SUPER PHYSICS

Chapter 13 Notes

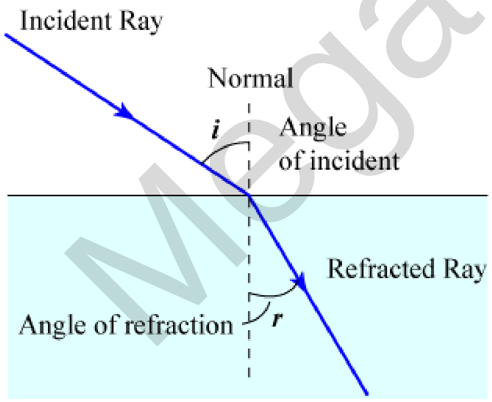
Light

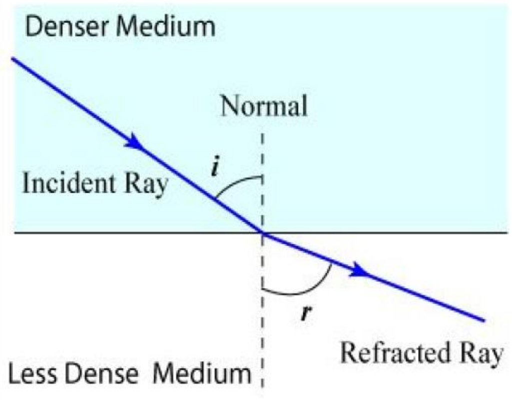
Laws of Reflection

- Angle of incidence is equal to angle of reflection
- Incident ray, reflected ray and normal all lie on same plane

Refraction

- Definition: Bending of light through different medium
- Light bends towards normal through denser medium
    - When light travels from optically less dense to optically denser medium, it bends towards the normal
    - When light travels from optically denser to optically less dense medium, it bends away from the normal
- Light travelling perpendicular to boundary passes undeflected





- Angle of Incidence: Angle between normal and incident ray
- Angle of Refraction: Angle between normal and refracted ray

Snell's Law: $n1\ \sin\theta 1 = n2\ \sin\theta 2$

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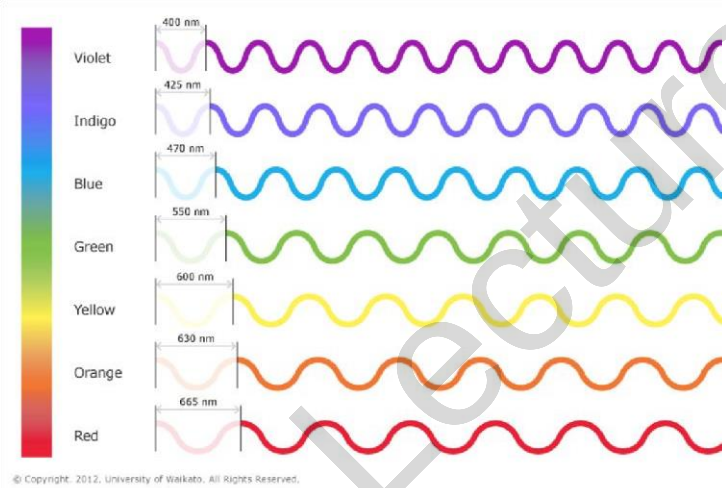
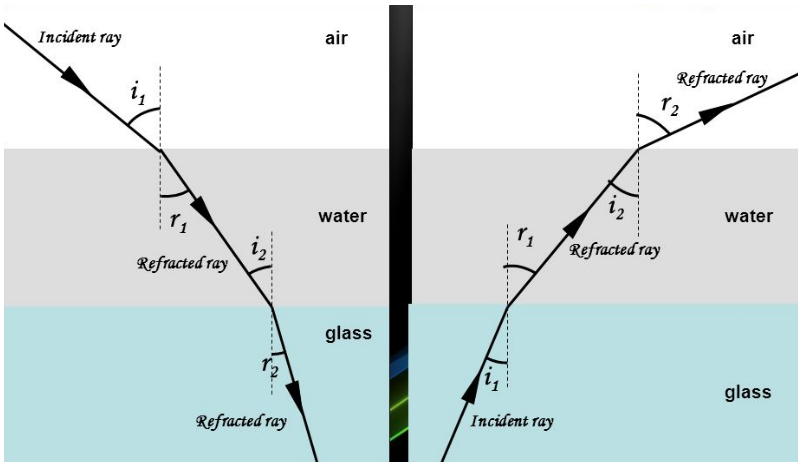
Rainbow Formation

