Indian Hills Community College presents the series Basics of Photonics Fundamentals (lasers & optics)

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Life. Changing.

WELCOME & THANK YOU FOR YOUR INTEREST

Greetings

- I am Frank Reed, Indian Hills's Grant Director & Principal Investigator for the *Developing Photonics Education in Iowa's Rural Secondary Schools* National Science Foundation Grant.
- I have been in the photonics (**lasers and optics**) field since 1989 when I graduated from Indian Hills and have been with IHCC since 1996.
- I do hope you enjoy and learn from these presentations.

- The presentations will cover the following.
  1. **Motivation, Light and the Nature & Properties of Light**
  2. Optical Components
  3. Basic Laser Safety
  4. Geometrical (RAY) Optics
  5. Physical (WAVE) Optics
  6. Principles of Lasers

Motivation

- Currently the U.S. laser & optics industry is growing by leaps and bounds,
  - Or as we like to say “at the speed of light”.
- The medical/bio-science area is the fastest growing followed closely by manufacturing.
  - These two areas will impact each of us on a personal basis.
- Nationally, there are ~2000 entry level photonics technician positions per year with ~20% filled.
- IHCC’s Laser & Optics 2020 graduates received an average starting salary of $61,800.00.
- To increase the number of these technicians, WE must market lasers & optics to our students.
- 70% of technicians working in U.S. photonics industry say that their jobs are intellectually challenging and have no worries about joblessness.
- IHCC’s NSF ATE Grant has the main objective of increasing the number of Photonics Techs in the U.S.
- One way to do that is to introduce teachers to the world of photonics.
  - Therefore, this opportunity is provided for you to learn more about lasers & optics with hope that you will include it in your course work.

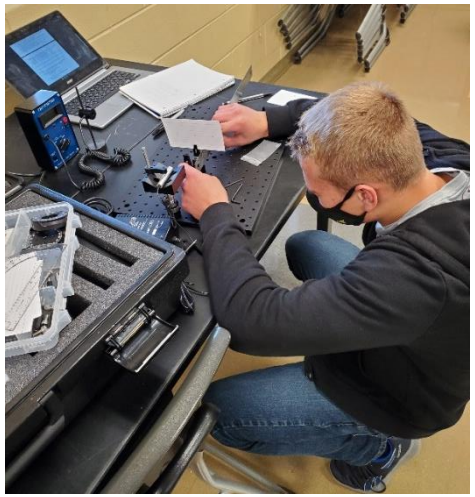
Motivation

Albia High School

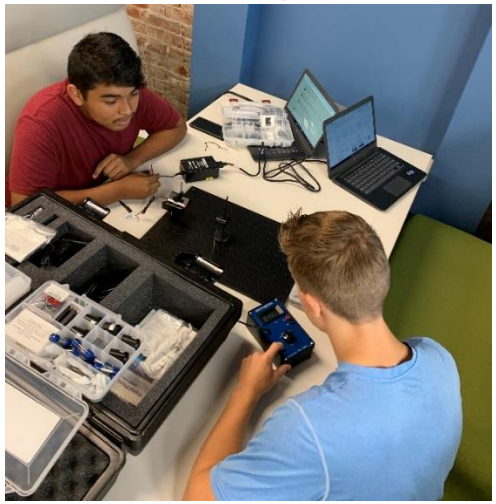
Centerville High School

Davis County High School

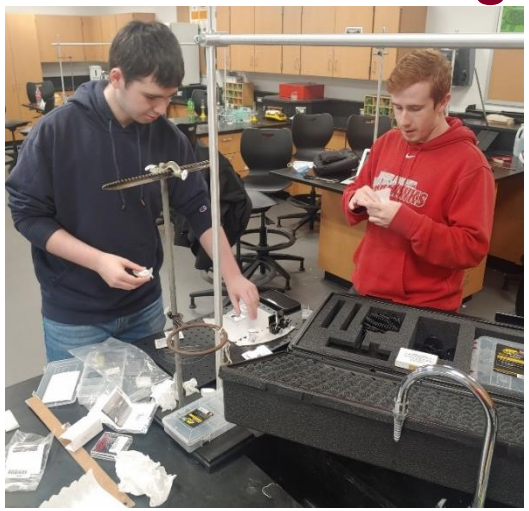
Hybrid (online & hands-on) High School Photonics Training



Davis County High School



Ottumwa High School



North Mahaska High School

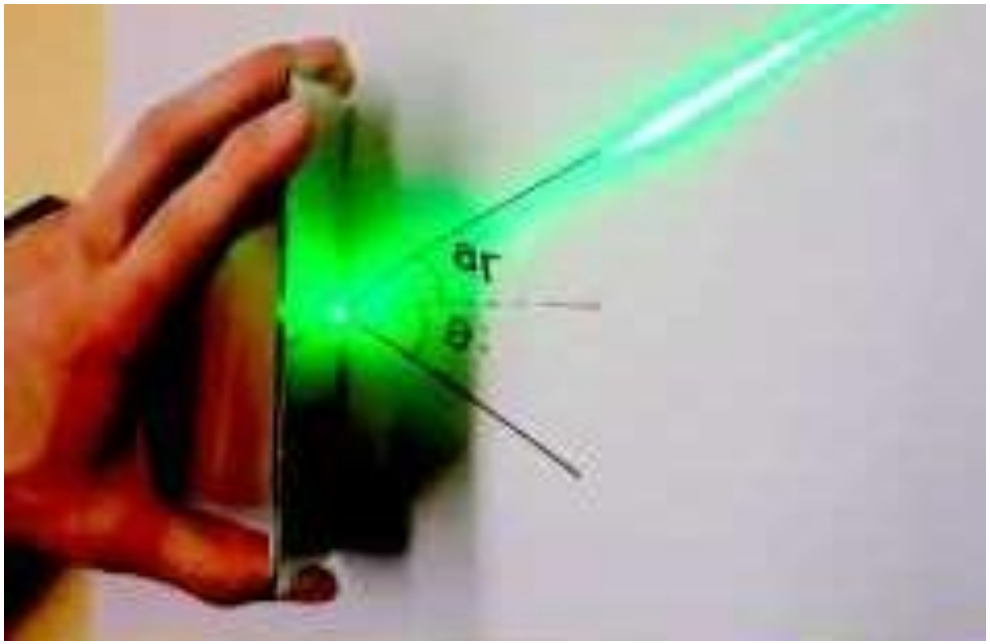
Basic Geometric (Ray) Optics

- Reflection
  - Plane surface
  - Spherical surface
- Refraction
  - Index of Refraction
  - Snell's Law of Refraction
  - Critical Angle & Total Internal Reflection
  - Dispersion of Light
- Mirrors
- Lenses

Reflection

LIGHT RAYS:

- Always travel in a straight line until they are manipulated
- Create images when they are emitted or reflected from an object
- May reflect, refract, scatter, absorb, or transmit
- Propagate out in all directions



