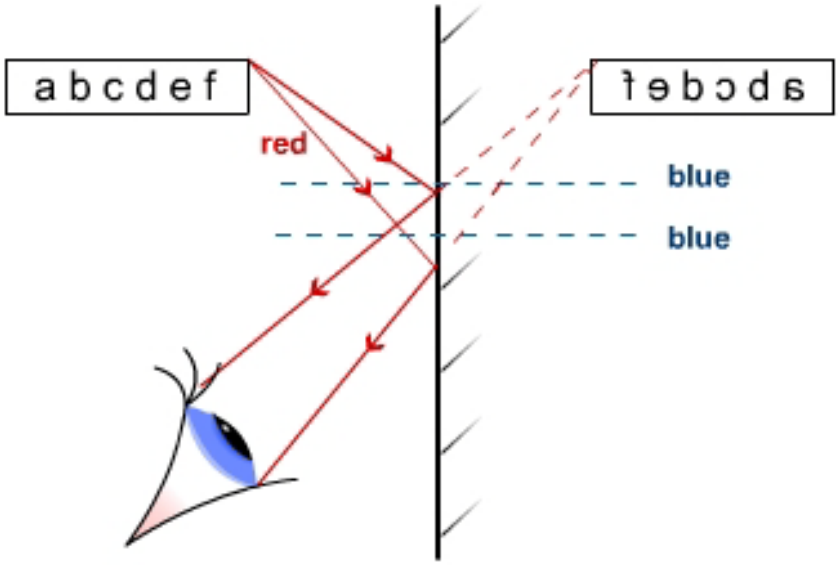
Angles measured with respect to ⊥ of reflecting surface & in front of mirror!!!

PLANE MIRROR-- IMAGE CHARACTERISTICS

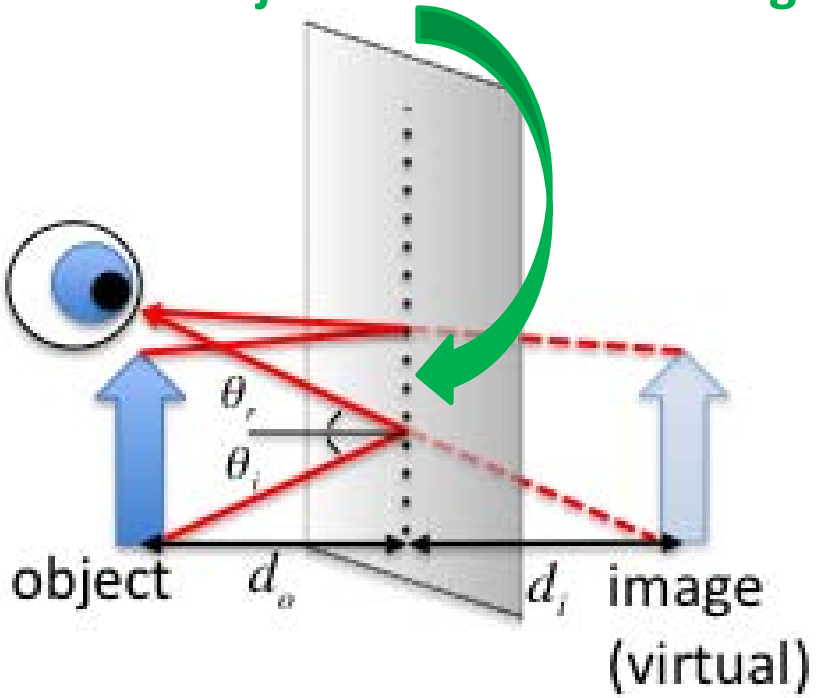
- Image SAME size
- Same distance behind mirror
- Upright
- Reversed—Flips Left to Right NOT up & down
- Virtual—not really there



NOTE: only extrapolate reflected ray to find image location & light RAY travels from OBJ to EYE



Note: Mirror must be at least ½ size of object to see entire image



Lab: Draw Your Face & Images, Images, Images

Turn in Lab sheet with responses & drawings NO REPORT

- **<u>Draw Your Face:</u>**
  - Using Visa-Vis marker draw your face on ½ of mirror & partner's face on other ½. ***Be accurate*** not artistic!!
  - Take measurements of face, compare to drawing & find ratio
    - Keep eyes open to keep to scale as much as possible
    - Indicate Pupils, center of ears, length of face (hairline to chin)
  - Determine what happens to the image & it's relative size as you & mirror move apart

Lab: Draw Your Face & Images, Images, Images

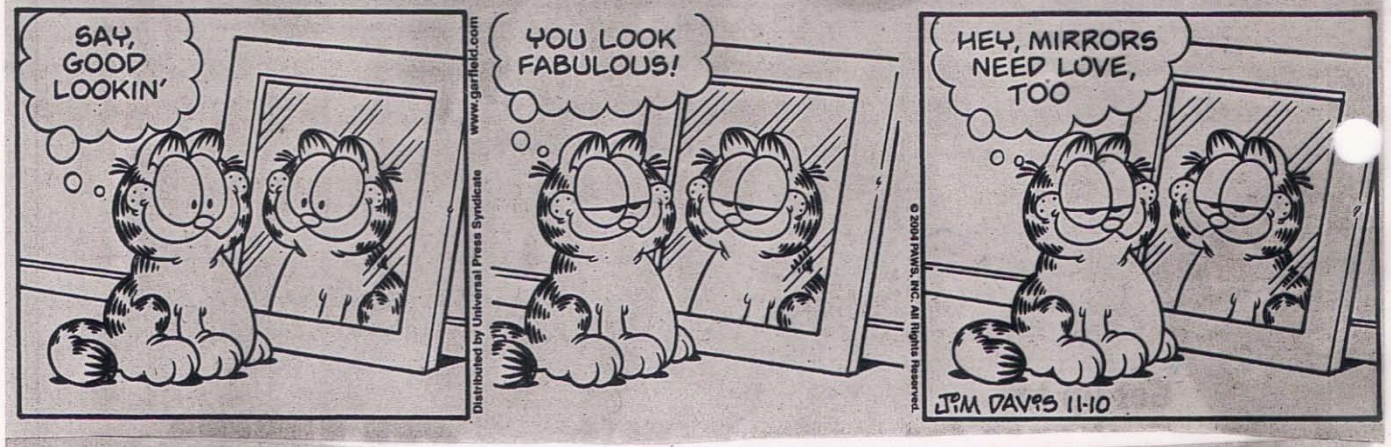
Images, Images, Images

Part 1

- Place plane mirror on supports in middle of paper & place upright pencil = "**object**" in front of mirror & determine image location behind mirror with 2nd pencil
  - Look at from all different angles until both agree
- Draw location of obj, image, & eye at angle to image
- Draw optical diagram: Draw in solid lines = true light path from object to eye in front of mirror & dashed lines = path light appears to take from image to eye behind mirror (light can't travel through opaque mirror)
- Draw dashed ⊥ line to mirror between lines going from eye to object and measure θ's and distances from image & object to mirror

Part 2

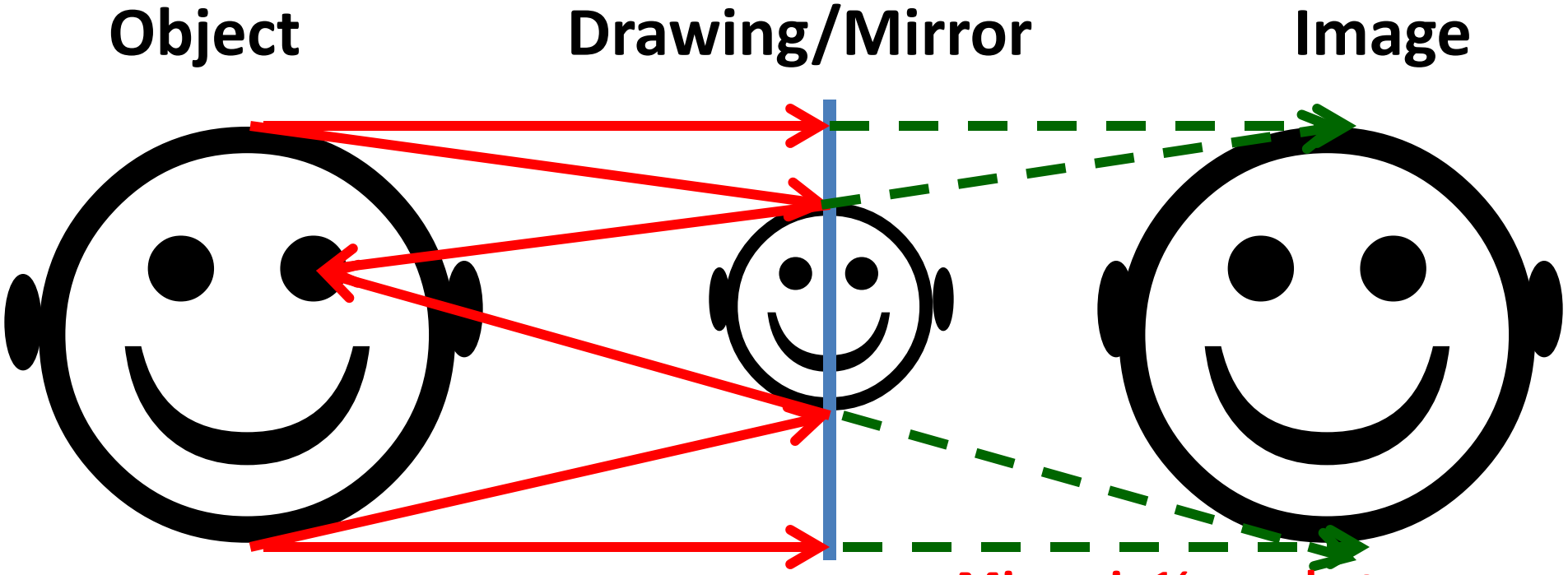
- Set 2 mirrors ⊥ to each other with pencil midway between. Outline location of mirrors, pencil, eye & images
- Decrease angle until see another full image, record angle & repeat until for at least 5 angles
- Draw geometrical diagram as in part 1 for one of the images. Record measurements of distances & angles



lagar the Horrible

Wizard of id

Post Lab: Draw Your Face



Ratio is 2:1 for object & drawing because Mirror is ½ way between

Size of the image inside mirror Decreased as you moved apart

What happened to the Size of Image relative to face drawing?

Stays same-Image fits drawn face because as back up both drawn face & image get smaller by same amount so always 2:1 ratio

In order to see your entire body, you would need what size of a mirror?

Mirror must be ½ height of object—can't just back up

Images, Images, Images

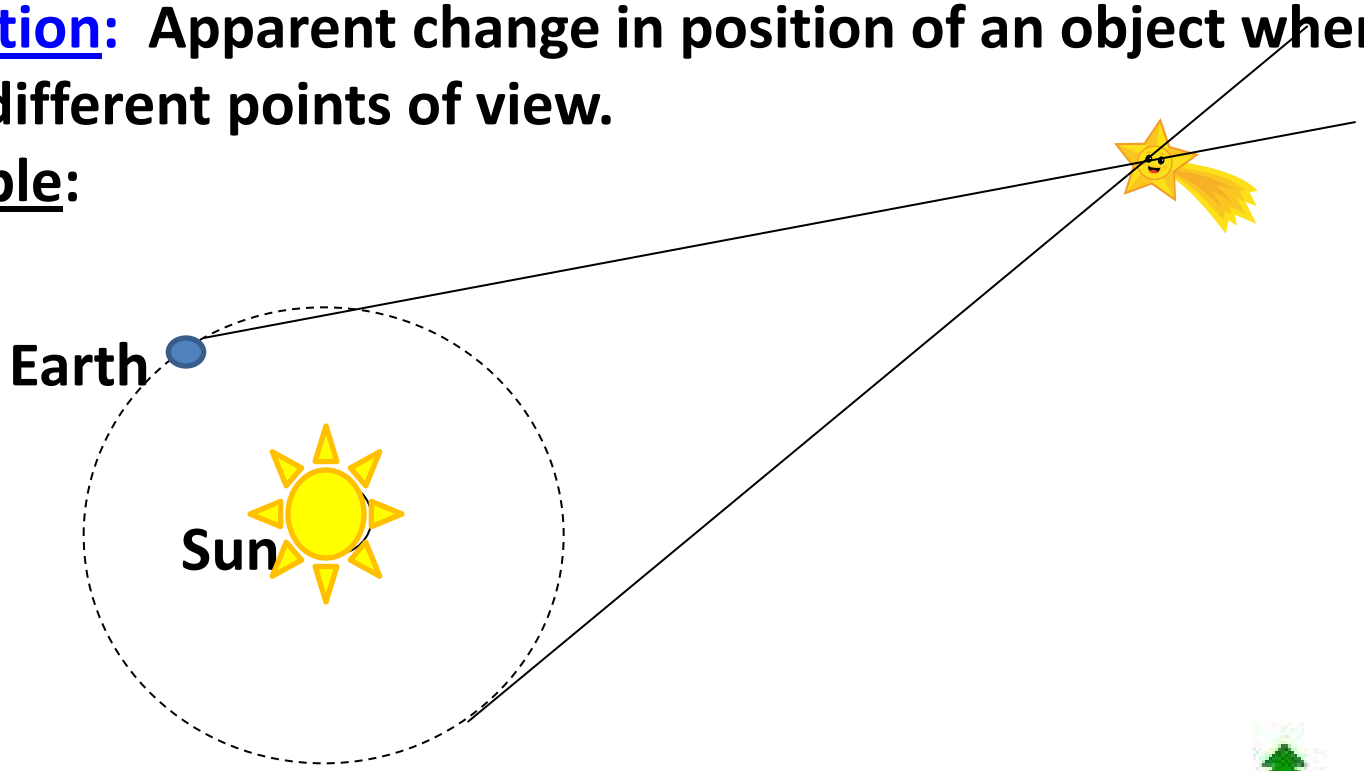
Part 1: Incident θ = reflected θ, distance in front = distance behind

