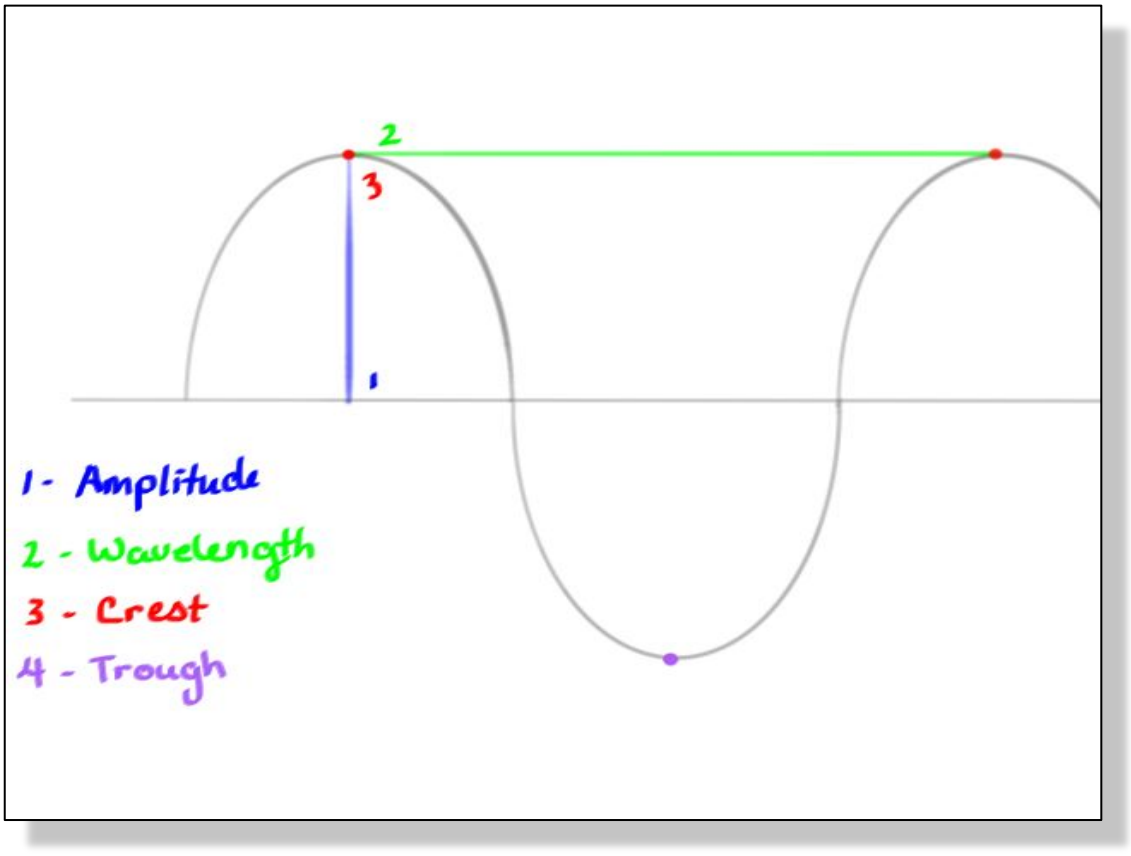
Lindsay Liang

Physics – Optics Summary Notes

Wave

- Where energy is transferred between two points in a medium without any net transfer of the medium itself
- Amplitude
  - The wave height from its position of rest to the crest (the highest point on the wave)
  - The greater the amplitude, the more energy the wave carries
- Frequency
  - Number of oscillations (cycles) the wave performs in one second
  - The higher the frequency, the more energy the wave carries
  - Unit for frequency: hertz (Hz): Cycles per second
- Wavelength
  - The distance between two crests (or troughs) on a wave
  - Measured in centimeters
  - Symbol: λ (Lambda)
- Crest
  - Highest point of the wave
- Trough
  - Lowest point of the wave
- Speed of the Wave
  - Speed of Wave = Frequency x Wavelength
  - $V = f \times \lambda$

Figure 1: Labeling a wave diagram



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Light

- Travels through space, as well as some materials
- Behaves in electromagnetic waves
- Does not require a medium for transmission
- Transferred through radiation
- The speed at which light travels is determined by the density of the medium it passes through
- Speed of light through a vacuum: 2.997925 x 10^{10} cm/sec

Electromagnetic Waves

- Are invisible
- Can travel through a vacuum
- Involve electric and magnetic fields
- Are measured using the electromagnetic spectrum