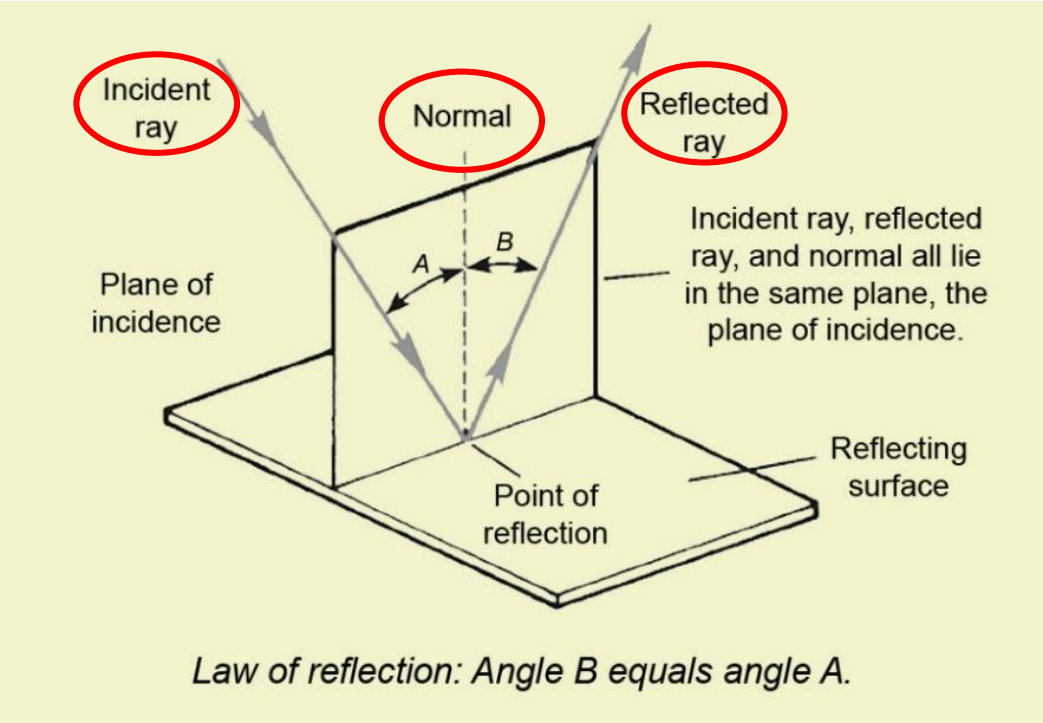
Specular & diffuse reflections of a light ray

Check this for an applet.

https://micro.magnet.fsu.edu/primer/java/reflection/specular/index.html

Law of Reflection

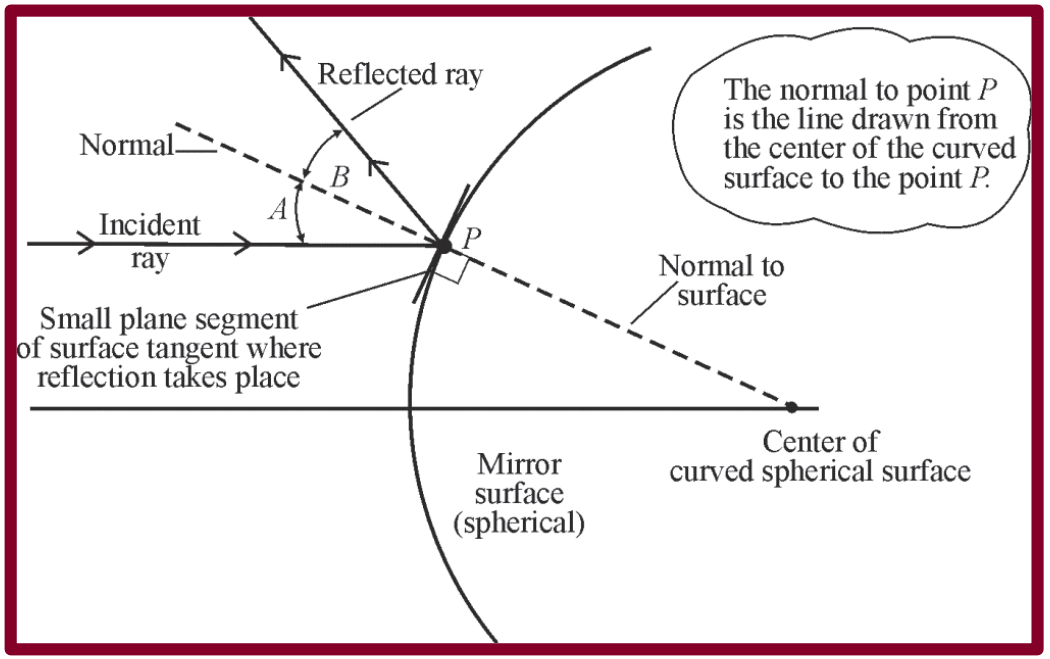
- The Law of Reflection:
  - The angle of reflection (B) equals the angle of incidence (A) when measured from the Normal.
  - Incident, reflected and normal all lie in the same plane.



Law of reflection: Angle B equals angle A.