- White light travels at the same speed in air
- When it enters the water droplet, blue light with shortest wavelength bends the most, red light with longest wavelength bends the least



Optical Density



- Glass is optically denser than air means light travels slower in glass than air and refracts more in glass than in air → Measured using refractive index, n

- Glass has refractive index n of 1.5 means in glass, speed of light is $2.0 \times 10^8 ms^{-1}$ or 1.5 times slower in glass than in air (air = 1.00, ice = 1.31, water = 1.33, crystal = 1.8, diamond = 2.4

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Refractive Index

$$n = \frac{c}{v}$$

Where n is the refractive index
c is the speed of light in air
v is the speed of light in medium

- Example 1: What is the speed of light in a medium with a refractive index of 2.4?

n = speed of light / speed of light in medium
2.4 = c/v
v = $3.0 \times 10^8 ms^{-1}/2.4$
= $1.3 \times 10^8 ms^{-1}$

Total Internal Reflection

- Occurs in **optically denser** medium, at angle **above** critical angle, c

Critical Angle:

$$sin_c = \frac{1}{n_m}$$

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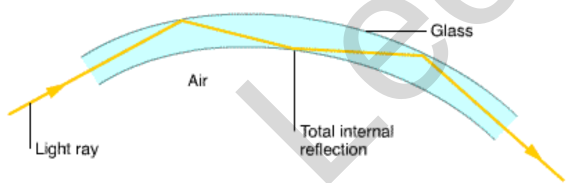
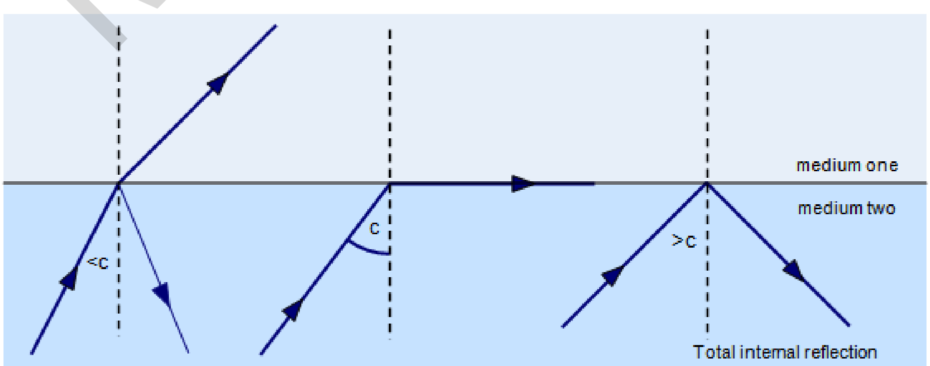
Optical Fibers

- Uses Total Internal Reflection
  - Information can be transmitted from one place to another by sending pulses of light through an optical fiber
  - Used in telecommunication to transmit telephone and cable television signals, and internet data
- Advantages
  - Light travels faster than electricity → Data travels faster than in metal wires
  - Less signal loss than metal wires + Weigh less than metal wires
  - Less expensive + Non-flammable



Angle of Incidence

- i < c → Refraction
- i = c → r = 90°
- i > c → Total internal reflection



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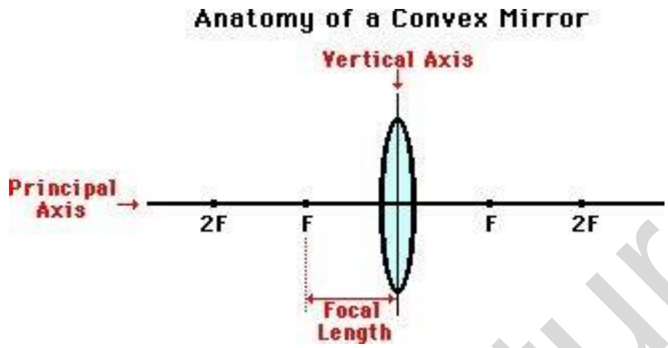
Thin Convex Lenses



- Optical Centre
  - The midpoint between the surfaces of the lens on its principal axis.
- Principal axis
  - The horizontal line passing through the optical centre of the lens.
- Focal point
  - The point where the refracted light rays converge
- Focal length
  - The distance between the centre of the lens and the focal point of the lens

