Optics

Refraction

Laws of refraction

Snell's law: $n_1 \sin i_1 = n_2 \sin i_2$

The refracted ray is in the same plane as the incident ray and the normal to the medium at the point of incident but on the opposite side of the normal from the incident ray.

Critical angle:

$if\ i = c\ and\ r = 90^\circ,\ \frac{n}{n_a} = \frac{1}{\sin c}$

$\frac{n_2}{n_1} = \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{t}{t'}$ (light passes from 1 to 2)

Combination of thin lenses:

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

Difference between real and apparent depth:

$d = t(1 - \frac{1}{n})$

Power of a lens:

$P = \frac{1}{f}$, f is in metres

Conjugate points:

$xx' = f^2$

Refraction at prism:

Angle of deviation : $d = i_1 + i_2 - A$ where $A = r_1 + r_2$

Minimum Angle of deviation : $d = 2i - A,\ (i_1 = i_2 = i,\ r_1 = r_2 = r,\ A = 2r)\ or\ n = \frac{\sin \frac{A+D}{2}}{\sin \frac{A}{2}}$

Maximum Angle of deviation : $i_1 = 90^\circ\ or\ i_2 = 90^\circ$

Refraction at prism:

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Maximum Angle of deviation : $i_1 = 90^\circ\ or\ i_2 = 90^\circ$

Convex lens with fixed object and image:

$f = \frac{s^2 - l^2}{4d}$, (where $d = u + v$ and l = distance between two convex lens)

$u + v > 4f \Rightarrow$ 2 real images

$u + v = 4f \Rightarrow$ 1 real image

$u + v < 4f \Rightarrow$ no real images

Lensmaker's equation:

$\frac{1}{f} = (\frac{n_2}{n_1} - 1)(\frac{1}{r_1} + \frac{1}{r_2})$, ($r$ is $+$ when convex towards optically less dense medium)

Optical Instruments

Magnifying glass:

convex lens, $u < f$, erect, magnified and virtual image

Normal adjustment : $v = D,\ M = \frac{\beta}{\alpha} = \frac{D}{f} - 1$

Abnormal adjustment : $v = \infty,\ M = \frac{D}{f}\ (D = -25cm)$

Astromomical telescope (Keplerian telescope)

convex lenses with

$f_o < f_e,\ f_o + f_e = d,\ u_o = \infty,\ v_o = f_o,\ u_e = f_e$

first image is diminished, inverted real, second is magnified inverted

Normal adjustment : $v_e = \infty,\ M = \frac{\beta}{\alpha} = m_o \times m_e = \frac{f_o}{f_e}$

Abnormal adjustment : $v_e = D,\ M = \frac{\beta}{\alpha} = m_o \times m_e = (\frac{D+1}{D})(\frac{f_o}{f_e})$

Compound Microscope:

convex lens, $f_o < f_e$, first image is magnified inverted real, second is magnified inverted virtual.

Normal adjustment : $v_e = D,\ M = \frac{\beta}{\alpha} = m_o \times m_e = (\frac{v_o}{f_o} - 1)(\frac{-D}{f_e} - 1)$

Abnormal adjustment : $v_e = \infty,\ M = \frac{\beta}{\alpha} = m_o \times m_e = (\frac{v_o}{f_o} - 1)(\frac{D}{f_e})$

Reflection

Laws of Reflection

The angle of reflection equals the angle of incidence. $(i = r)$

The reflected ray is in the same plane as the incident ray and the normal to the mirror at the point of incidence.

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ (where u = object distance, v = image distance, f = focal length)

Linear magnification : $m = \frac{v}{u} = \frac{l}{h} = \frac{v}{f} - 1$

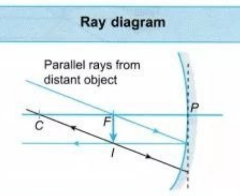
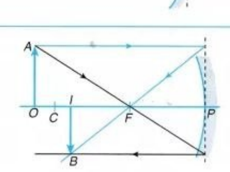
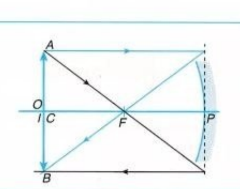
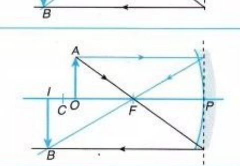
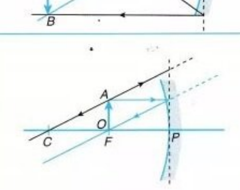
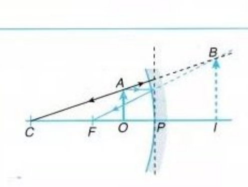
Angular magnification : $m = \frac{\beta}{\alpha} = \frac{v}{f} - 1$