Part 2: Kaleidoscope equation: $(360^\circ/\theta) - 1 = \#$ images seen

PARALLAX

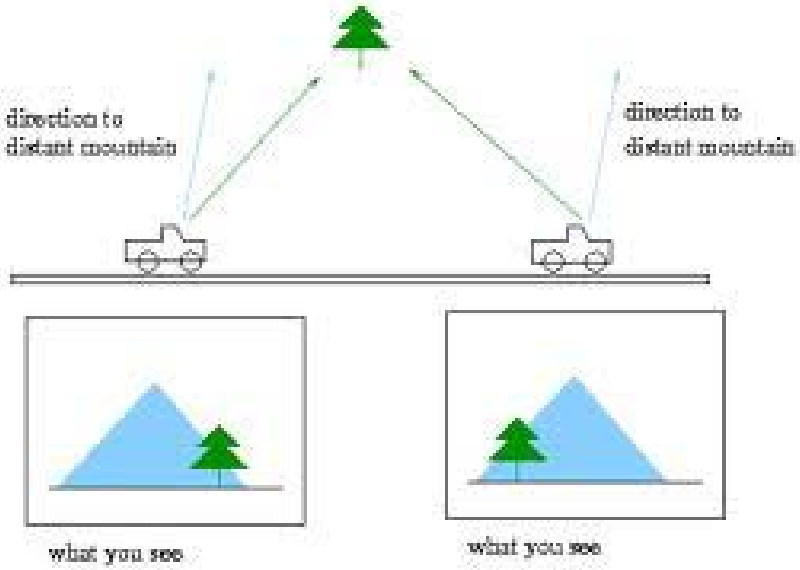
Definition: Apparent change in position of an object when viewed from different points of view.

Example:

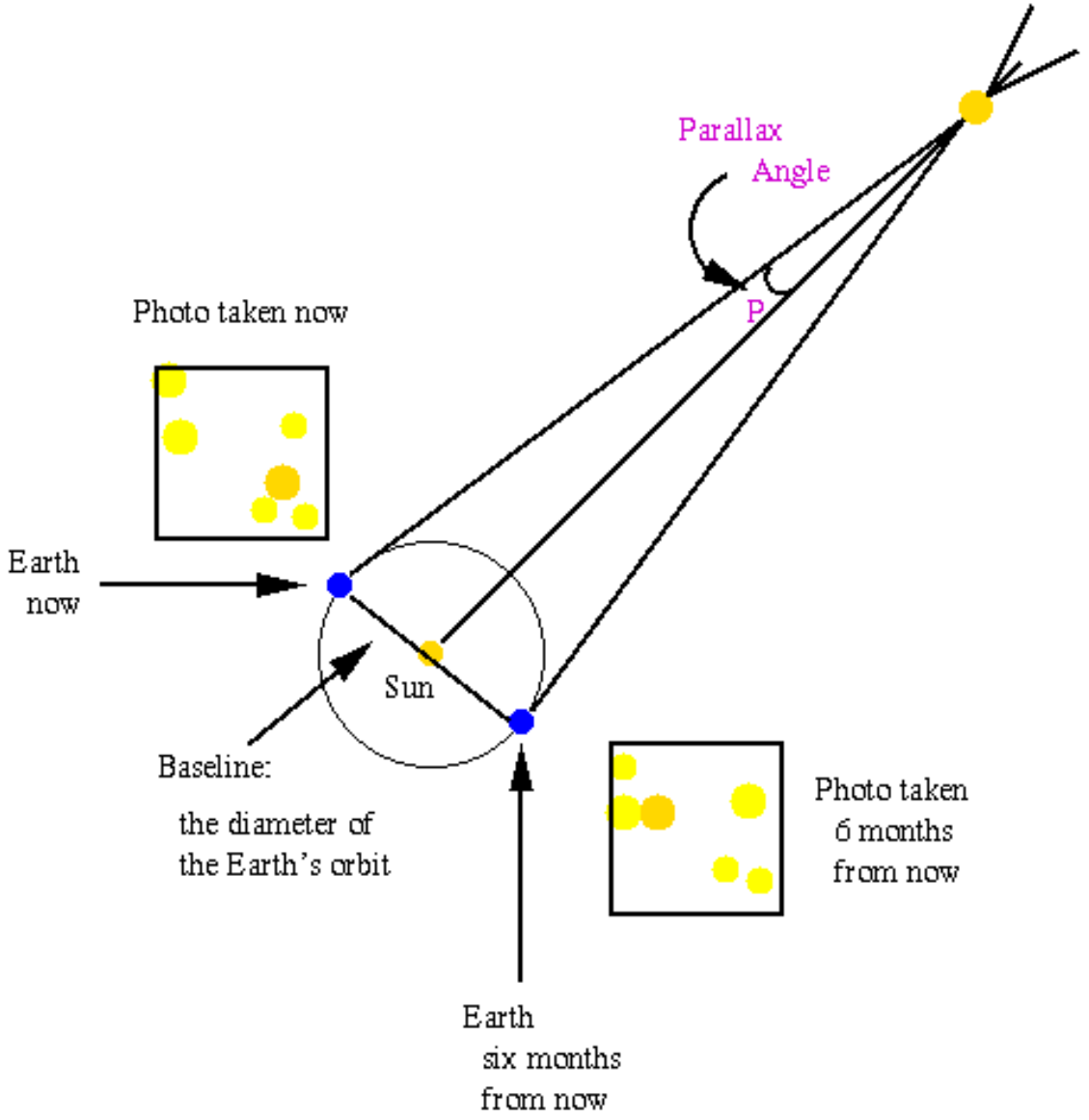


Uses:

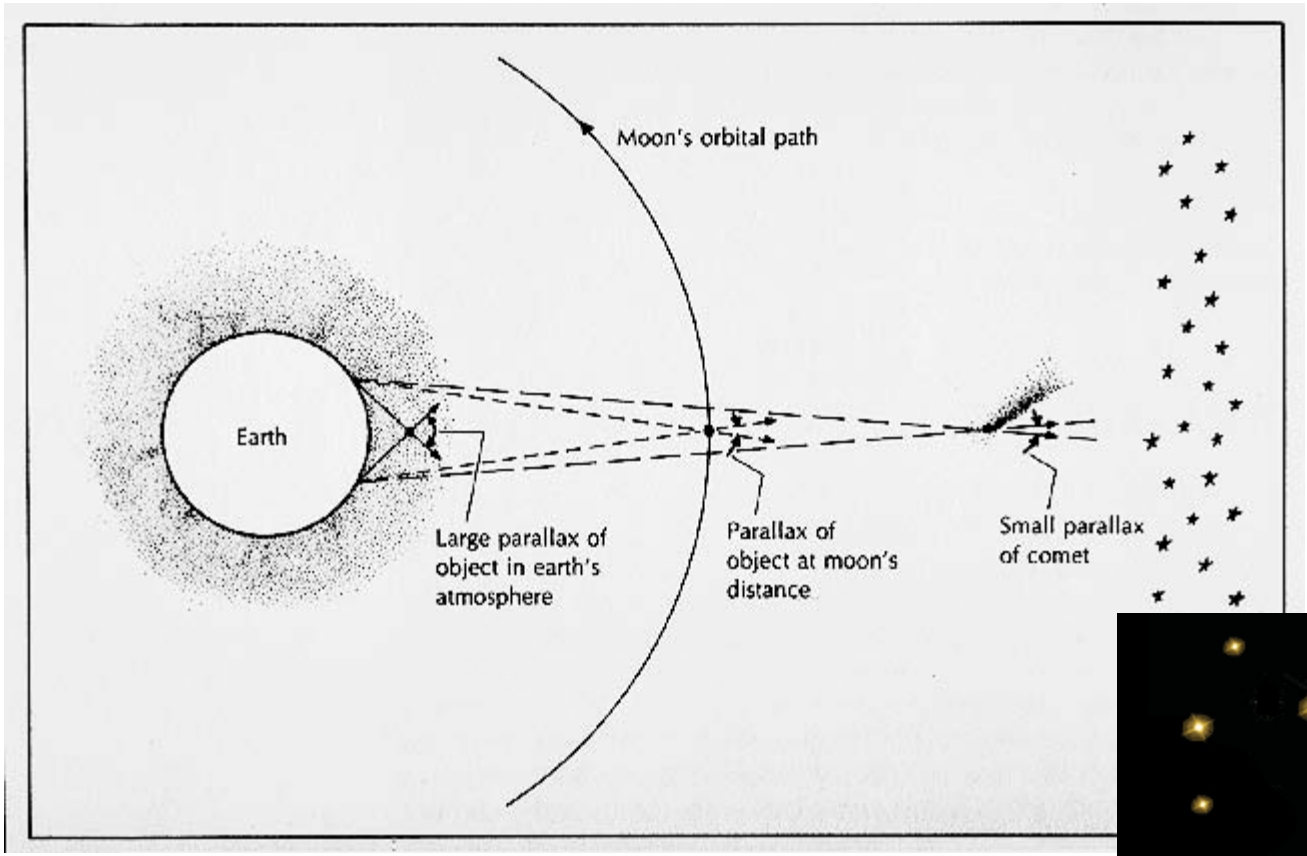
- Astronomy
- Eyes
- Binoculars
- 3DDD glasses & movies
- Surveying
- Navigation
- Sports
- Light lab

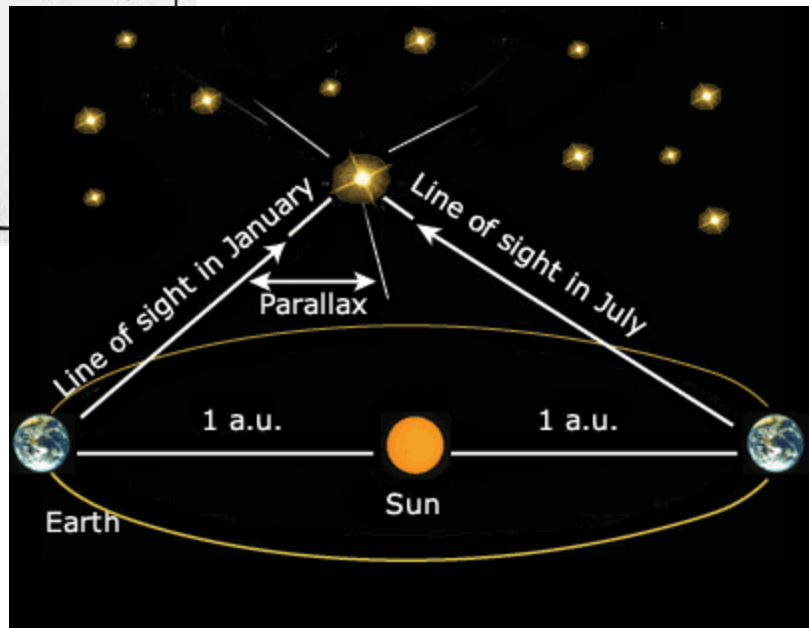


Determine distance by Parallax: Use geometry of right Triangles



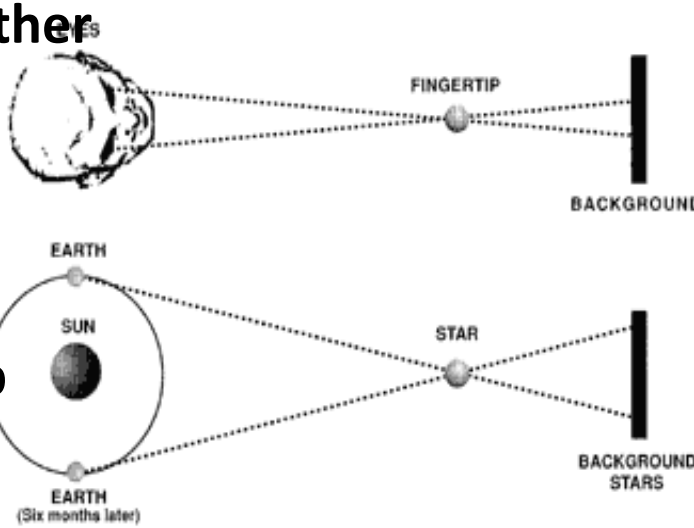
- Closer objects have bigger parallax angle & shift more compared to more distant objects