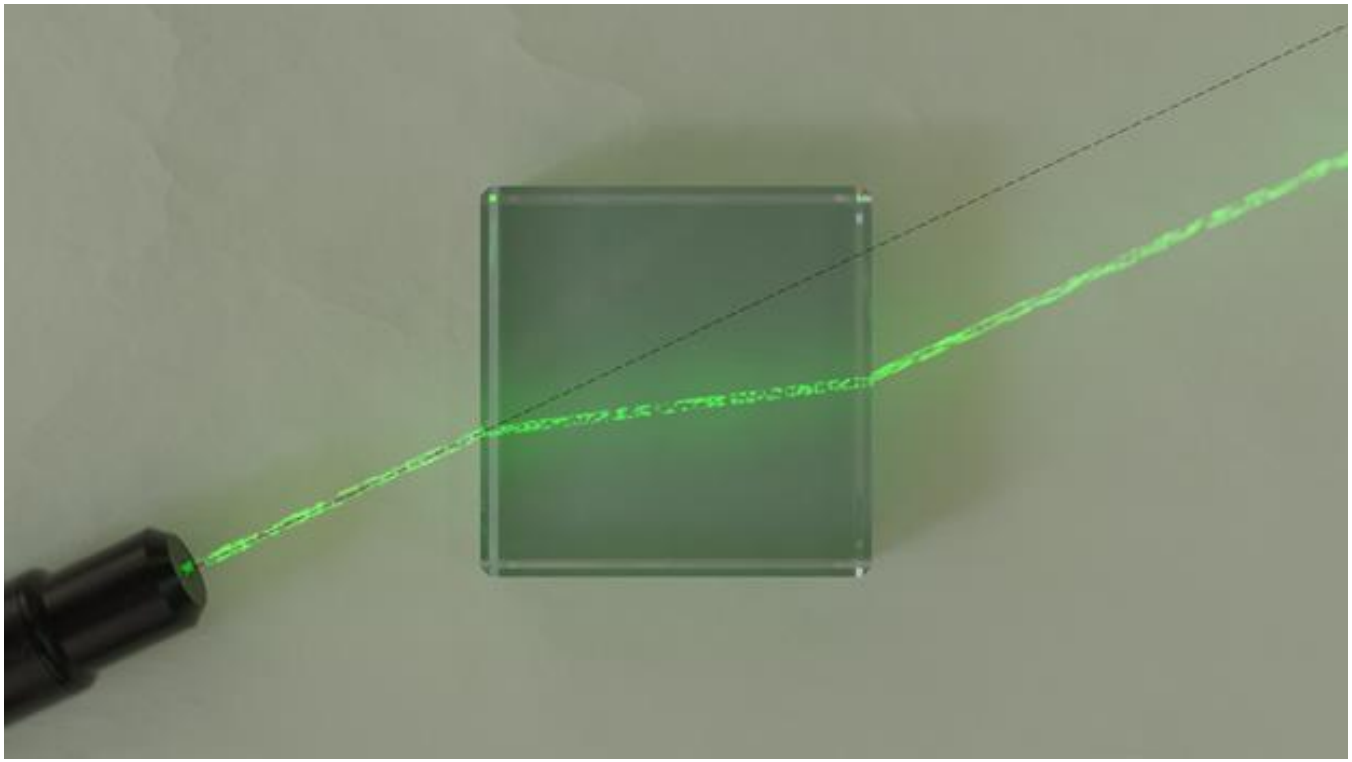
Law of Reflection

- Normal is always 90° to the point of reflection whether on a flat or spherical surface.
- The *law of reflection* holds for a spherical surface (convex or concave).
- At each reflection point on the curved surface, a *surface tangent* can be drawn with a *normal* to a point *P* on the surface where the light is incident, as shown in the figure



Refraction

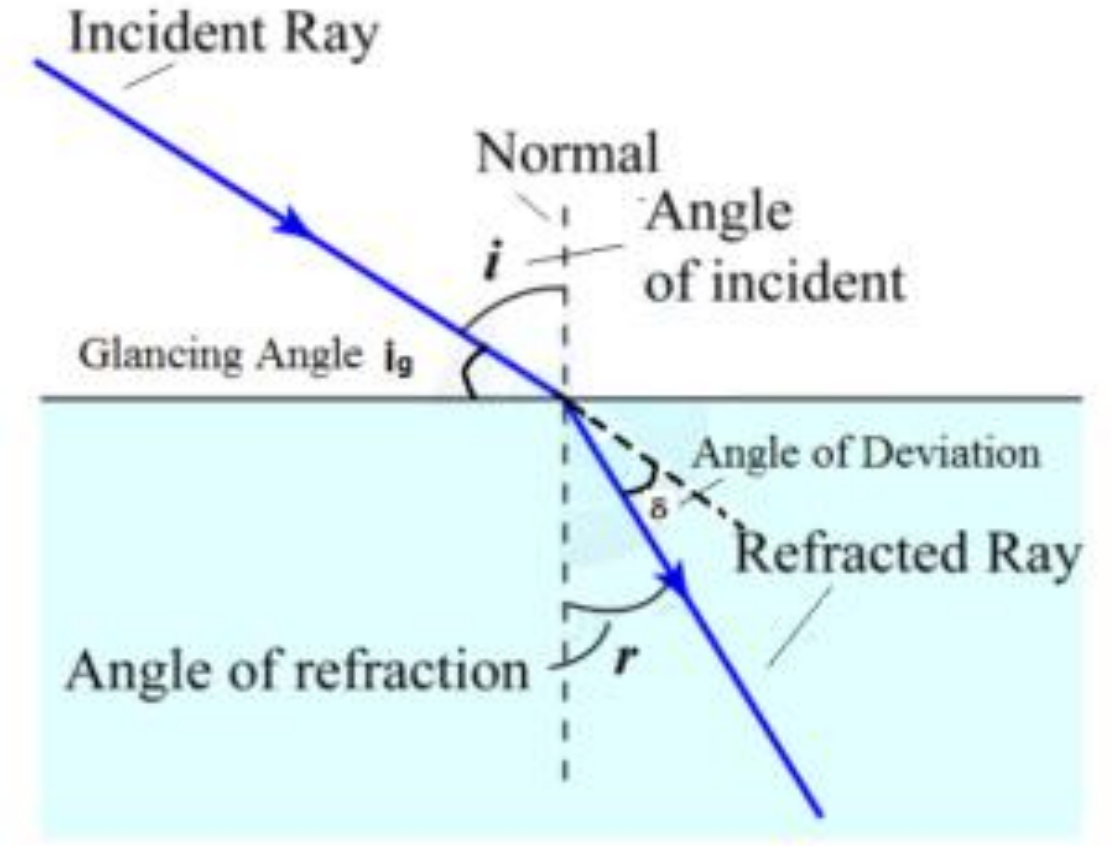
- Bending of light as it makes the transition from one media to another with a different index of refraction.



Snell's Law of Refraction

Snell's Law of Refraction:

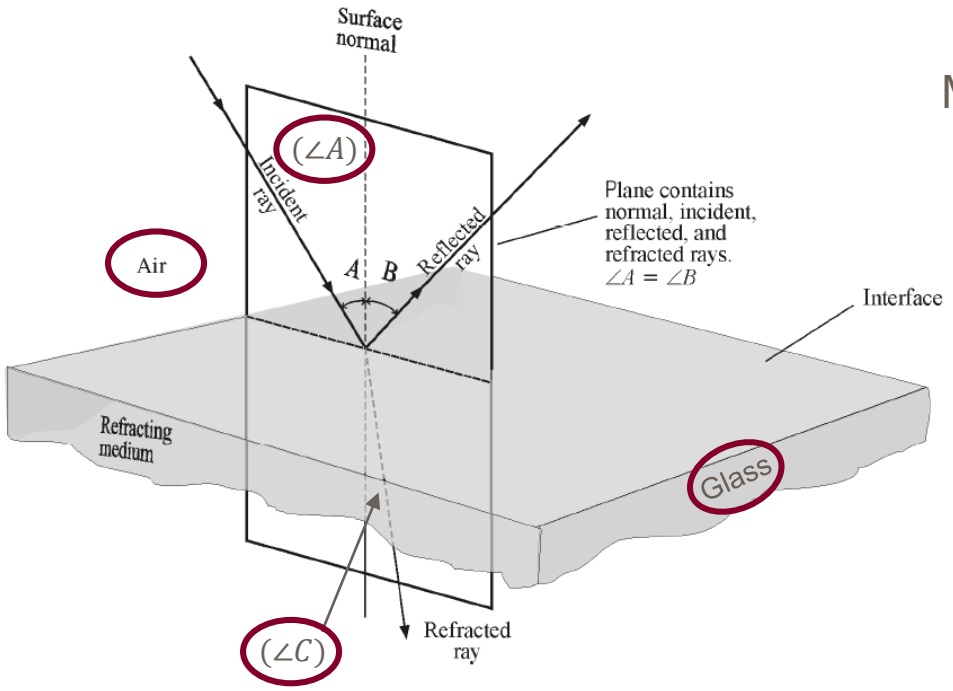
Incident & Refracted Ray, and Surface Normal all lie in the same plane.