Electromagnetic Spectrum

- Order (lowest frequency to highest frequency)
    - Radio, Microwave, Infrared, Visible (red, -> orange, -> yellow, -> green, -> blue, -> violet), Ultraviolet, X-Ray, Gamma Ray
- We can only see the 'visible' part of the spectrum
- The colours differ because they have different wavelengths (red with the greatest, (less energy) and violet with the smallest (more energy))
- Visible light has a wavelength range of about 3900 Å to 7700 Å

Additive Colour Theory of Light

- The three primary colours of light are blue, green and red
- If any two of these colours are mixed, a secondary colour may be obtained

Subtractive Colour Theory of Light

- When light strikes an object some wavelengths of light reflect off the object
- Other wavelengths are absorbed by the object
- Colours of objects depend on the wavelengths that are reflected
- Colours that are absorbed are 'subtracted' from reflected light that we see
- Example: Blue objects reflect blue and absorb all other colours
- Black objects absorb all colours
- White objects reflects all colours

Light from the Sun

- Result of a fusion reaction
- Hydrogen atoms combine to produce helium – energy is released
- Excited atoms release this energy in the form of light (photons)

Light from Incandescence

- Light emitted because of high temperatures
- Higher temperature, different colours (from red -> orange -> yellow -> white -> bluish white)

- Incandescent light bulbs have a tungsten filament that glows when an electric current (that causes the tungsten to heat up) passes through it.
- Incandescent light bulbs use 5% to 10% of the electricity given to produce light, the rest wasted as heat

Light from Electric Discharge
- Light emitted by passing an electric current through a gas
- In an electric discharge tube
    - A vacuum lowers the pressure
    - Small amount of gas (ie nitrogen) is placed in the tube
    - Electric current passes through the gas, exciting the atoms
    - Excited release their excess energy, emitting light in the process
    - The light's colour is characteristic to the gas
        - Na – Yellow
        - Ne – Red
        - He – Gold
        - Ar – Periwinkle
        - Kr – Grey-off-white
        - Hg – Blue/green

Light from Phosphorescence
- Light emitted because of exposure/absorption of UV light, but will continue to admit light during the absence of UV light for an extended period
- Glow in the dark

Light from Fluorescence
- Light emitted because of absorption of UV light
- Florescent Light Tubes
    - Tube is filled with mercury gas at a low pressure
    - Inside is coated with a fluorescent powder (ie phosphorus powder)
    - Energy causes the electrodes to emit electrons
    - When electrodes collide with mercury, the atoms become exited
    - Mercury atoms release excess energy as UV light, which is absorbed by the phosphorus lining, causing it to emit visible light
    - Fluorescent light bulbs are 4-5 times more efficient than incandescent bulbs (produce the same amount of light, but less heat and energy)

Light from Luminescence
- Light emitted from an object that has not been heated
    - Chemiluminescence
        - Light produced by a chemical reaction
        - No heat produced
        - Example: Glow-sticks
    - Bioluminescence
        - Light produced by living organisms as a chemical reaction (or chemiluminescence in an organism)
        - Little or no heat produced
        - Example: Fireflies

    - Triboluminescence
        - Light produced by scratching, rubbing or crushing certain crystals

The Ray Model of Light

- Light will travel in a straight line if it is moving through the same medium
- Light can change directions using reflection and refraction
- Ray: path followed by light in one direction
- Beam: a bundle of rays
- Converging beam: rays move closer together
- Diverging beam: rays moving further apart
- Ray Diagram: drawings that show the path of rays
- Geometric optics: use of light rays to see the path of where light strikes an object
- Incident Light: light emitted from a light source
- Transparent: transmit all of the incident light, objects can be seen clearly through them
- Translucent: transmit almost all light, some are scattered (absorbed or reflected), so objects are not seen clearly
- Opaque: does not transmit incident light, objects cannot be seen

Shadows

- Formed when some/all of the light hitting an object is absorbed or reflected by it
- Size depends on:
    - Size of the object blocking the light
    - Distance of the object from the light source (further – bigger, closer – smaller)

Reflection: Flat Mirrors

- Mirror: a polished surface that exhibits reflection
- Plane mirror: a mirror with a flat surface
- Reflection: light bouncing back from any surface
- Image: reproduction of an object, produced through light
- Incident ray: original incoming ray
- Reflected ray: ray bouncing off a reflecting surface
- Normal: perpendicular to the plane at which the incident ray hits
- Angle of Incidence: angle between the normal and the incident ray
- Angle of Reflection: angle between the normal and the reflected ray