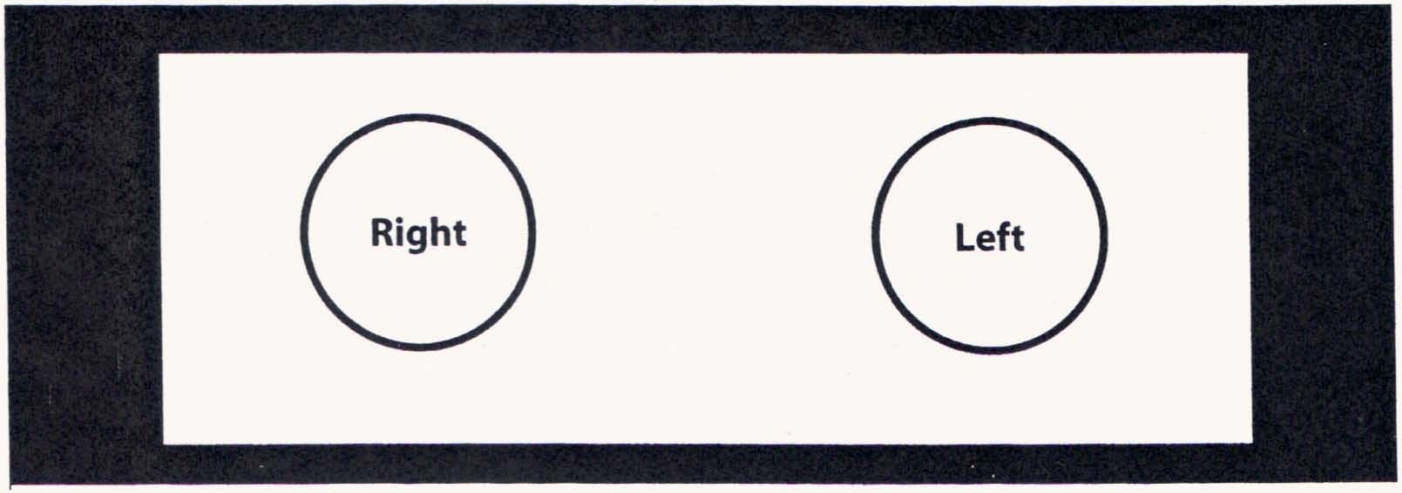




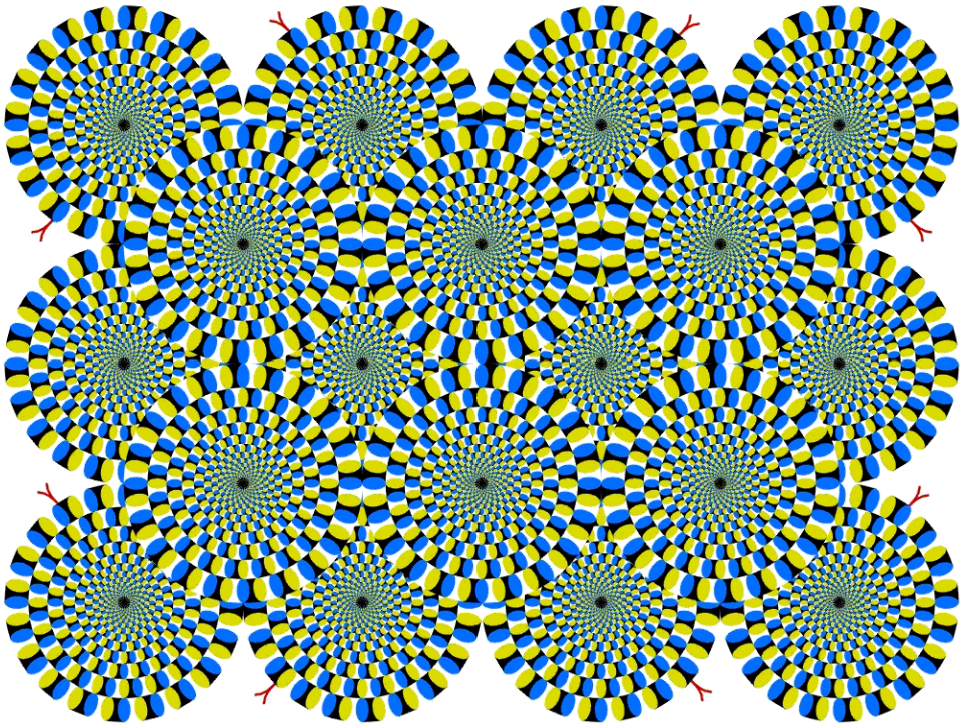
Parallax Demos

- Hold index finger horizontally out at arms length & look at distant object
  - Should see two fingers
- Now bring other index finger at arms length SLOWLY horizontally towards other one.
  - Should see Vienna finger sausage between index fingers
- Make triangle with both hands & center distant object between them. Then close one eye then other.
  - One that keeps object centered within triangle is dominant eye
- Start with parallax tubes apart then bring together
  - See one image
- Then focus sight up the inside of parallax tube
  - 2 images
- Then with 1 tube on dominant eye, put hand nearest other eye next to tube & slide hand up & down tube
  - See hole in hand
- Using film canister with opening up to eye look through hole at finger at arms length
  - Finger & distant object in focus because black reduces reflection so light comes in parallel, eliminates parallax & increases field of depth



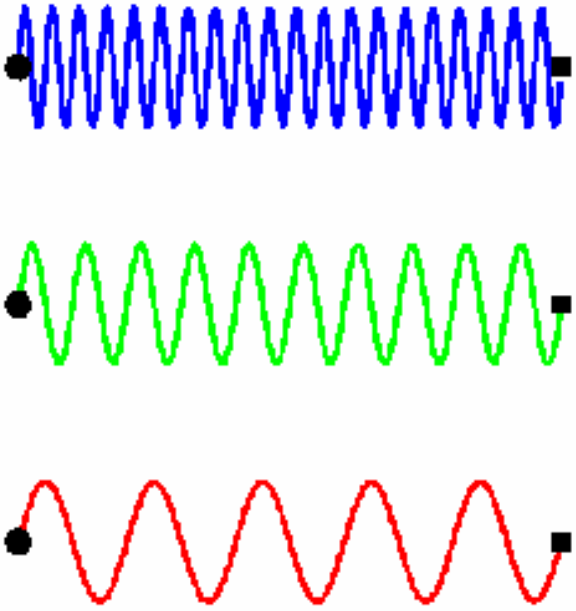


USE THIS STEREOGRAM to determine which eye is dominant. Looking at this diagram, cross your eyes slightly until three circles appear. The word you read in the center circle indicates your dominant eye. *ASTRONOMY:* ROEN KELLY



- **Use peripheral vision like looking past circles then fix sight on one circle**
- **circles appear to rotate using peripheral but really not moving when fix sight on one circle**

ATMOSPHERIC PHENOMENA



► Scattering explains such phenomena as:

Blue skies	Blue moon
Red sunset	Blue Ridge mountains
Blue-green ocean	White clouds

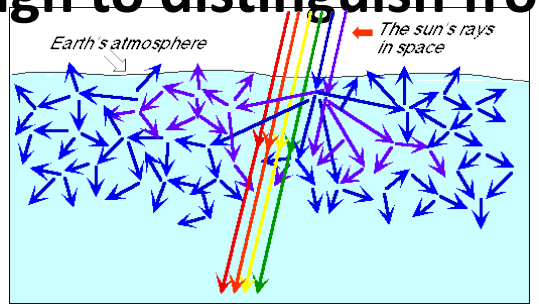
► Scattering ≈ $1/\lambda^4$

♦ Since blue = 475 nm so $1/475^4 = 2 \times 10^{-8}$ More scattered

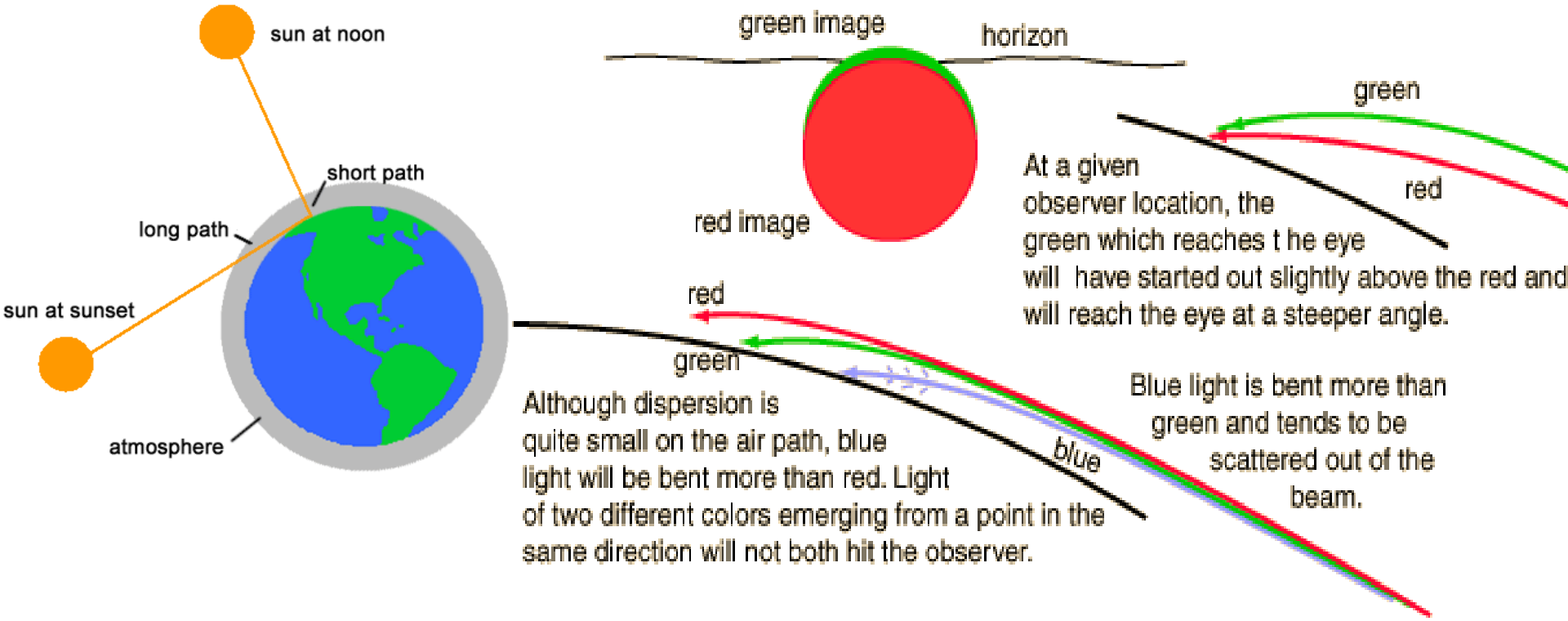
red = 650 nm so $1/650^4 = 5.6 \times 10^{-12}$ Less scattered

♦ In fact, blue is scattered 10x more than red!

♦ 98% air = O_2 & N_2 molecules scatter blue more since they are of comparable size to blue wavelength & that's what reaches our eye the most. (Sky is actually violet by cones in eye are red, green & blue so not sensitive enough to distinguish from blue)



♦ How do you explain red sunsets? White clouds? Blue moon?



Red Sunset: At sunset light has longer distance thru atmosphere to travel so all other λ scatter too much & only red λ left to reach eye.

"Green Flash": occurs just before the last part of the sun disappears from view at sunset is caused by the same atmospheric refraction and scattering effects which produce the red sunset.