Thin Lens

- Formula → $\frac{1}{u} + \frac{1}{i} = \frac{1}{f}$

Where u = distance of object from optical centre,

i = distance of image from optical centre,

f = distance of focal point from optical centre

- When u > f, image formed is real, inverted, and on opposite side of lens as object

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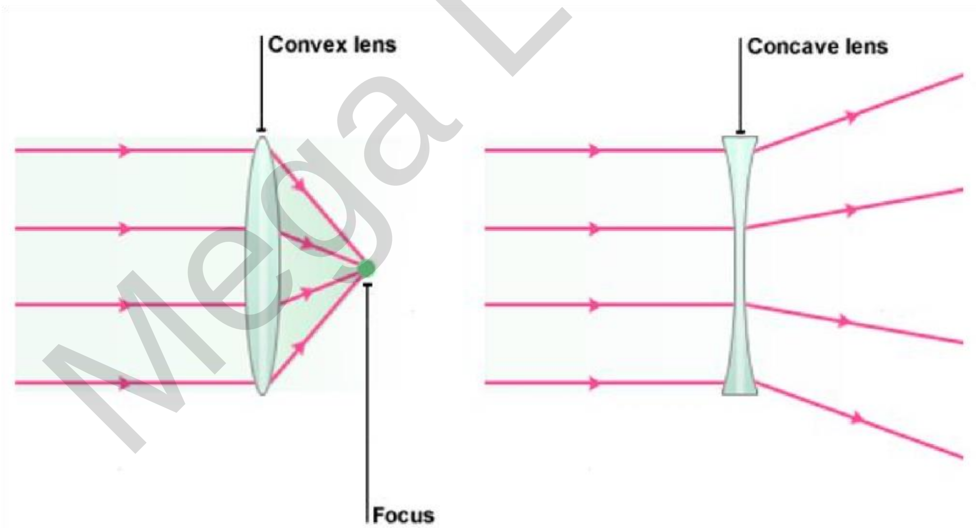
- When u < f, image formed is virtual, upright and on same side of lens as object

How do diverging lenses work? (concave)

- As light rays travel from air to lens, optically less dense to denser, decreasing speed of light, resulting in change in direction

How do converging lenses work? (convex)

- Cause the light rays to converge at a focal point
- Light rays hit lens at different angles, so they refract at different angles
- Angle of refraction is largest at lens edge while no refraction occurs in the middle
- Depending on distance of object from optical center, image has different characteristics (see thin lens formula)



Thin Converging Lens

- Ray passing through optical centre continues in same direction without bending
- Ray passing through thin lens, parallel to principal axis, always hits focal point

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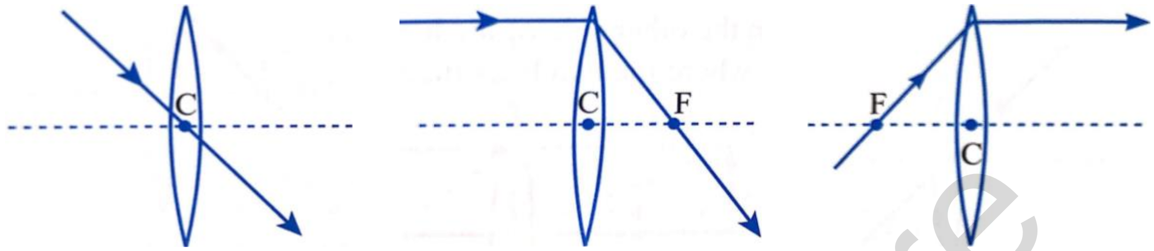
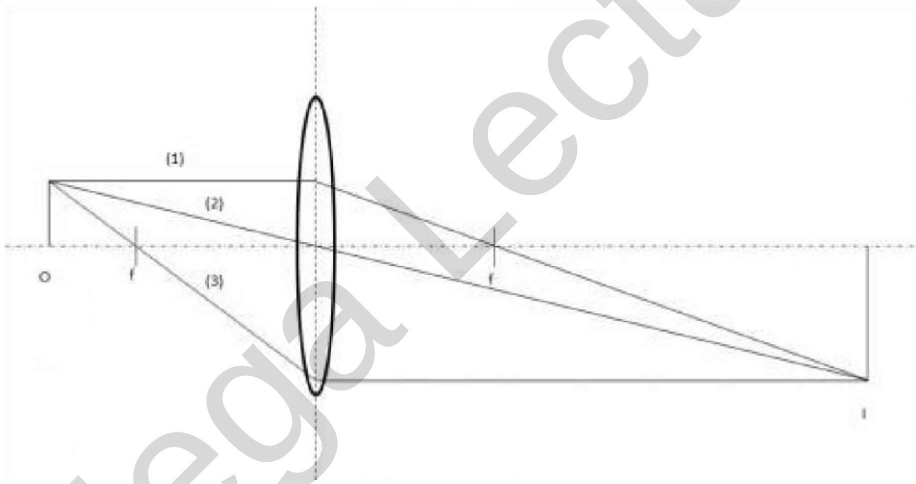
- Ray passing through focal point always travels parallel to principal axis