Laws of Reflection

- $\Theta i = \Theta r$ (Angle of Incidents = Angle of Reflection)
- Ray of incidence, ray of reflection and the normal all lie on the same plane

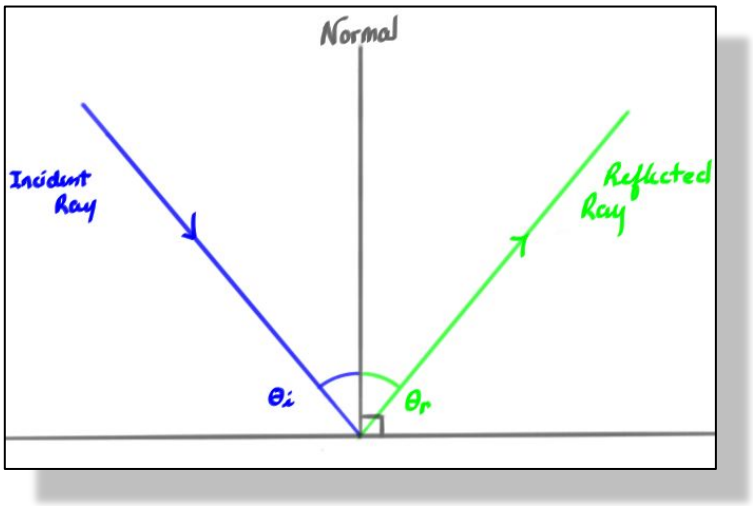


Figure 2: On a plane mirror, the Normal will be perpendicular to the plane, and the angle of incidence and the angle of reflection will always be the same.

Specular and Diffuse Reflection

- Specular/Regular Reflection: the reflection of light off a smooth surface
- Diffuse/Irregular Reflection: the reflection of light off irregular surfaces

Locating Images in Plane Mirrors

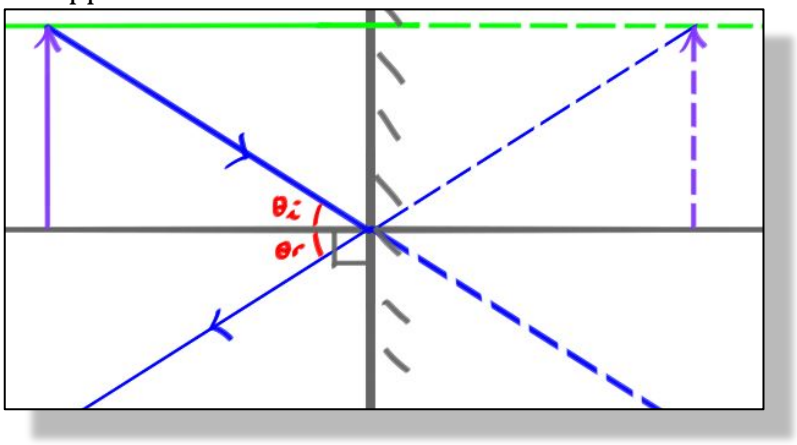
- Four characteristics can describe an image
  - Size – image size compared to the object size
  - Attitude – upright, laterally inverted (left is right, vise versa), vertically inverted (upside-down)
  - Location – image in relation to the reflecting surface (ie beyond C, at F)
  - Type – whether the image is real or virtual
  - ** Real Image: rays converging at a point, can be captured on a screen
  - **Virtual Image: cannot be captured on a screen, but can be seen by the eye, will appear behind the mirror
  - 

Figure 3: Ray diagram - reflection in a plane mirror

- An image in a plane mirror:
  - Is the same size as the object
  - Is upright, but laterally inverted (right is left, vice versa)
  - Is located the same distanced directly behind the mirror the object is in front
  - Is virtual

Locating Images in Curved Mirrors

- Center of Curvature (C): center of the sphere of which the mirror is formed
- Radius of Curvature: distance from C to the mirror
- Vertex: Middle of the mirror
- Principal Axis (PA): line drawn through the vertex, and is perpendicular to the surface
- Focal Point (F): the point where parallel rays converge that is half the distance from the center of curvature and the mirror on the Principal Axis
- Focal Length (f): The distance between the vertex and the Focal Point
- Converging/Convex Mirrors – light rays come to a point
    - Light rays that are parallel to the principal axis will reflect to go through F
    - Light rays traveling through F will reflect back from the mirror parallel to the principal axis
    - Rays passing through C will reflect back on themselves
    - Rays striking the vertex will reflect back with an angle of reflection equal to the angle of incidence (using the normal, ie the principal axis)
    - When drawing, the first ray will originate form the tip of the object (represented by an arrow), and will be parallel to the principal axis
    - The second ray will originate from the tip of the object and go through F
    - There are five different possibilities of ray diagrams involving concave mirrors