♦ **How do you explain red sunsets? White clouds? Blue moon?**

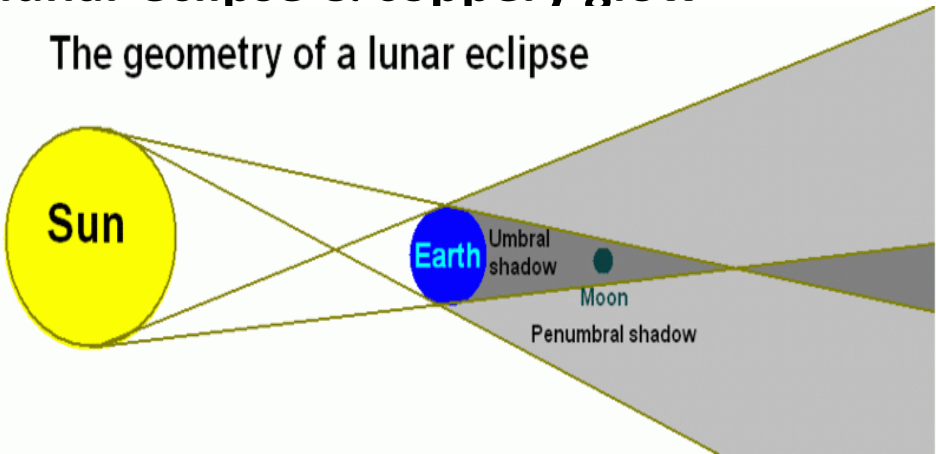
White clouds: equally scatter all λ so see white

Blue moon = *3rd full moon in a season that has four full moons or the second full moon in one calendar month. Extra full moon every 2-3 yrs.*

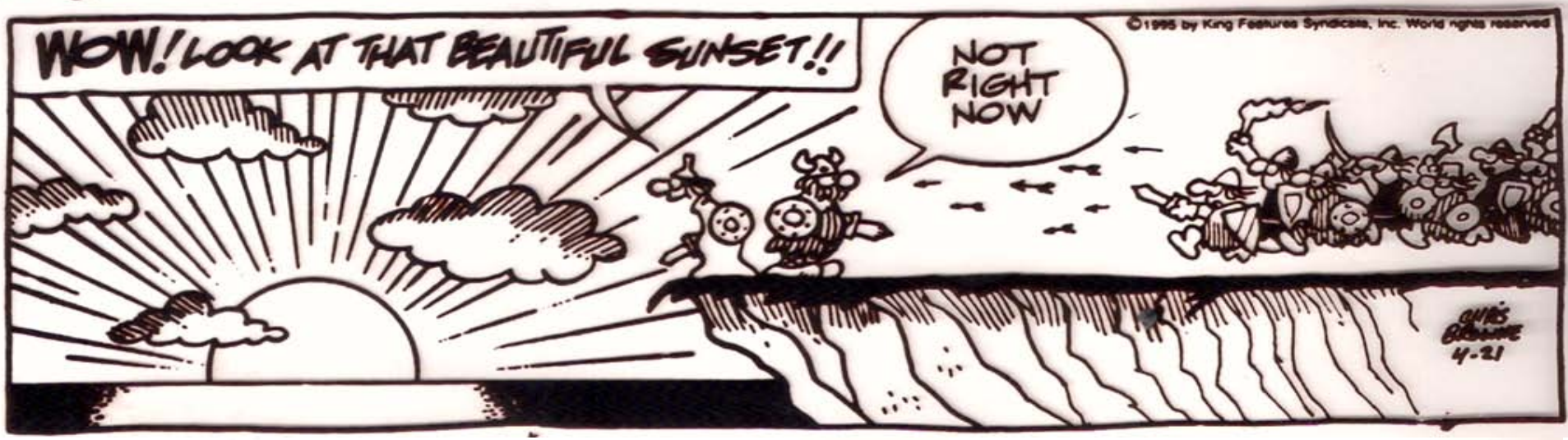
A bluish colored moon is caused by the Tyndall effect: the scattering of light by Large particles from volcanic ash or forest fires (colloidal particles in suspension) that are wider than red λ with no other size particles present so red λ scattered most & blue transmitted to shine on moon so appear blue = RARE

Red Moon: When dusty or Fire = Mixture of different particles causes blue & other λ to scatter more & transmits red because not fit in molecule size so see red moon

Copper moon: blue is scattered by N_2/O_2 molecules &remaining light is bent (refracted) into umbral shadow making lunar eclipse & coppery glow



Hagar the Horrible

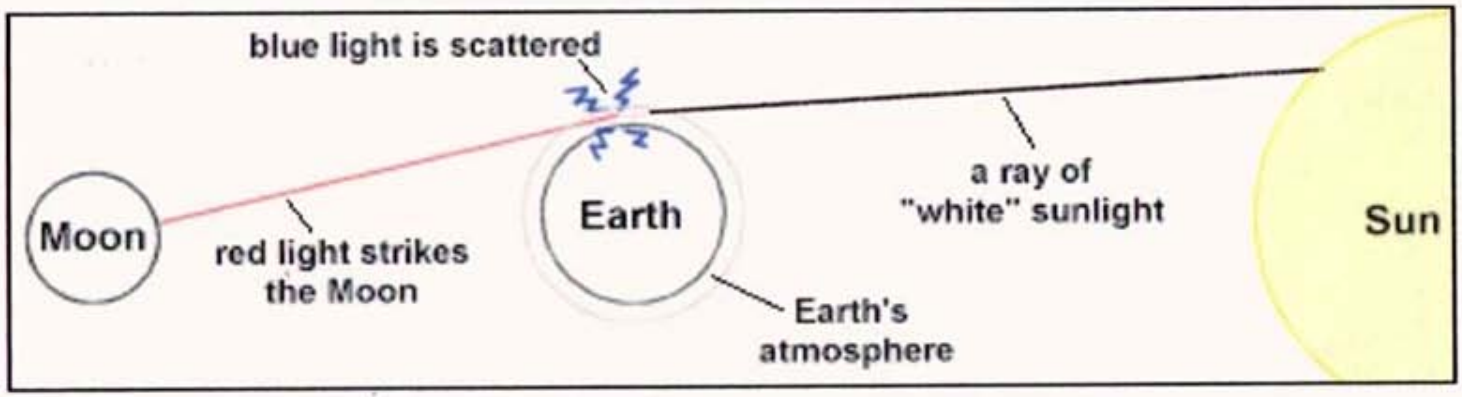


Calvin & Hobbes

ATMOSPHERIC PHENOMENA

Scattering ≈ $1/\lambda^4$ explains blue sky, red sunset, blue moon, white clouds, etc.

Why isn't the moon totally dark when Earth gets between it and the sun? It's because of Earth's atmosphere. (continued below)



White light from the Sun is a mixture of all the colors of the rainbow. When a ray of "white" sunlight passes at grazing incidence through Earth's atmosphere, molecules and aerosols in the air scatter blue light in all directions (this is why the sky is blue). The remaining reddish light is bent (refracted) into Earth's umbral shadow zone, giving the eclipsed Moon a coppery glow. Copyright-free image credit: Tony Phillips.

RED and BLUE 3DDD

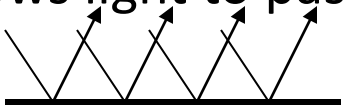
- Enhances parallax of eyes
- Eyes (cones) sensitive to red & blue
- λ's far apart in spectrum
- Must be looking at red & blue object

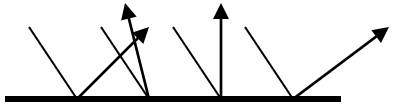
Demo: Red/Blue 3DDD glasses w/comics &

**Hollywood EX: Spy Kids 3D Game Over

LIGHT TERMINOLOGY

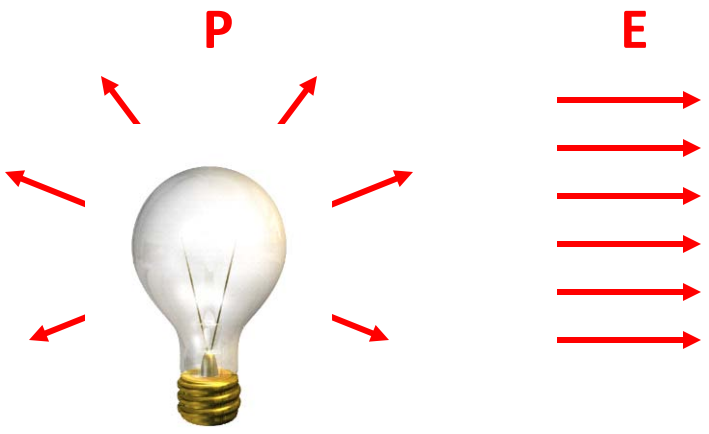
- **Opaque:** Light not pass thru
- **Translucent:** allows light pass thru but diffuse so not see thru
- **Transparent:** allows light to pass thru specular & see thru clearly

Specular:  all reflect same direction Ex. mirror

Diffuse :  reflect in different directions Ex. wood

- **Radiant Flux (Φ_e)-Watt (W):** Total Light Energy emitted per time (P = E/t)
- **Intensity (I) – candela (cd):** amount of light emitted from a point source
  Luminous flux (P) – lumens (lm): apparent light (radiant flux adjusted for eye perception & efficiency) emitted in all direction measured at d = 1m
- **Illuminance (E) – lux (lx) = lm/m²:** amount of light that hits a surface area at a distance = d

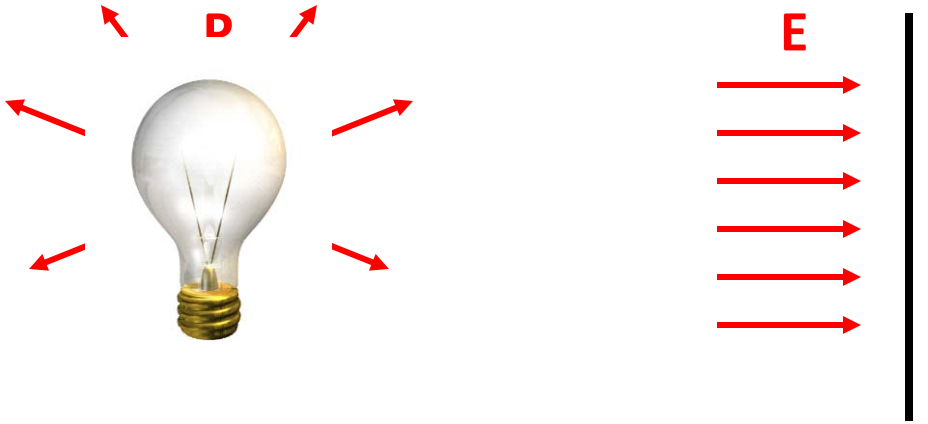
$$E = I/d^2 = P/4\pi d^2$$

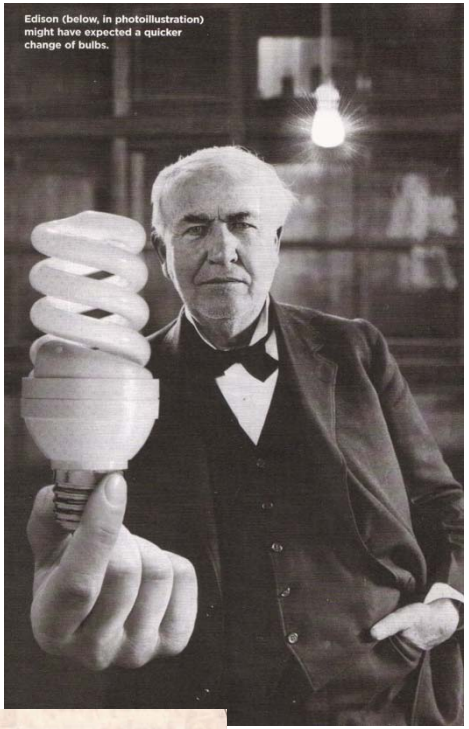


- **Inverse square law**
- **2 ways to increase illuminance:**
  1. **Brighter bulb (uses more energy)**
  2. **Move closer (less energy, inverse square)**

Example Problems: Illuminance

$$E = I/d^2 = P/4\pi d^2$$





#1: 150 W light bulb

P = 2275 lm

Calculate E at d = 3 m

$$E = I/d^2 = P/4\pi d^2 = \frac{2275\ lm}{4\pi(3m)^2} = 20.11\ lux$$

#2: I = 64 cd

Calculate E at d = 3 m

$$E = I/d^2 = \frac{64\ lm}{(3m)^2} = 7.1\ lux$$

CONVEX OR DIVERGING

Can ONLY make VIRTUAL images

http://www.youtube.com/watch?v=tlLeW1B9v4E&feature=relmfu

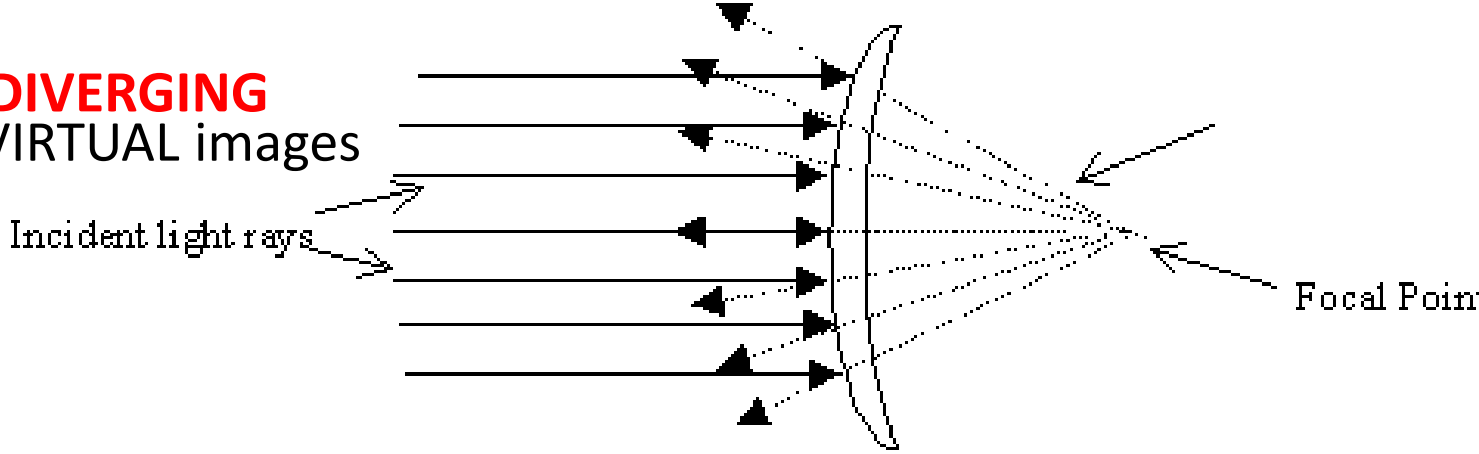


Figure 1a: A convex mirror diverges the reflected light rays so the image appears behind the mirror.