Ray Diagrams:



- Ray 1 is parallel to principal axis
- Ray 2 passes through optical centre
- Ray 3 passes through focal point f

Terms to describe the Image

- Orientation
  - Upright / inverted
- Size
  - Diminished / same size / magnified
- Type
  - Real (can be captured on screen) / virtual

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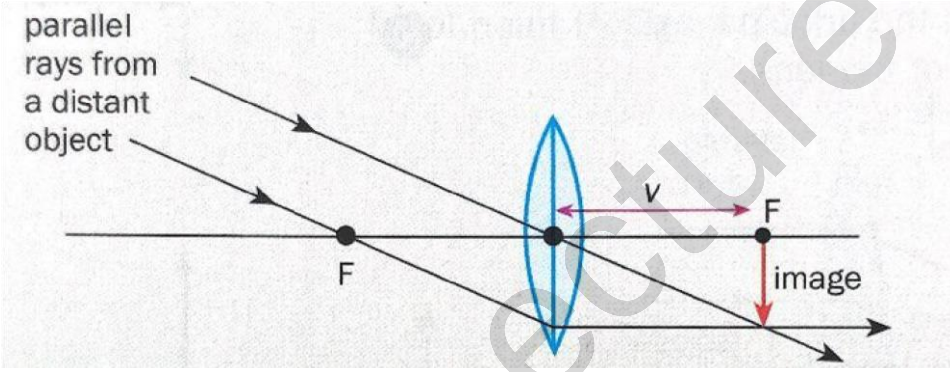
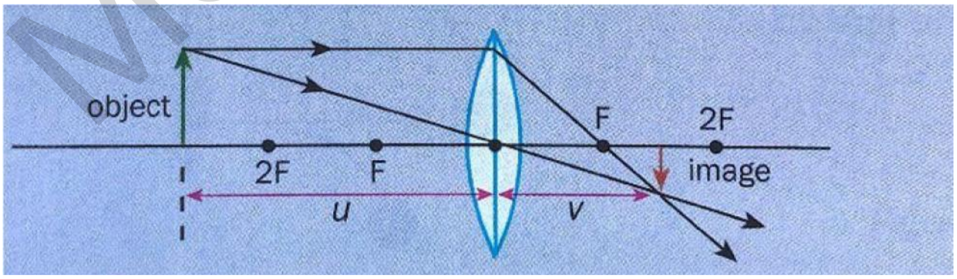
Case 1: *the rays are usually PARALLEL!

- U (object dist) = infinite
- v (image dist) = F
- Inverted, diminished, real
- Used in telescope