Snell's Law of Refraction

Snell's Law of Refraction continued:

- The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.
  - 'n' represents the index of refraction



$$\frac{\boldsymbol{sin\theta_i}}{\boldsymbol{sin\theta_r}} = \frac{\boldsymbol{n_r}}{\boldsymbol{n_i}}$$

May also be written as

$$\boldsymbol{n_i sin\theta_i = n_r sin\theta_r}$$

n_i = index of refraction of material 1 (Air)

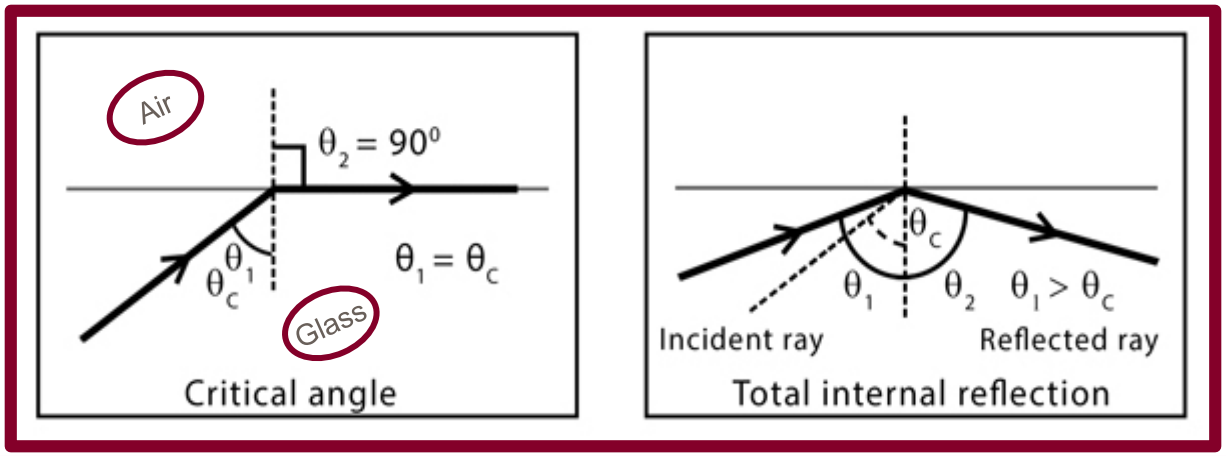
n_r = index of refraction of material 2 (Glass)

θ_i = angle of incidence $(\angle A)$

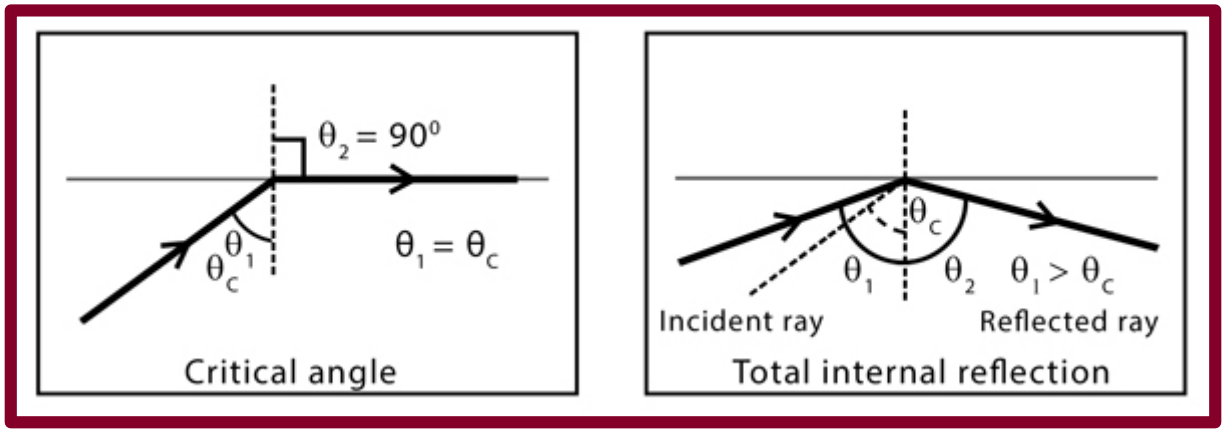
θ_r = angle of refraction $(\angle C)$

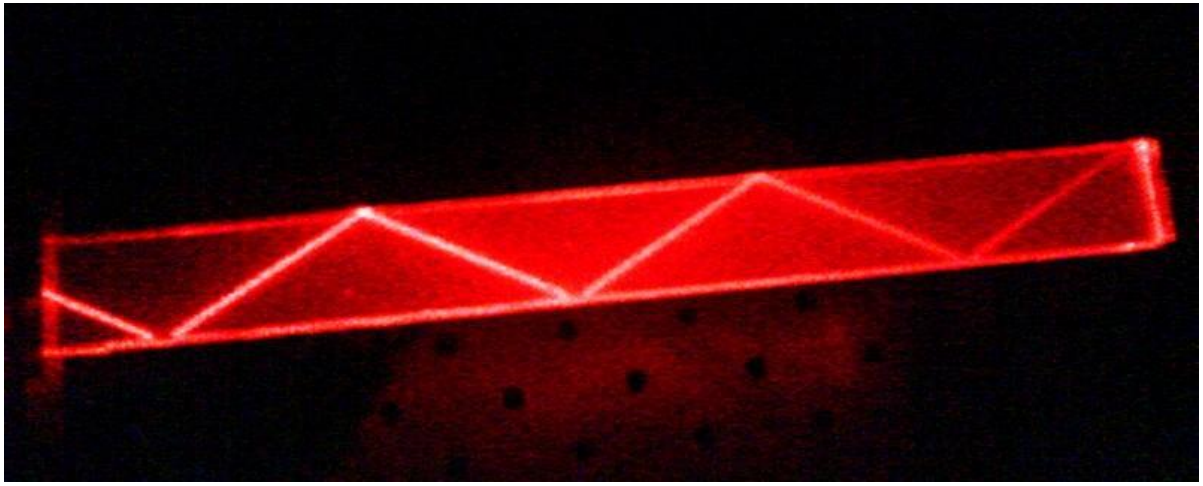
Critical Angle & Total Internal Reflection

- When light travels from a medium of *higher index (glass) to one of lower index (air)*, and is incident at the *critical angle* ($\theta_1 = \theta_c$).
- Then the refracted ray will bend from the normal at 90° thereby traveling *along the interface* between the two media.
- At an angle *greater than* the critical angle ($\theta_1 > \theta_c$), *total internal reflection* occurs and the ray reflects back into the same medium from which it came, obeying the Law of Reflection.
- This is essentially how communication in an optical fiber works.