PARALLEL INCIDENT RAYS REFLECT THROUGH FOCAL PT ON CURVED MIRROR

CONCAVE OR CONVERGING

Can make REAL and VIRTUAL images

http://www.youtube.com/watch?v=YjFB6je1T9g&feature=player_embedded#!

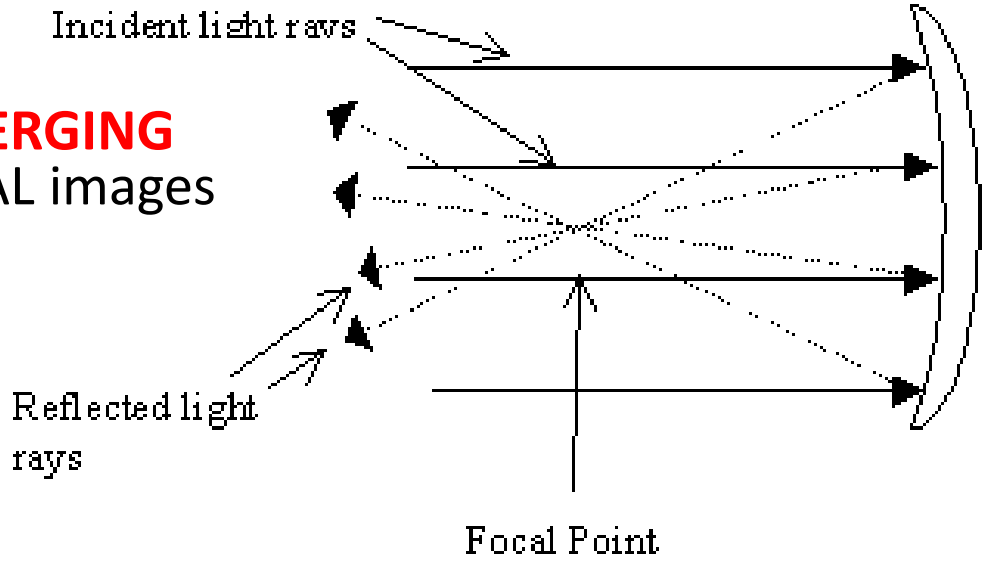


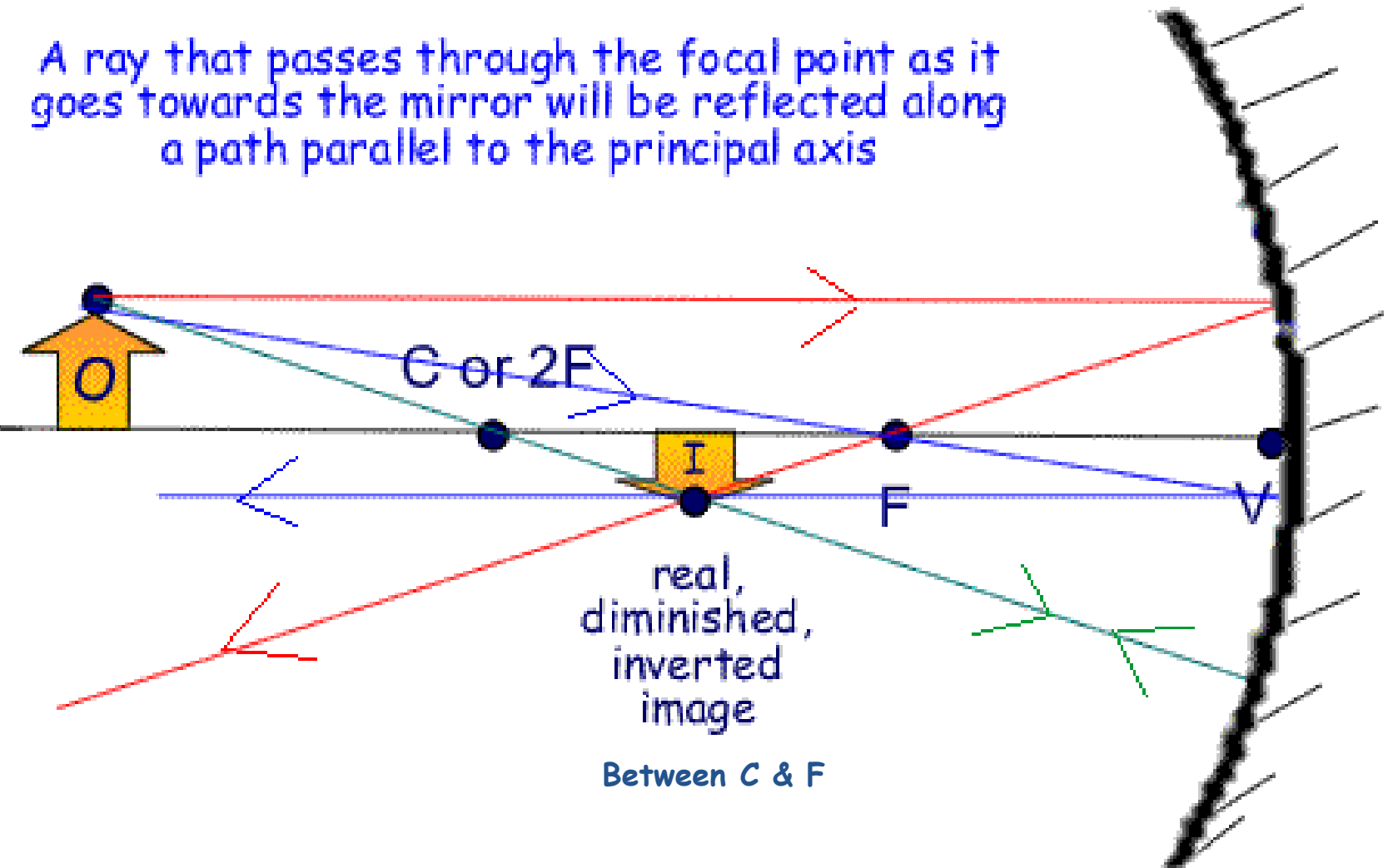
Figure 1b: A concave mirror converges the reflected light rays so an image may appear in front of the mirror.

Concave w/object beyond C

A ray travelling parallel to the principal axis passes through the focal point after reflection by the mirror

A ray that passes through the centre of curvature of the mirror is reflected back along its own path

A ray that passes through the focal point as it goes towards the mirror will be reflected along a path parallel to the principal axis



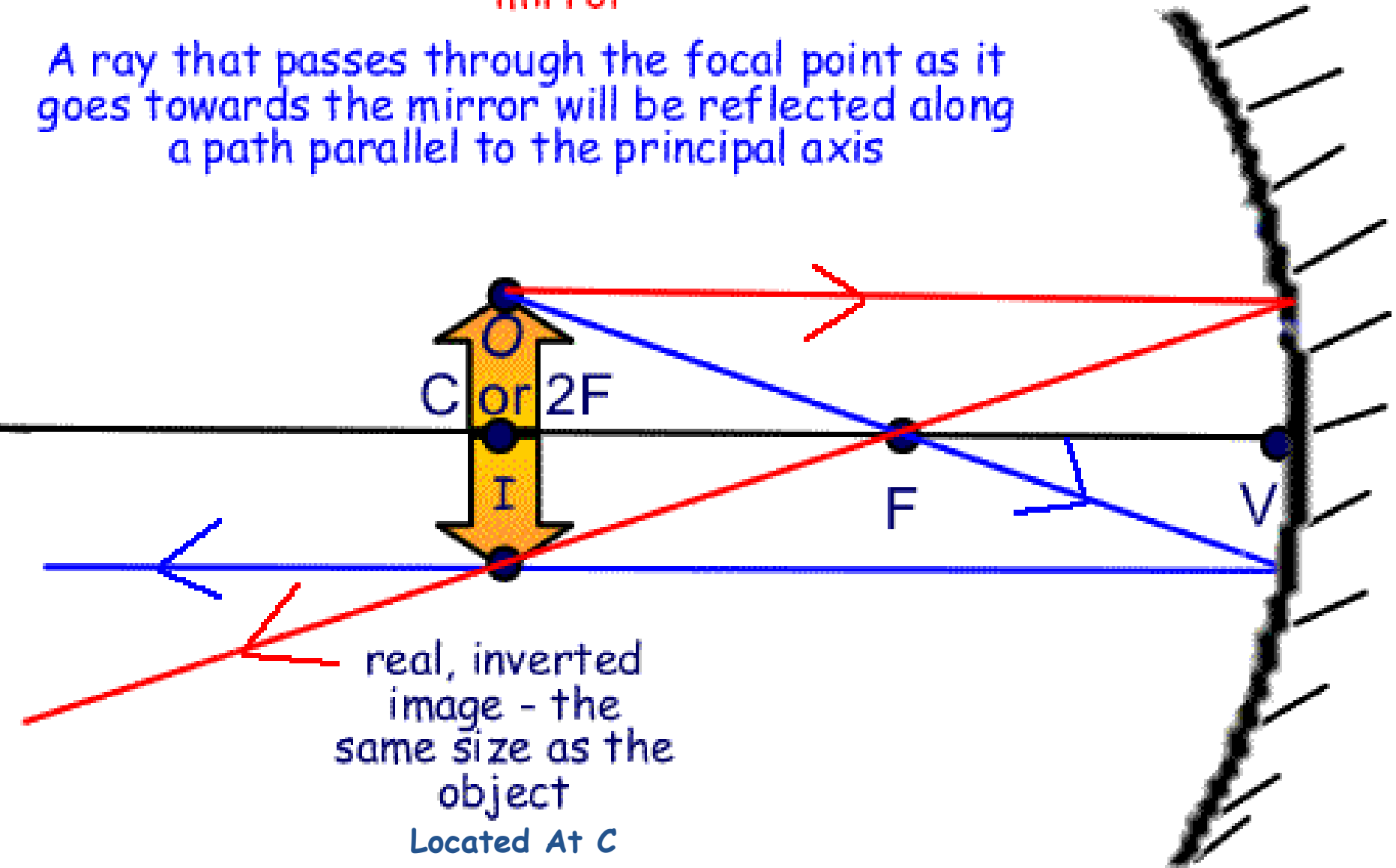
real, diminished, inverted image

Between C & F

Concave w/object at C

A ray travelling parallel to the principal axis passes through the focal point after reflection by the mirror