Number of images

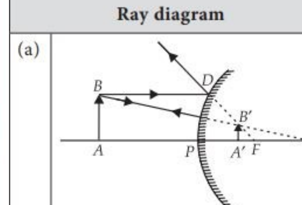
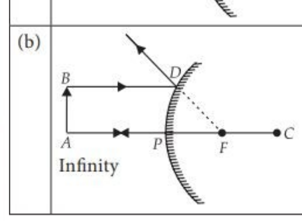
$n = \frac{360^\circ}{\theta} - 1$ (if n is even or n is odd when object lies on angle bisector)

$n = \frac{360^\circ}{\theta}$ (if n is odd when object does not lie on angle bisector)

Curved

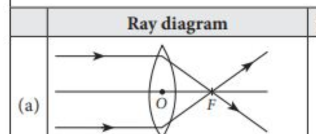
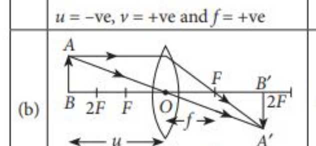
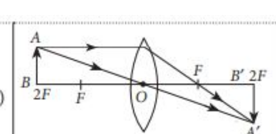
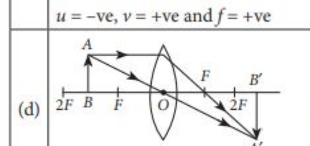
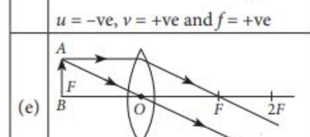
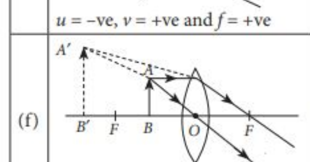
Object distance, u	Ray diagram	Image distance, v	Characteristics
• At infinity • $u = \infty$		• At F • $v = f$ (focal length) • $v = \frac{1}{2}r$ (r = radius of curvature)	• Image is real, inverted and diminished.
• Slightly beyond C • $u > 2f$ • $u > r$		• Between C and F • $f < v < 2f$ • $\frac{1}{2}r < v < r$	• Image is real, inverted and diminished.
• At C • $u = 2f$ • $u = r$		• At C • $v = 2f$ • $v = r$	• Image is real, inverted and same size as object.
• Between C and F • $\frac{1}{2}r < u < r$		• Beyond C • $v > 2f$ • $v > r$	• Image is real, inverted and magnified.
• At F • $u = f$ • $u = \frac{1}{2}r$		• At infinity • $v = \infty$	• Image is virtual, upright and very large (magnified). • Reflected rays are parallel.
• Between F and P • $u < f$ • $u < \frac{1}{2}r$		• Behind the mirror • v = negative	• Image is virtual, upright and magnified.

Convex mirror

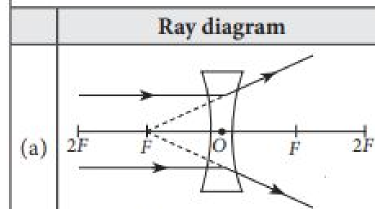
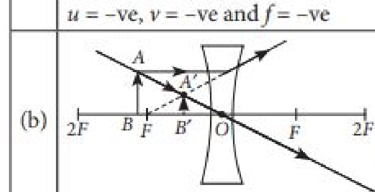
	Ray diagram	Object position	Image position	Nature of image
(a)		Between infinity and the pole	Behind the mirror between the focus and the pole	Virtual, smaller and erect
(b)		At infinity	Behind the mirror at the focus F	Virtual, point-sized and erect

▸ **Image formation by lenses :**

Convex lens

	Ray diagram	Position of object	Position of image	Nature of image
(a)	 $u = -ve$, $v = +ve$ and $f = +ve$	At infinity	At F	Real, inverted and highly diminished
(b)	 $u = -ve$, $v = +ve$ and $f = +ve$	Between infinity and $2F$	Between F and $2F$	Real, inverted and diminished
(c)	 $u = -ve$, $v = +ve$ and $f = +ve$	At $2F$	At $2F$	Real, inverted and same sized
(d)	 $u = -ve$, $v = +ve$ and $f = +ve$	Between F and $2F$	Beyond $2F$	Real, inverted and enlarged
(e)	 $u = -ve$, $v = +ve$ and $f = +ve$	At F	At infinity	Real, inverted and enlarged
(f)	 $u = -ve$, $v = -ve$ and $f = +ve$	Between F and O	On the same side of the lens	Virtual, erect and enlarged

Concave lens

	Ray diagram	Position of object	Position of image	Nature of image
(a)	 $u = -ve$, $v = -ve$ and $f = -ve$	At infinity	At F	Virtual, erect and highly diminished
(b)	 $u = -ve$, $v = -ve$ and $f = -ve$	Between infinity and O	Between F and O	Virtual, erect and diminished