Critical Angle & Total Internal Reflection

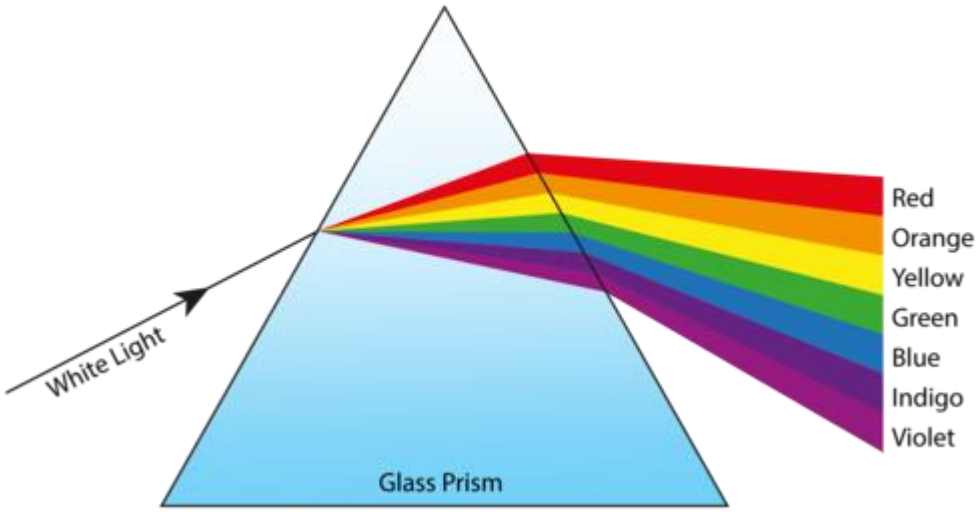




Red laser beam proving TIR in solid glass rod

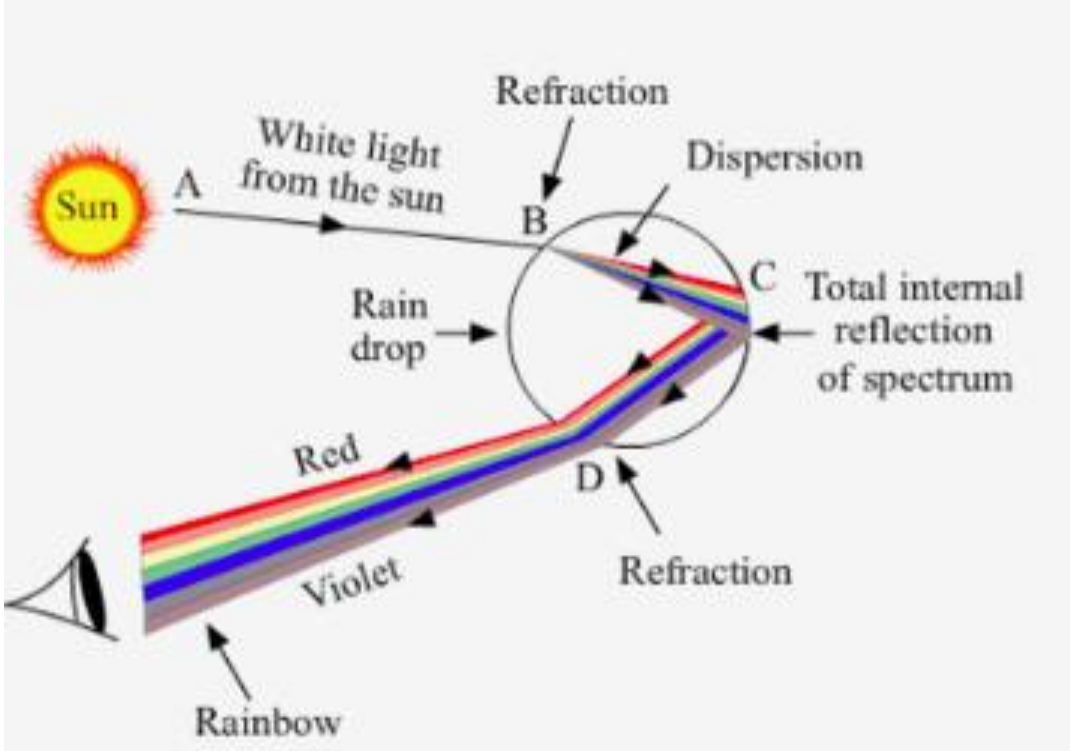
Dispersion

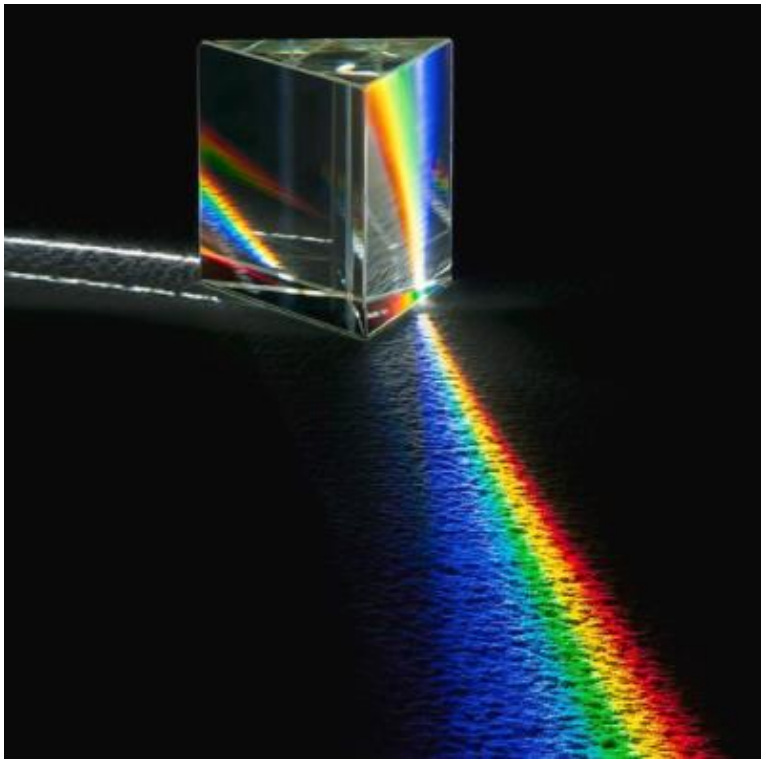
- The index of refraction or refractive index is wavelength dependent
- Values of *n* change as the wavelength, **λ** (lambda) changes.
- Index of refraction for flint glass is about 1% higher for blue light (around 450 nm) than for red light (around 650 nm).
- The variation of refractive index *n* with wavelength λ is called *dispersion*.