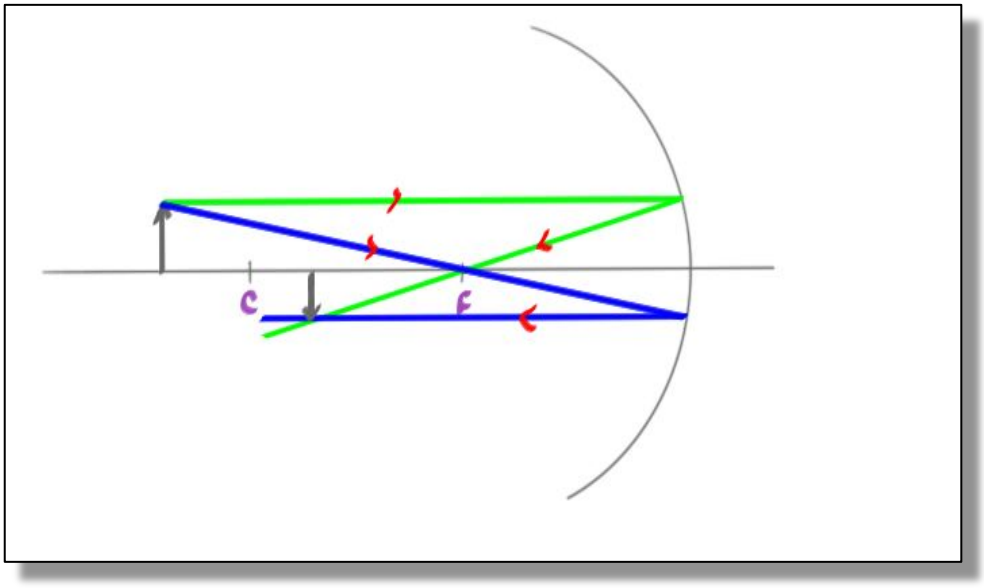


Figure 4: Object beyond C

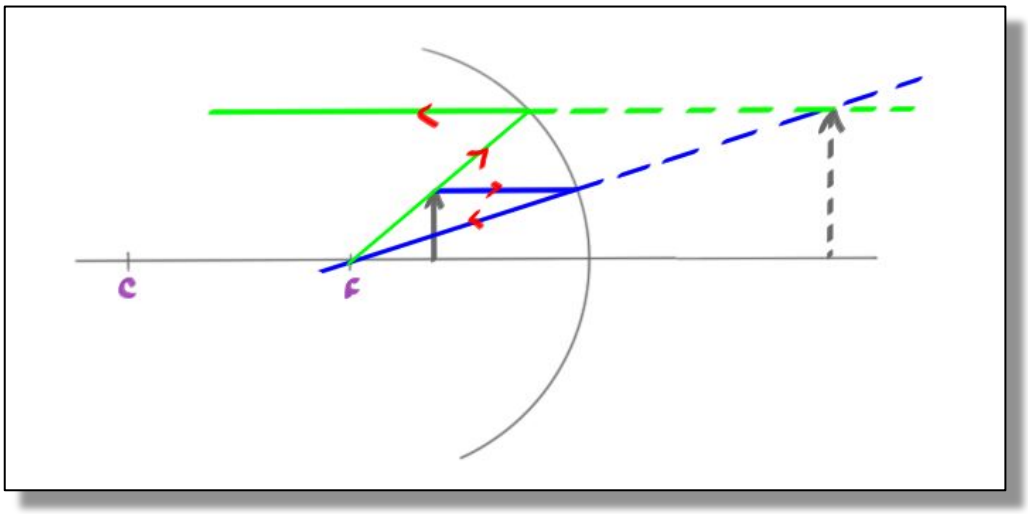


Figure 5: Object between the Mirror and F

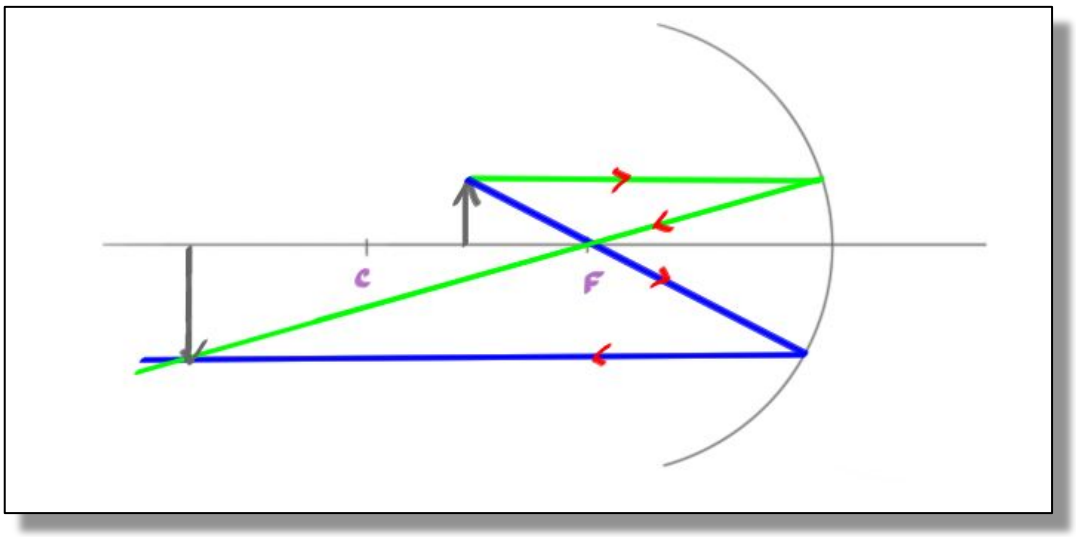


Figure 6: Object between C and F