A ray that passes through the focal point as it goes towards the mirror will be reflected along a path parallel to the principal axis



real, inverted image - the same size as the object

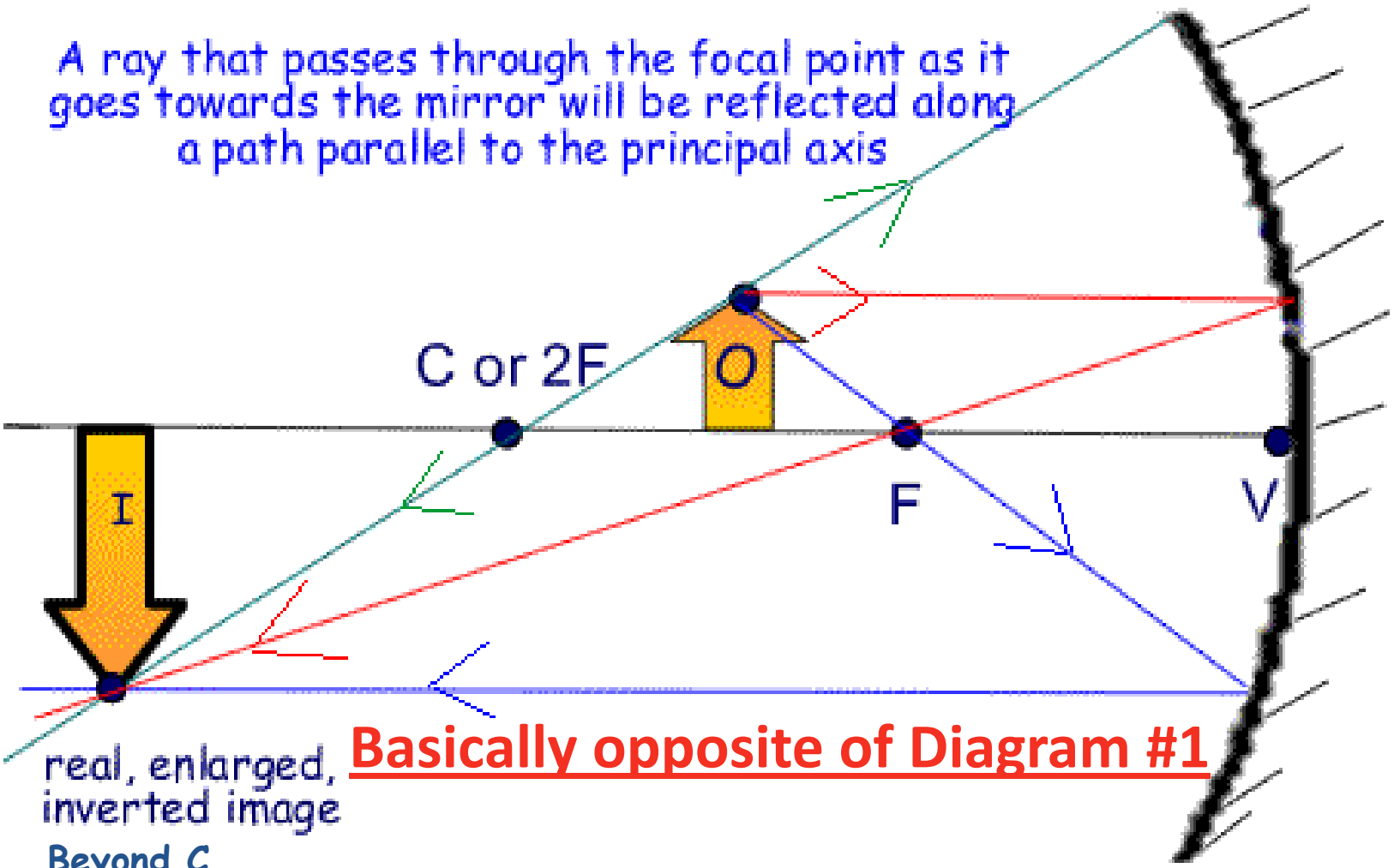
Located At C

Concave w/object between C & f

A ray travelling parallel to the principal axis passes through the focal point after reflection by the mirror

A ray that passes through the centre of curvature of the mirror is reflected back along its own path

A ray that passes through the focal point as it goes towards the mirror will be reflected along a path parallel to the principal axis



real, enlarged, inverted image

Beyond C

Basically opposite of Diagram #1

Concave w/Obj at F

A ray travelling parallel to the principal axis passes through the focal point after reflection by the mirror

A ray that passes through the centre of curvature of the mirror is reflected back along its own path

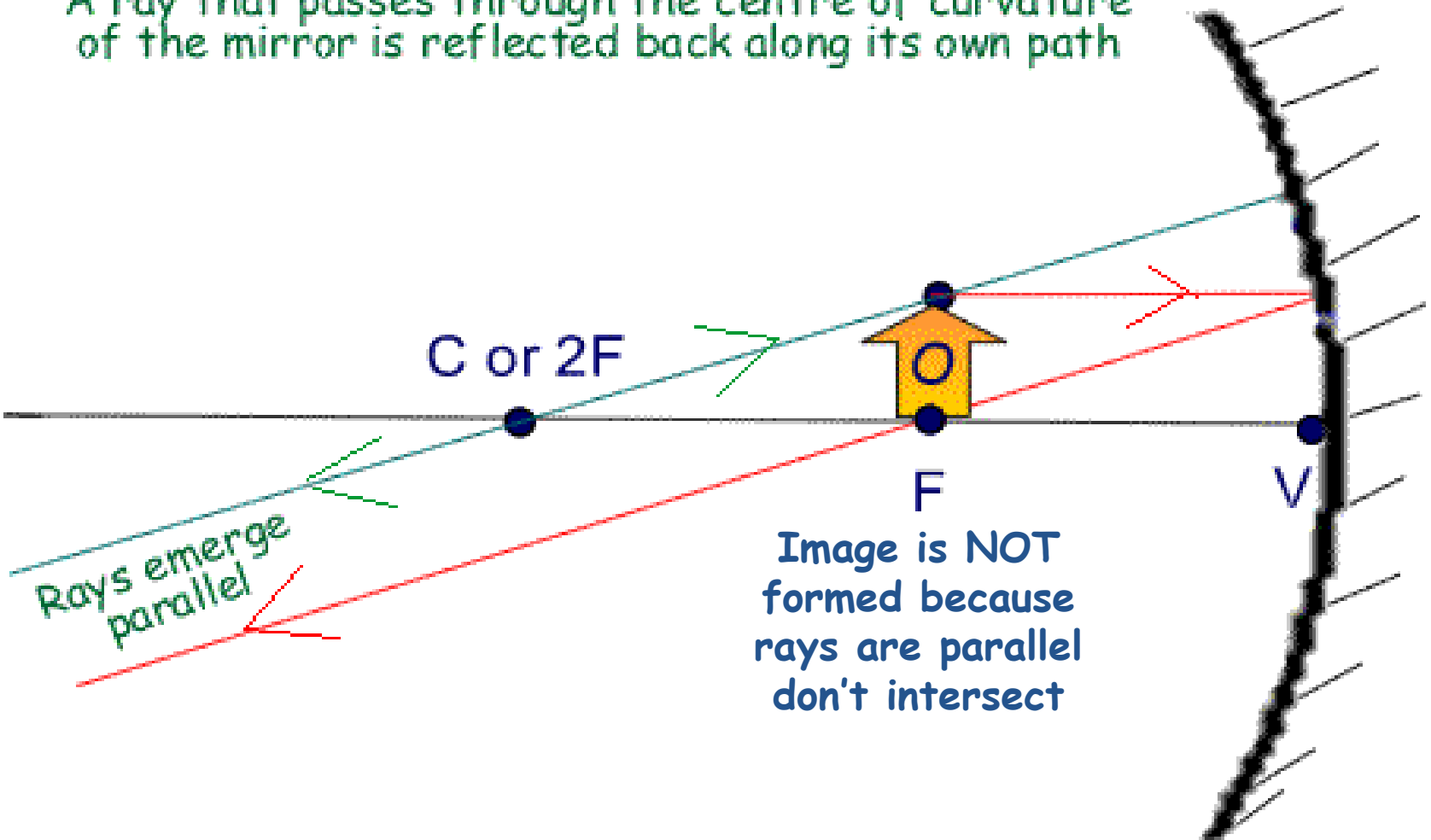
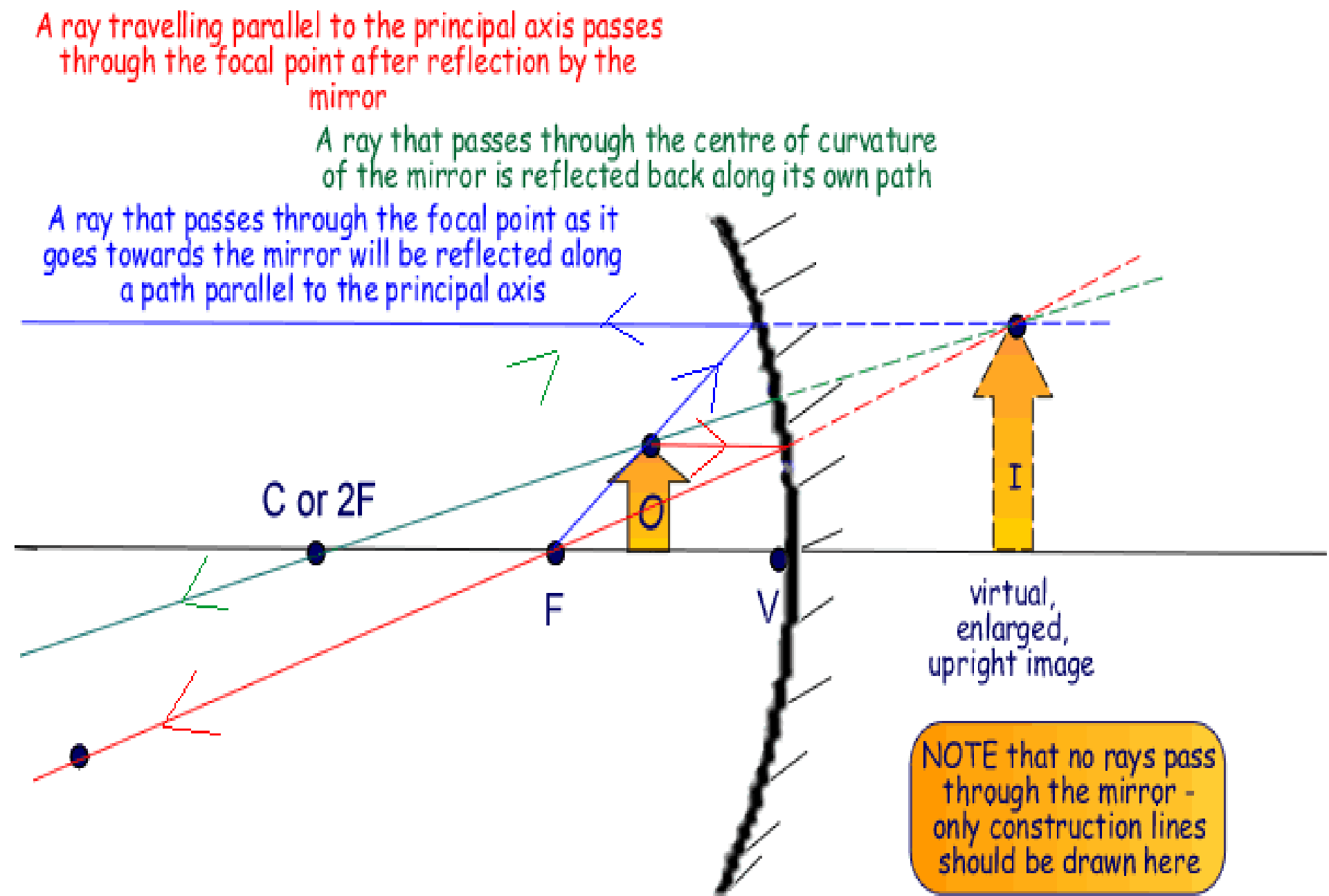
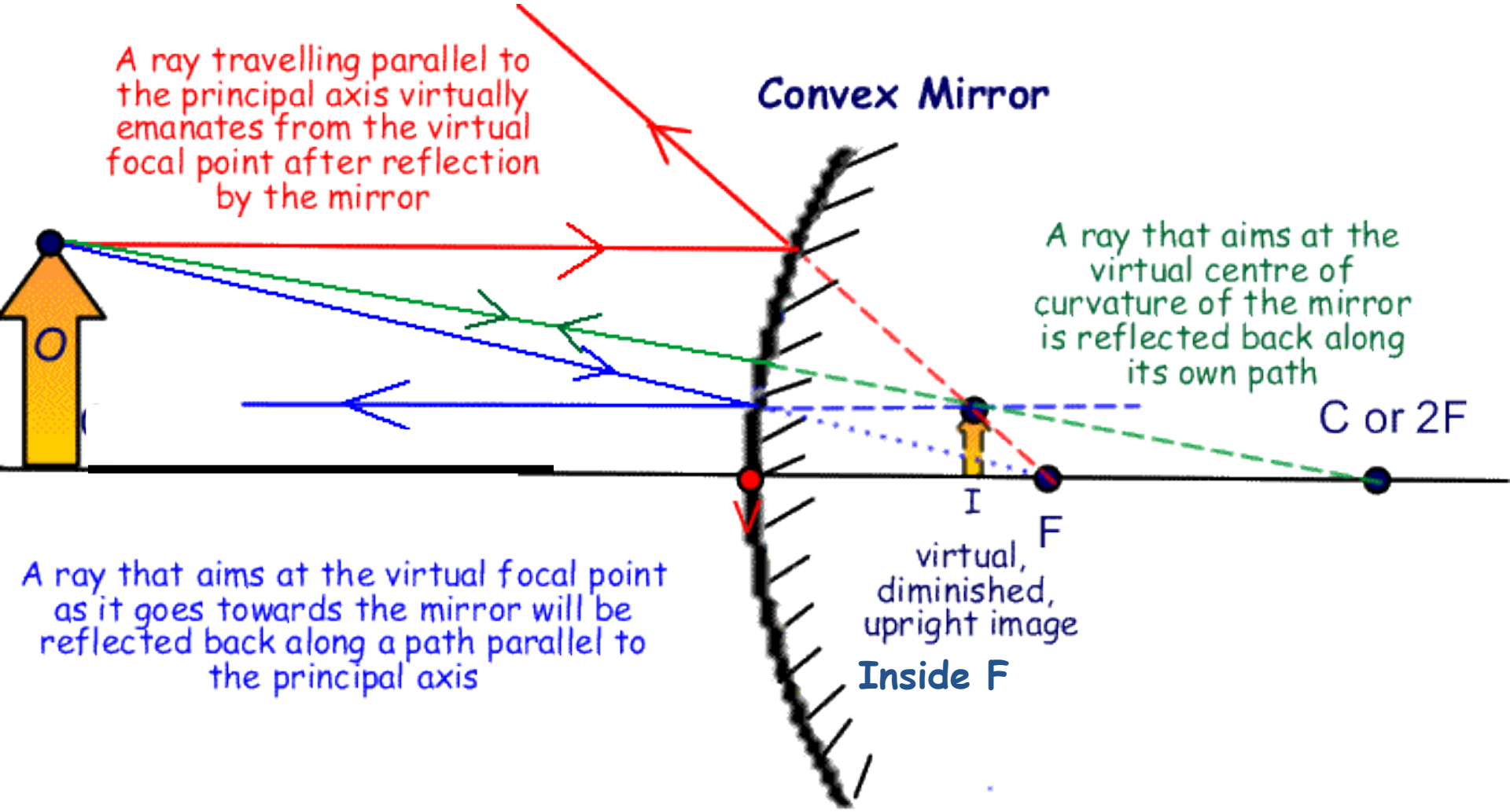