Dispersion

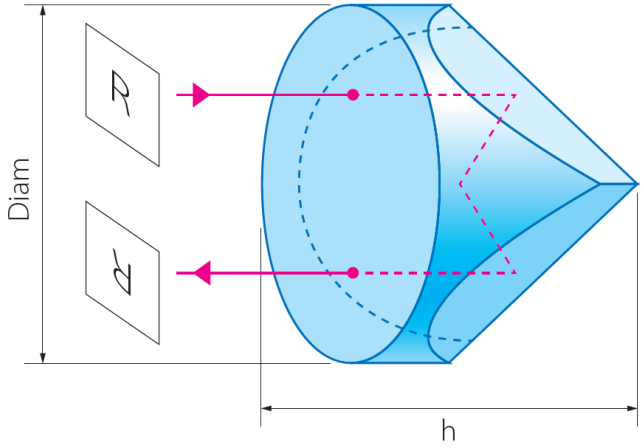
- Dispersion is how white light separates to all visible colors.
- This is why a rainbow is visible after a rain, as the white light from the sun disperses in the raindrops (.
- Therefore white is the combination of all colors while black is the absence of all colors.

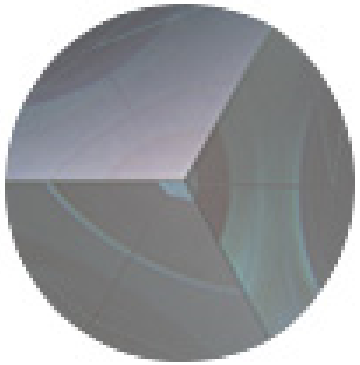


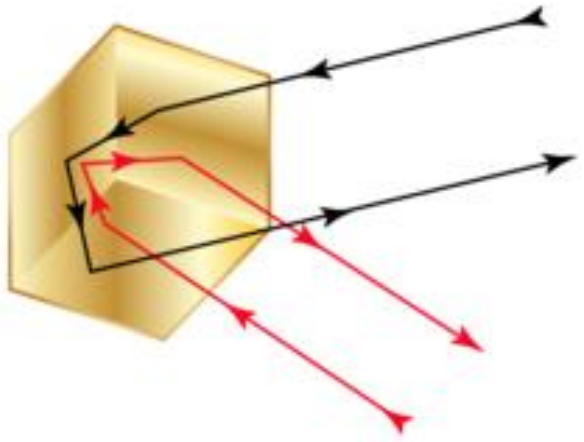


Prisms

- Total internal reflection is used in “retroreflecting” prisms, or those that redirect the reflected light along the **same path** as the entering light.
- Three symmetrical planes form the inside corner of a cube
- When a ray of light reflects from the first side, it’s reversed to the next side, and then transferred to the last plane. It’s then sent back to the source

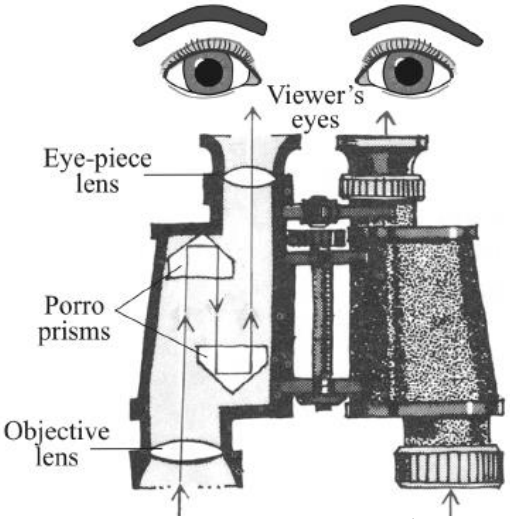






Prisms

- **Right angle: (a)** Deviate the direction of light by 90°
- **Porro: (b)** Right angle prism in a Porro configuration.
  - When light is incident through its hypotenuse, light (image) will be deflected 180-degrees and flipped.
  - Used to change the orientation of an image.
- **Dove: (c)** Right angle prism with apex removed.
  - Used to invert images.
- **Porro: (d)**
  - Used in binoculars, telescopes, and microscopes where there are space restrictions.



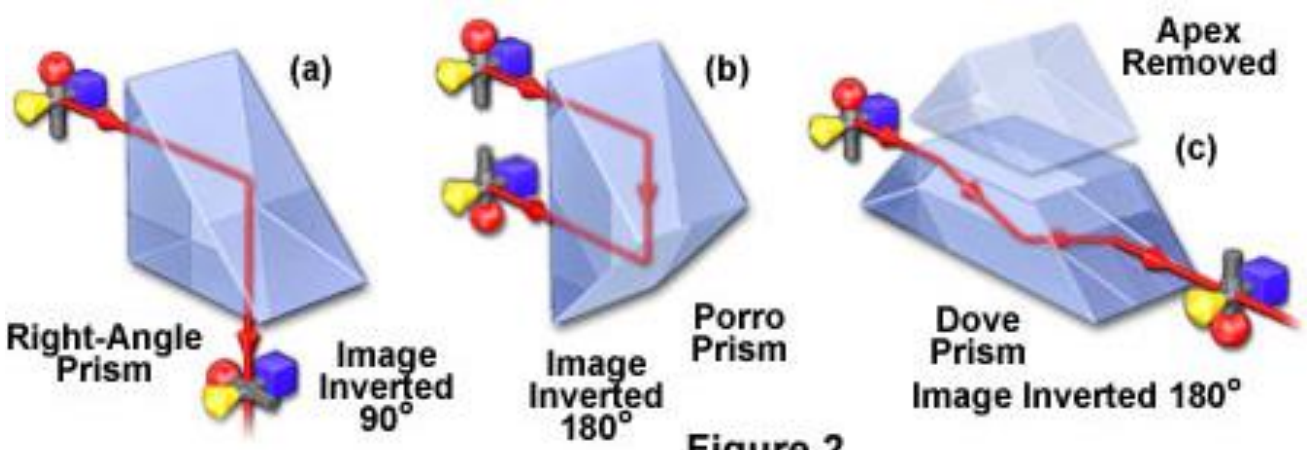
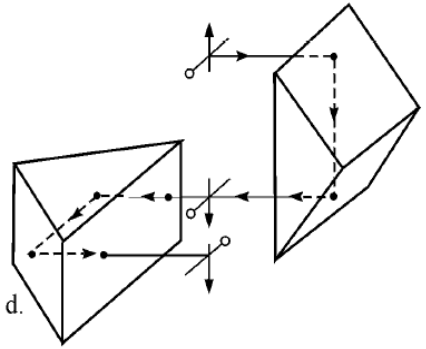


Figure 2



Prisms

- **Penta: (a)** Deviates the beam 90-degrees without deflection left-to-right or top-to-bottom.
- **Roof: (b)** Used in binoculars or when a right angle deflection of an image is required.
  - The image is deflected left-to-right not top-to-bottom.
- **Rhomboid: (c)** Creates an output beam that is displaced from and parallel to the input beam.
  - Does not change the direction of the beam, nor does it invert the image.