Case 2

- u > 2f
- f < v < 2f
- Inverted, diminished, real
- Used in camera, human eye



Case 3

- u = 2f
- v = 2f
- Inverted, same size, real

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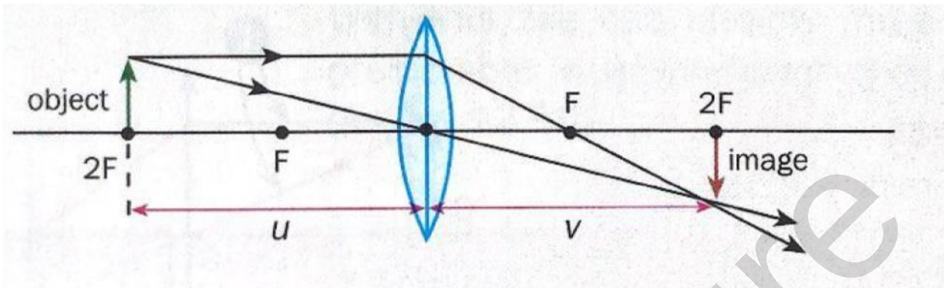
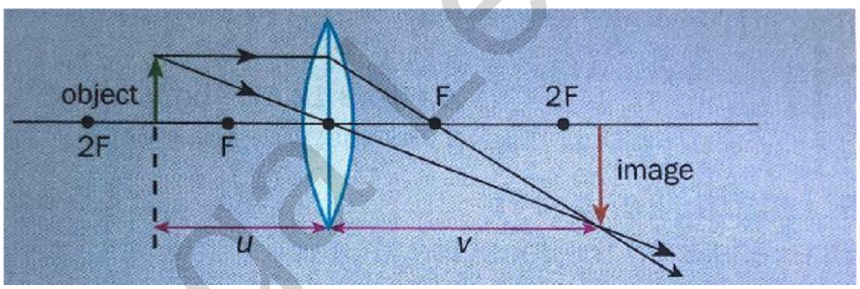
- Used in photocopier



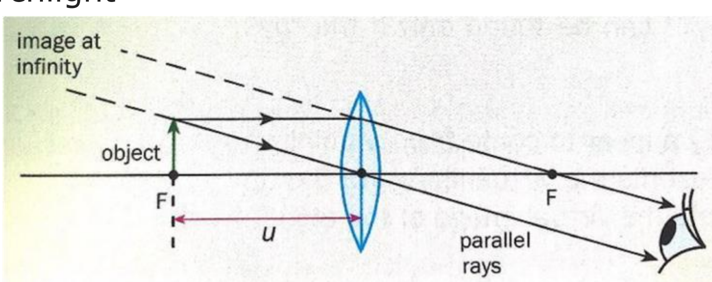
Case 4

- f < u < 2f
- v > 2f
- Inverted, magnified, real
- Used in projector



Case 5

- u = f
- v = infinity
- Inverted, magnified, real
- Used in torchlight



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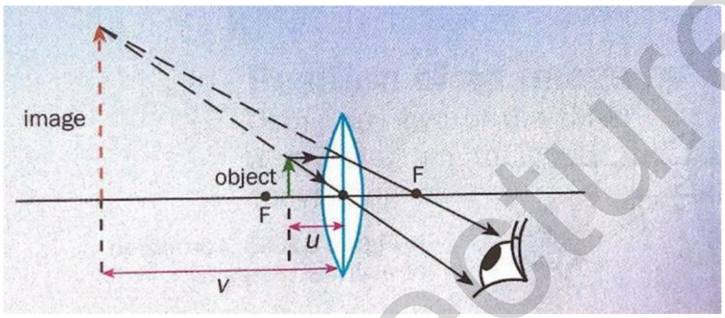
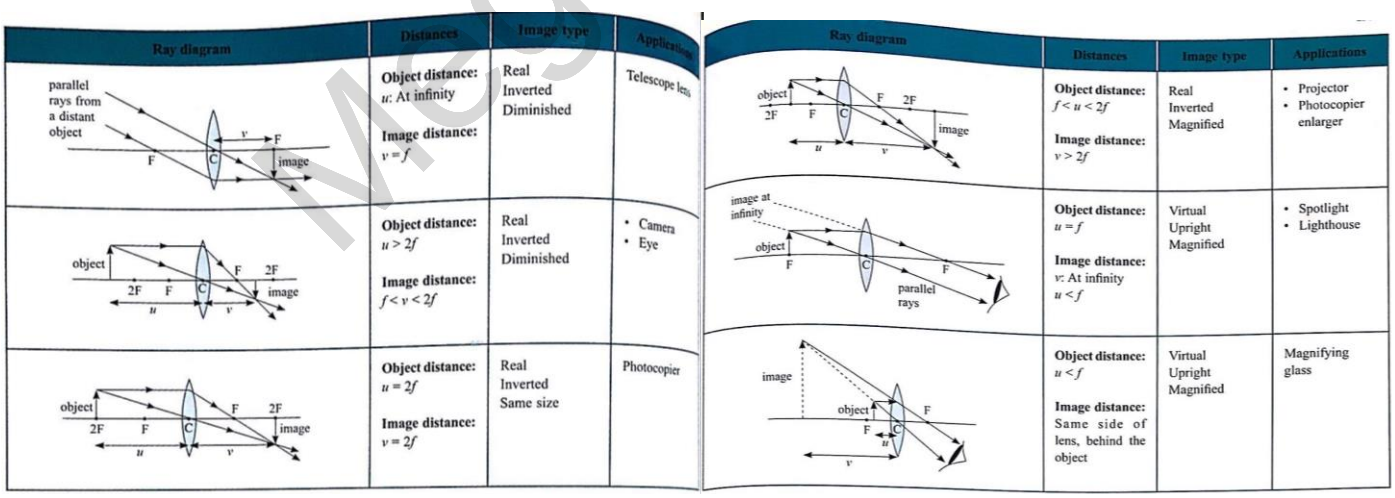
Case 6