Image is NOT formed because rays are parallel don't intersect

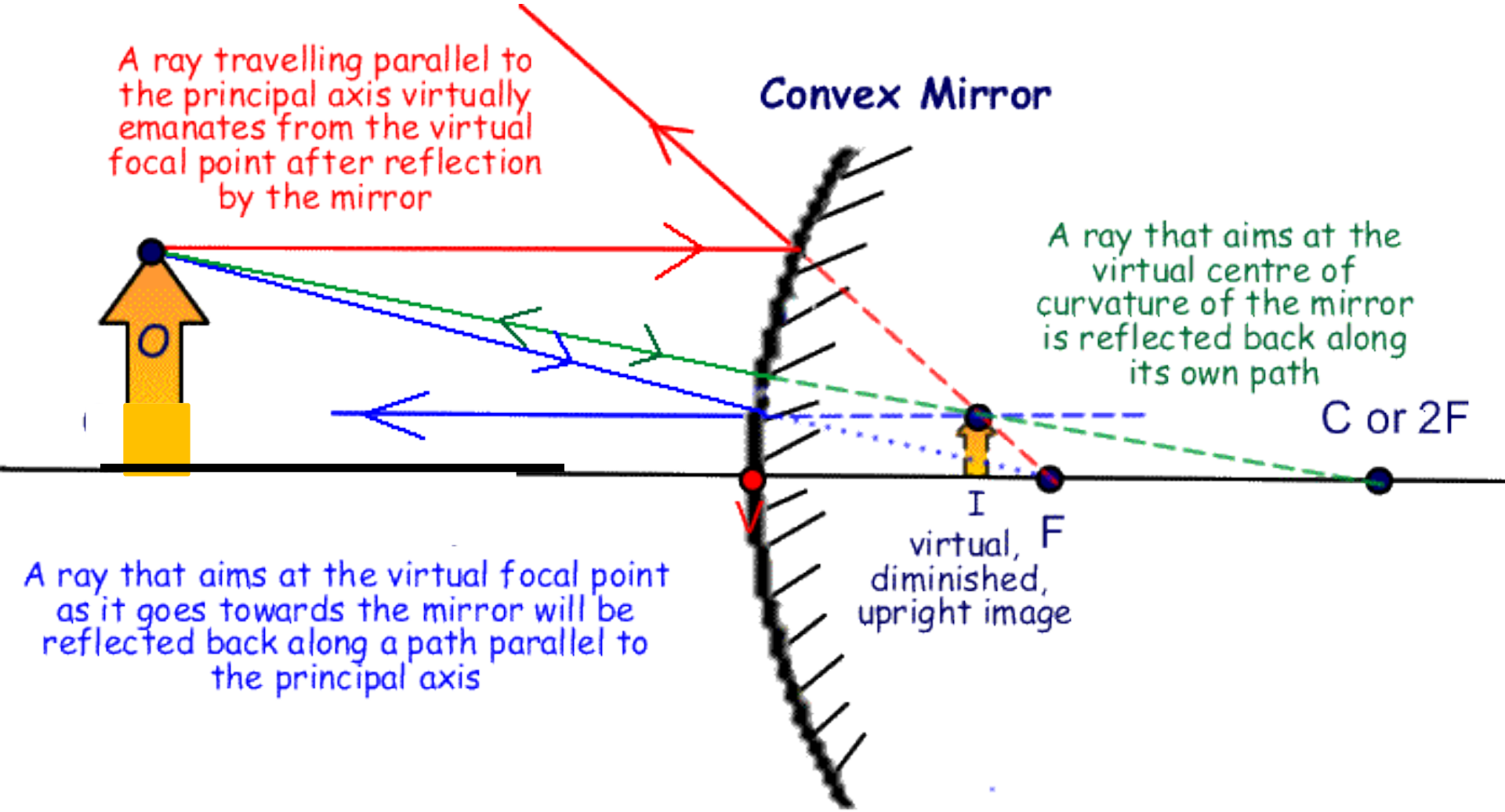
Concave w/Obj closer than F



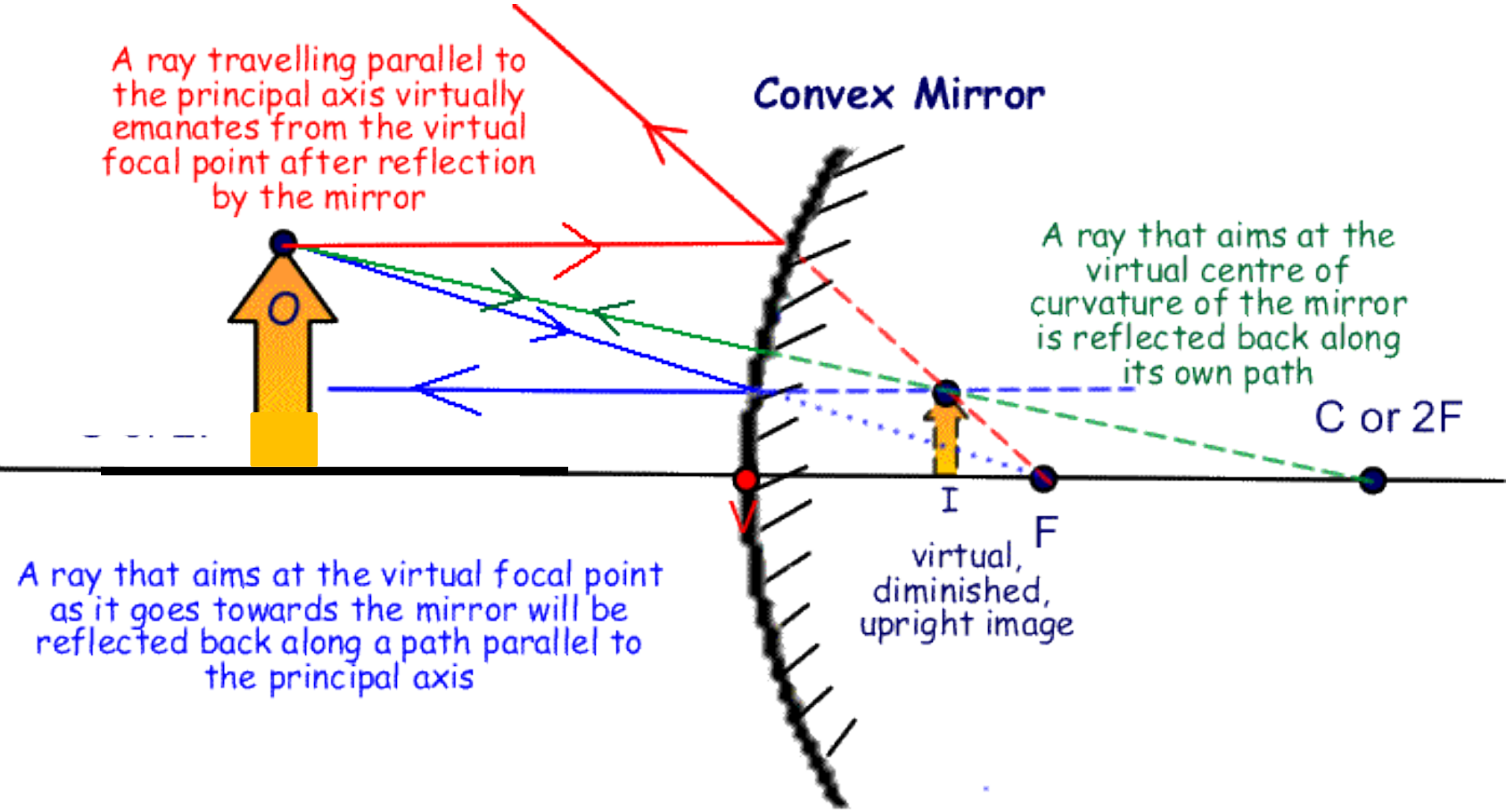
Convex w/obj Beyond Far Away



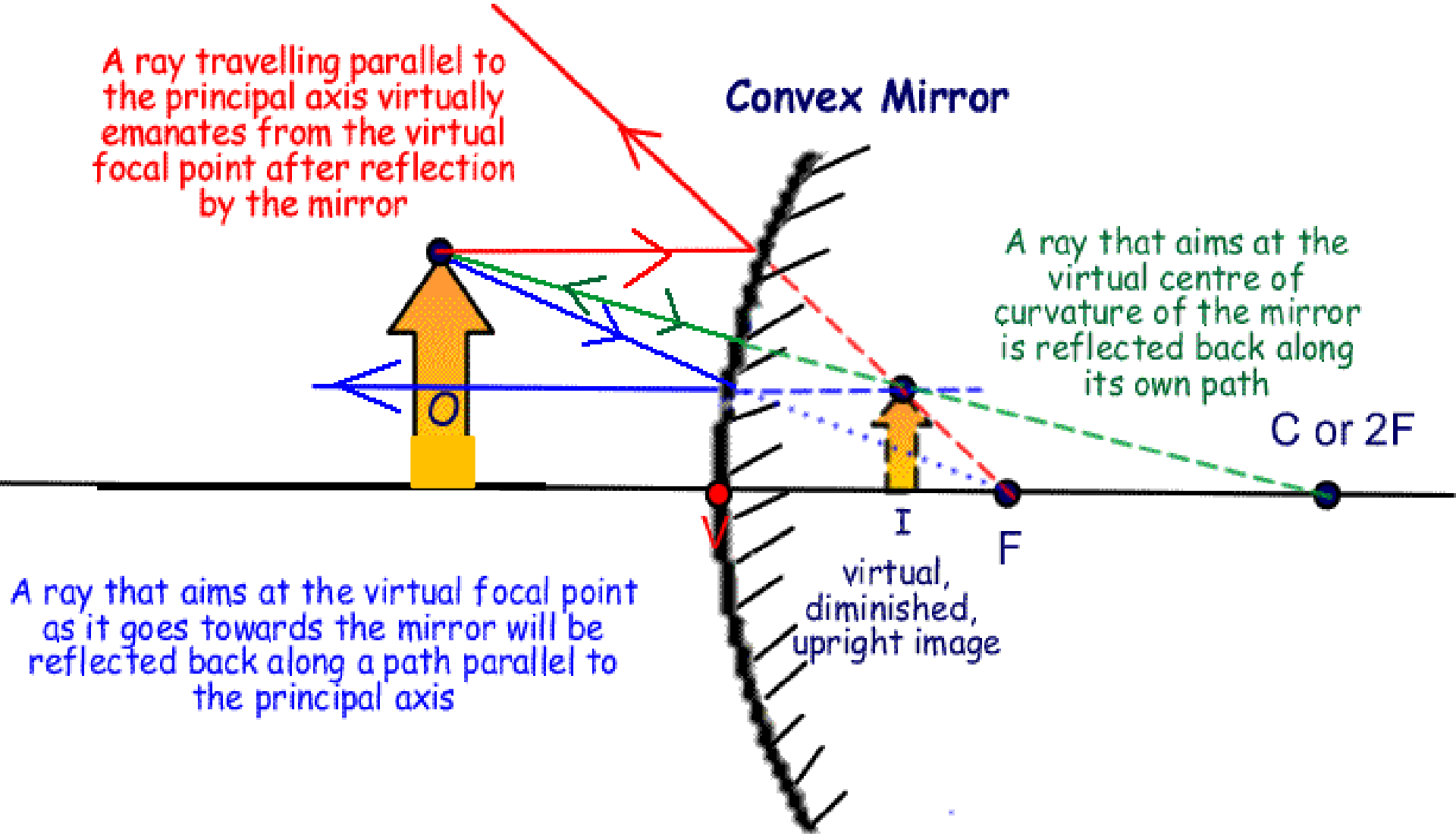
Convex w/Obj Closer



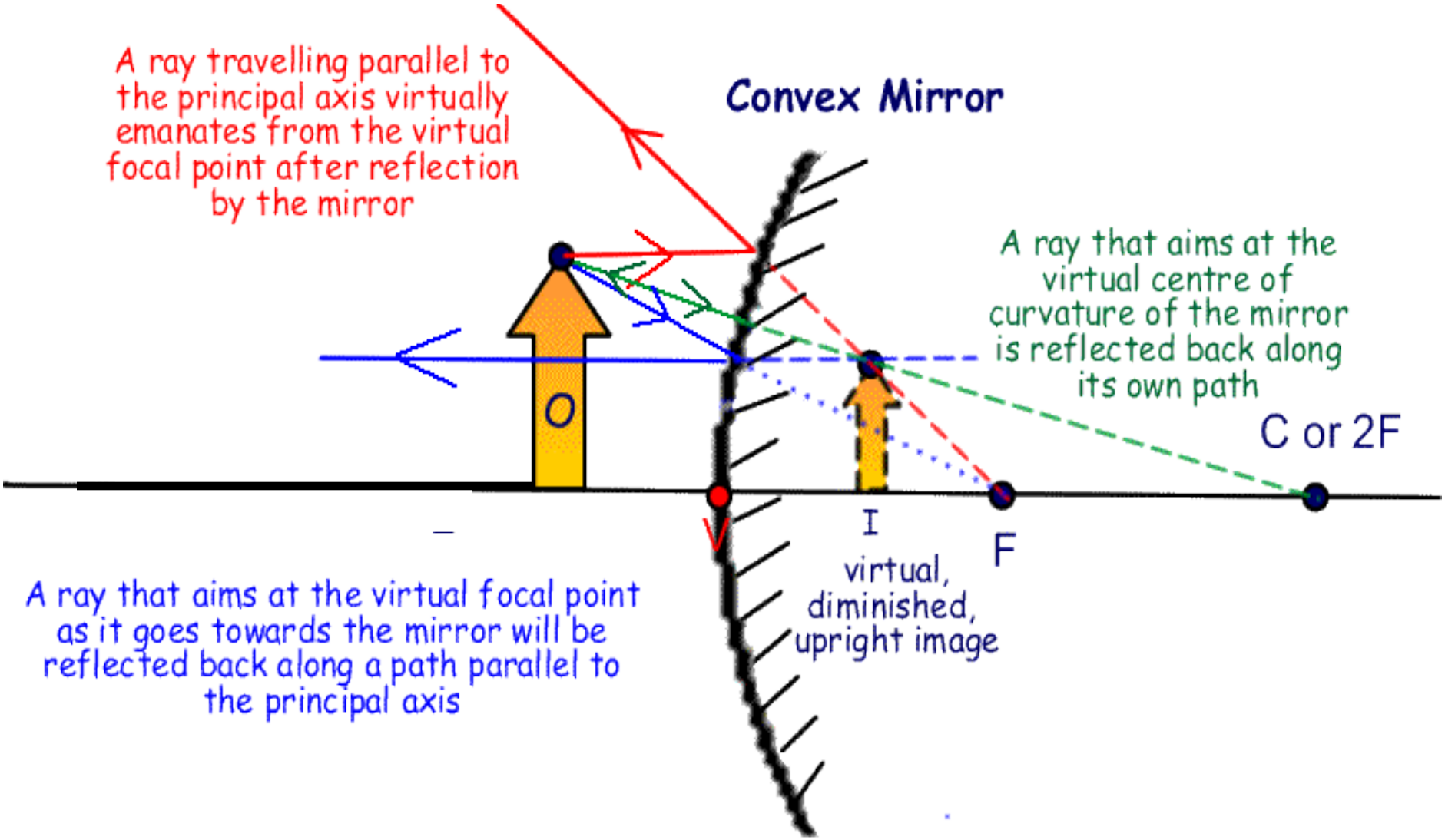
Convex w/Obj still closer



You Guessed Convex w/Obj closer again



Convex w/obj Very Close



Mirror Equation:

$$\frac{1}{f} = \frac{1}{i} + \frac{1}{o}$$

Note:

+ i = real image in front of mirror (concave only)

- i = virtual image = appears behind mirror

Convex f = - # because behind mirror

Magnification:

$$m = \frac{-i}{o}$$

Note:

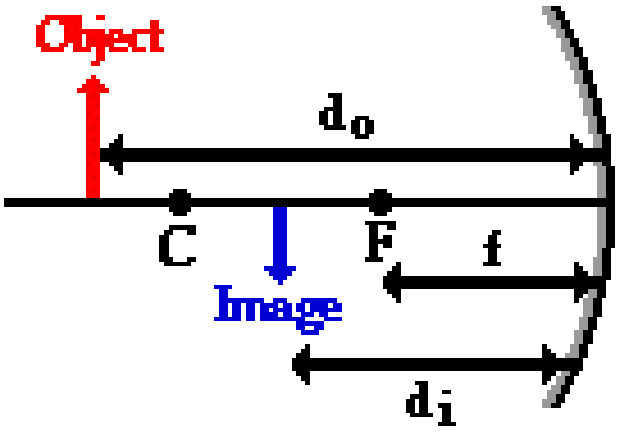
+ m = upright

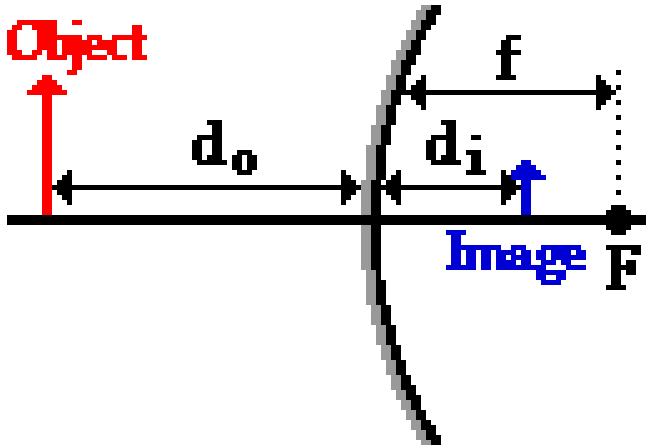
- m = inverted

m < 1 = smaller image

m = 1 = same size image

m > 1 = larger image

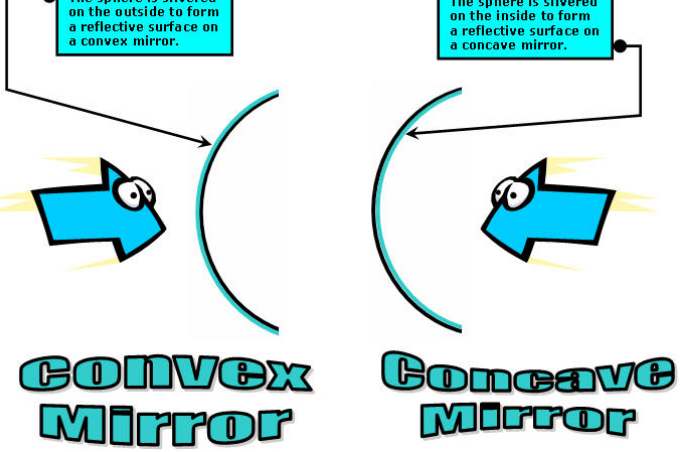




*****USE EQUATIONS WITH DIAGRAMS TO CONFIRM IMAGE LOCATION & TYPE**

SHOW HOW TO DO # 8 & #12 ON REFLECTION STUDY SHEET

CURVED MIRROR REVIEW



Concave Mirrors (Bulge inwards)-

Image characteristics

- Reversed
- Size varies
- Distance varies