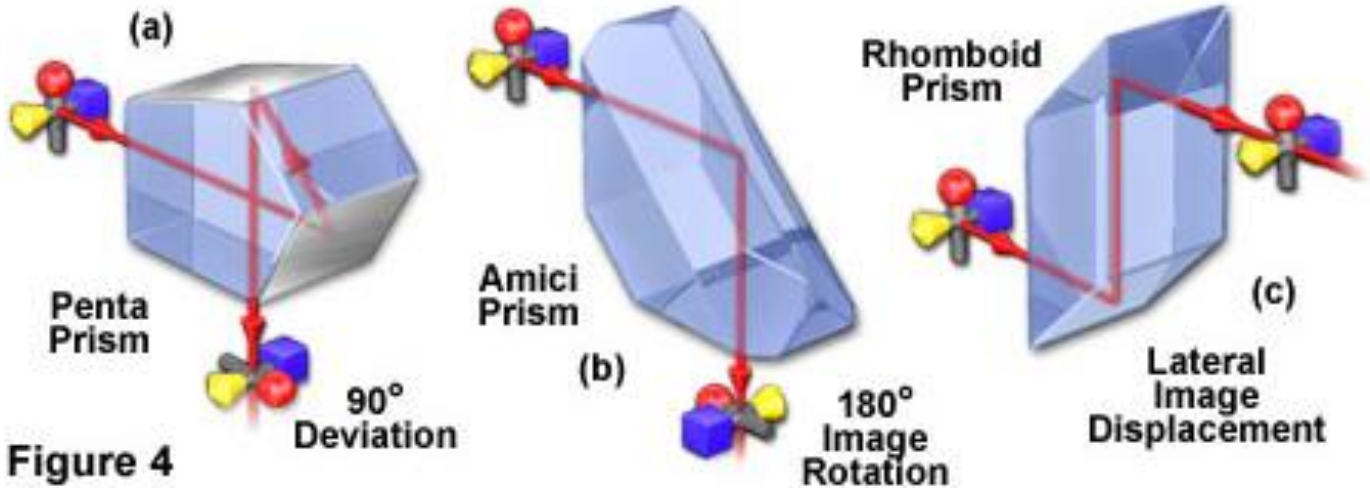
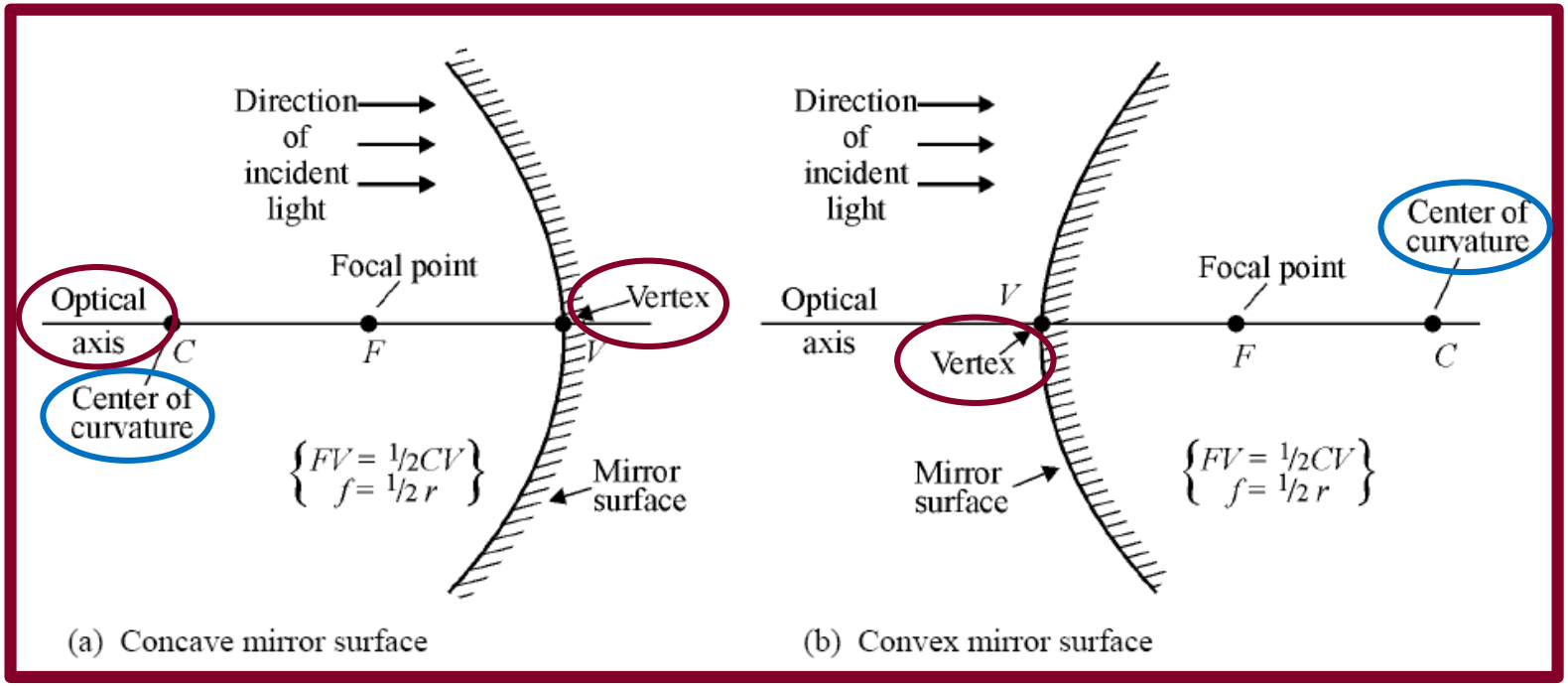


Figure 4

Mirrors

- Vertex is point where optical axis intersects the mirror.
- The mirror on the left is a concave, positive, converging mirror.
  - The center of curvature (*C*) is on the left.
- The mirror on the right is a convex, negative, diverging mirror.
  - The center of curvature (*C*) is on the right.



Mirrors

- **Parallel** rays are light rays coming from a very distant source (such as the sun) or as part of a collimated laser beam.
- The *law of reflection* requires that the ray be reflected so as to pass through a focal point *F* in front of a concave mirror (Figure 4-17a) or be reflected **to appear** to come from a focal point *F* behind a convex mirror (Figure 4-17b).
- A line drawn from the center of curvature *C* to **any point** on the mirror such as *P* is a *normal* line and bisects the angle between the incident and reflected rays, as shown.