- u < f
- v = behind object
- upright, magnified, virtual
- Used in magnifying glass



Summary of ray diagrams



Ray diagram	Distances	Image type	Applications
	Object distance: u: At infinity **Image distance:** $v = f$	Real Inverted Diminished	Telescope lens
	Object distance: $u > 2f$ **Image distance:** $f < v < 2f$	Real Inverted Diminished	• Camera • Eye
	Object distance: $u = 2f$ **Image distance:** $v = 2f$	Real Inverted Same size	Photocopier

Ray diagram	Distances	Image type	Applications
	Object distance: $f < u < 2f$ **Image distance:** $v > 2f$	Real Inverted Magnified	• Projector • Photocopier enlarger
	Object distance: $u = f$ **Image distance:** v: At infinity $u < f$	Virtual Upright Magnified	• Spotlight • Lighthouse
	Object distance: $u < f$ **Image distance:** Same side of lens, behind the object	Virtual Upright Magnified	Magnifying glass

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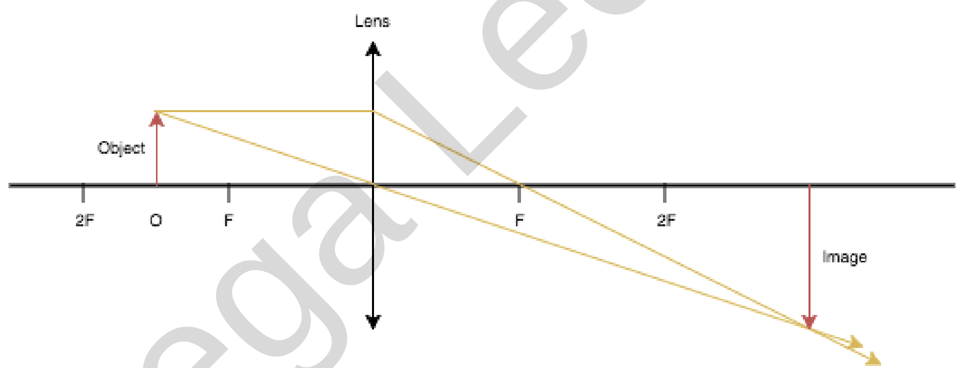
How to Draw Ray Diagrams

- Draw two arrows from the top of the object to indicate the light rays reflected from the object (must draw b)
  - Light ray parallel to principal axis
  - Light ray that passes through optical centre
- Locate point where the light rays intersect and draw the top of the image there
- If the focal point is not on the opposite side of the lens (i.e. light rays diverge as below), extend the light rays until they converge and draw the image there



Example 1:

If the focal length of the camera is 10 cm, where should the object be placed from the camera?

- Not 20 cm (exactly 2F), >20cm

Example 2:

A light ray travels into a thin converging lens. Which is the emergent ray?

- A: Draw an object to the light ray + another light ray through the optical center as this ray will not bend, and will converge with the emerging ray

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Example 3:

Half the lens is blocked. What changes occur to the image formed?

- Less bright

Example 4:

A lens forms a blurred image of an object on a screen. How can image be focused on screen?

- Use a lens of longer focal length at the same position

Example 5:

A glass block is replaced with one which has higher refractive index. Total internal reflection now occurs at the top surface. Why?

- With higher refractive index, light ray is refracted more when it enters the glass block → Smaller angle of refraction and larger angle of incidence at B (inside block) that is greater than critical angle → Total internal reflection
- As **refractive index increases**, **critical angle** becomes **smaller** → Angle of incidence is now greater than critical angle → Total internal reflection