- Upright or inverted
- Real or virtual

Depends on Object location

*****Know cases shown for image type & location!!!**

NEED TO DRAW 3 DIAGRAMS ON TEST

Real image = formed by the intersection of converging rays; image can be projected on screen

Convex Mirrors (Bulge out)-

Image characteristics

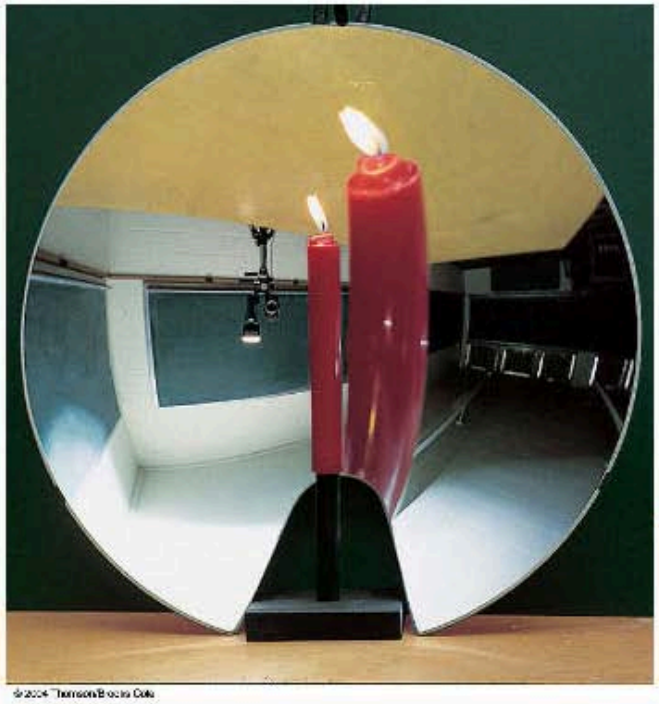
- Smaller — Image gets bigger closer Obj is to mirror but still smaller than obj
- Virtual
- Upright
- Reversed

ALWAYS

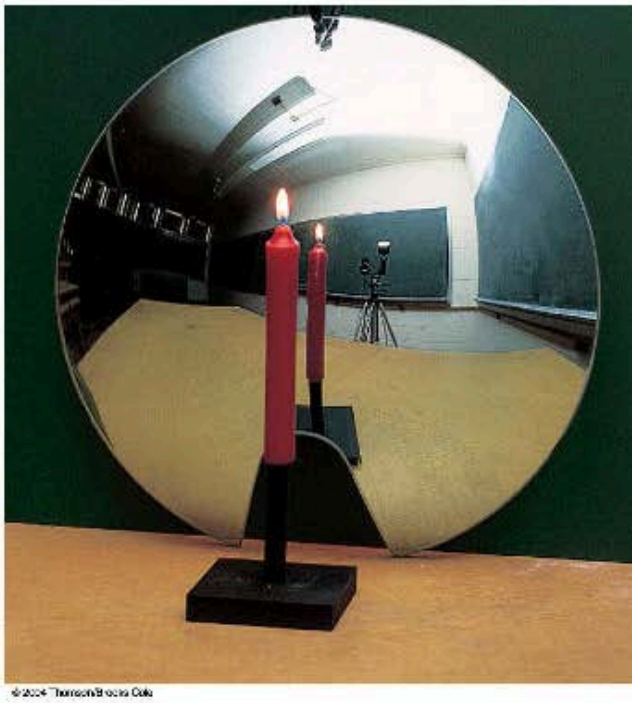
- Distance varies but always closer than F & closer obj is = closer image is to mirror

What type of mirror are producing the images & where is the object located with respect to C & F?

Concave At C



Concave Before F



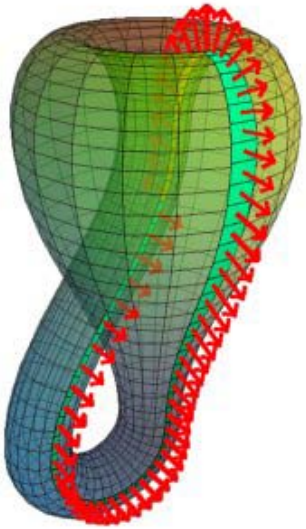
Convex ??? Before C

Illusions

http://www.michaelbach.de/ot/

- Rotating princess square
- Devil's fork square
- Geometric & Angle Illusions
- **Moon Illusion
- Space, 3-D, Size consistency

← Klein bottle



Good Website for More Info

http://www.cyberphysics.co.uk/topics/light/reflection.htm

Man playing horn,
or woman sillho

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