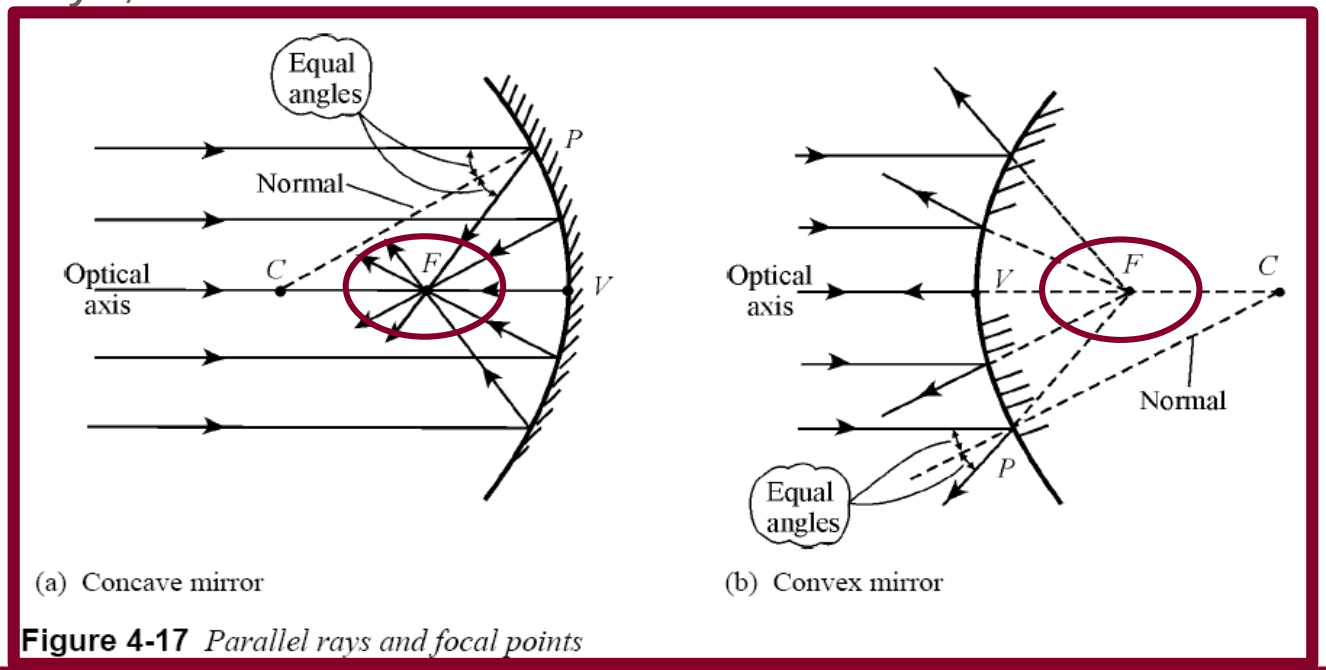


Figure 4-17 *Parallel rays and focal points*

Lenses, Convex/Converging/Positive

- Have positive spherical (curve outward) surfaces.
- Center-thickness is greater than edge-thickness.
- Focus light to a pre-defined point based on surface curvature.
- Biconvex: both surfaces are positive.
  - Utilized when the object being imaged is **much closer** to the lens.
- Plano-convex: one surface remains flat while the second has a positive curve.
  - Applied when the object being imaged is **far away** from the lens.
- Positive Meniscus: both sides curve in the same direction, center-thickness **>** edge-thickness.
  - Designed to minimize spherical aberration & to shorten the focal length of an optical system.

Note the parallel/collimated light ray entering from the left.

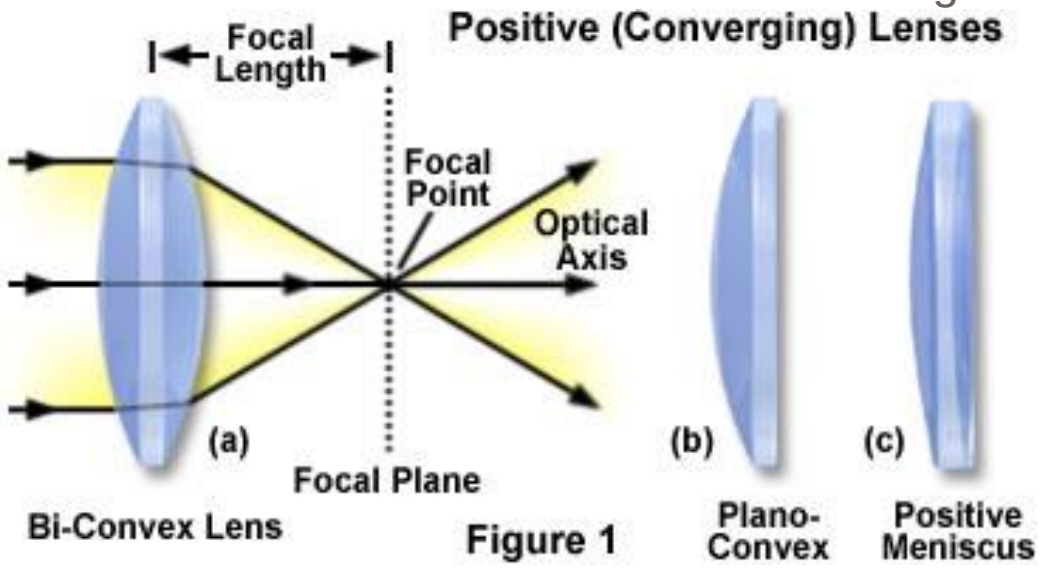


Figure 1

Lenses, Concave/Diverging/Negative

- Have negative spherical (curve inward) surfaces
- Center-thickness is less than edge-thickness
- Diverge (disperse) light from pre-defined point based on surface curvature
- Bi-Concave: both surfaces are negative.
  - Utilized to expand & collimate a laser beam.
- Plano Concave: one surface remains flat while the second has a negative curve.
  - Applied to reduce spherical aberration, coma and distortion
- Negative Meniscus: both sides curve in the same direction, center-thickness **<** edge-thickness.
  - Used to reduce or eliminate spherical aberration or increase resolution in optical systems.

Note the parallel/collimated light ray entering from the left.

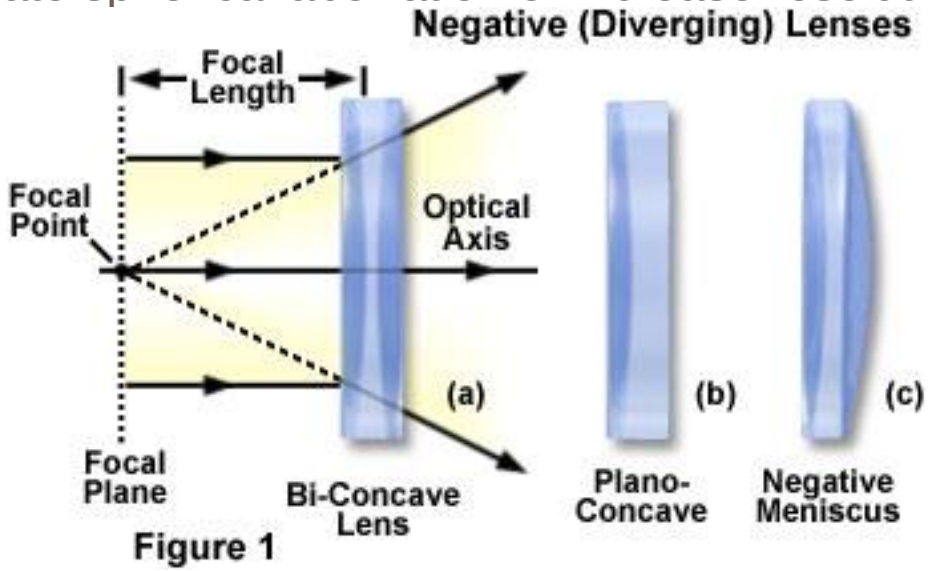


Figure 1

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