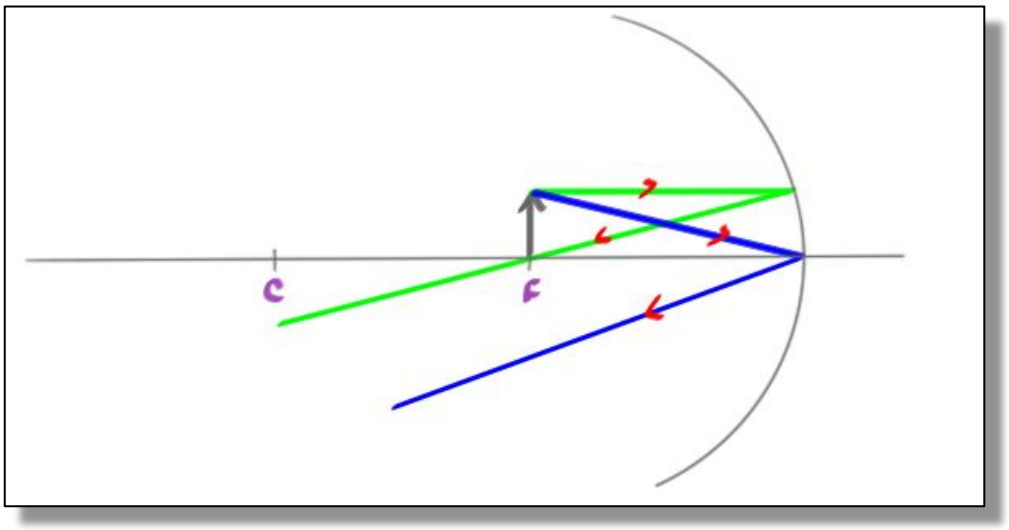


Figure 7: Object at F

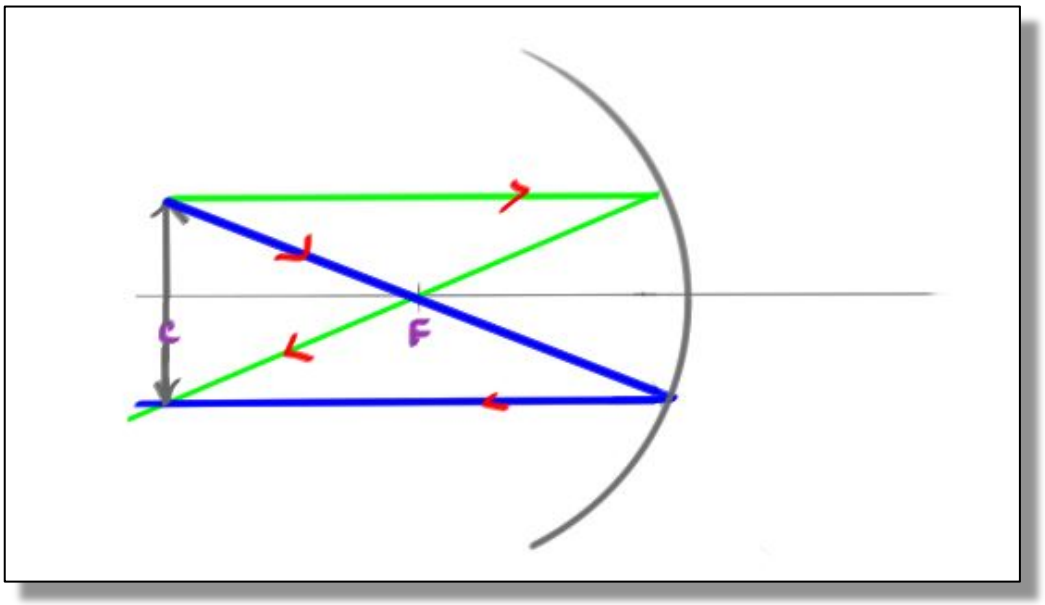


Figure 8: Object at C

- Diverging/Concave Mirrors – light rays disperse
  - Rays parallel to the principal axis reflect as if they had come from F
  - Rays aimed at F will reflect parallel to the principal axis
  - Rays aimed at CF will reflect back upon themselves

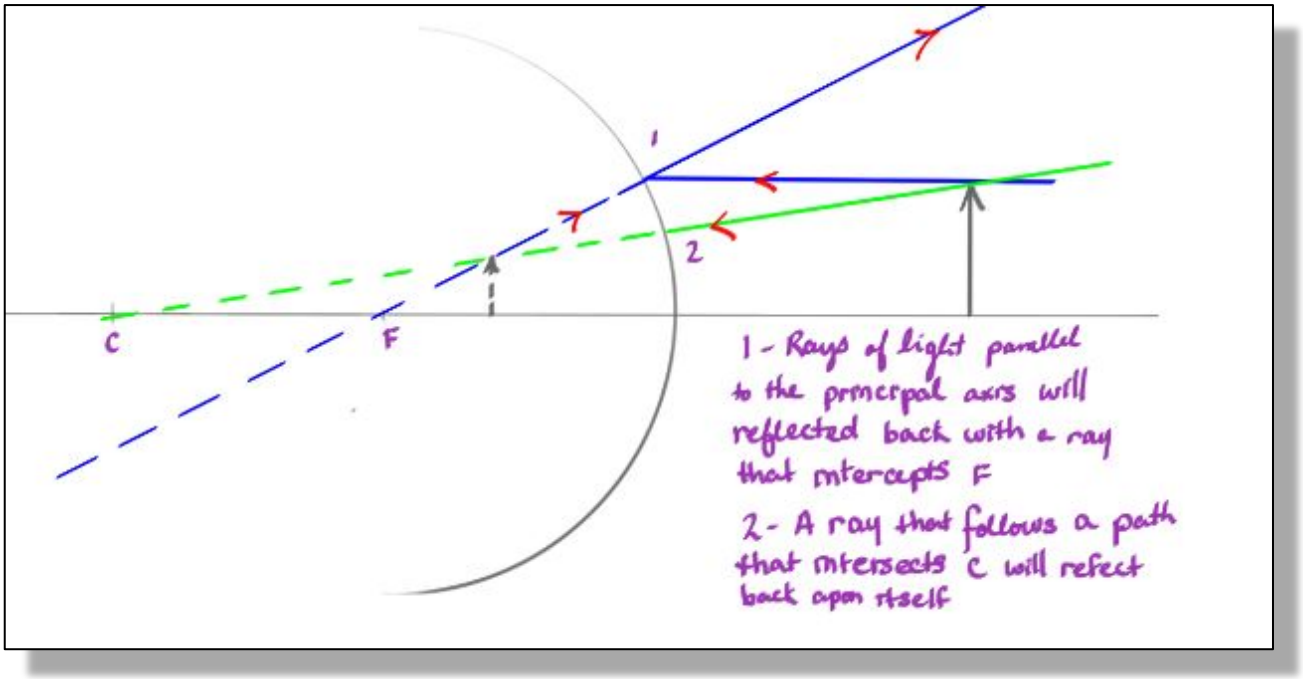


Figure 9: Concave Mirror Ray Diagram