PHYSICS 534

ANSWERS

EX SE-52 Lens Part-1 /2

YUKAWA

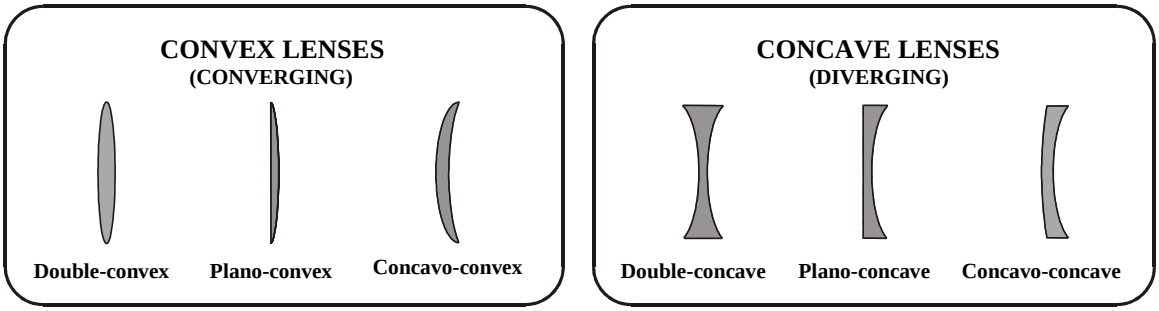
Hideki Yukawa received the Nobel prize for physics in 1949 for his theoretical work on nuclear physics.

LENSES

Whereas mirrors produce images by reflection, lenses produce images by refraction. Depending upon their "thickness", lenses are classified as "thick" or "thin". In this course, we will only consider "thin" lenses. In effect, therefore, we disregard the thickness of the lens assuming it to be a line.

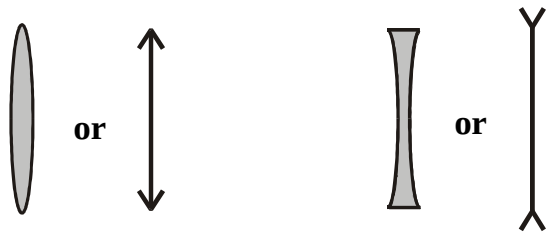
There are two main types of lenses called ***convex*** (also known as ***converging***) and ***concave*** (also known as ***diverging***). Convex lenses are thicker in the middle than at the edges while concave lenses are thicker at the edges than in the middle.

Both convex and concave lenses each have three variations as illustrated below.



↳ ***REMEMBER***: Convex lenses are thicker in the middle and thinner at the edges while concave lenses are thinner in the middle and thicker at the edges.

When representing "thin" lenses in a diagram, it is sometimes more convenient to simply draw an arrow rather than the actual lens. Using this method, an arrow is used to represent the lens as illustrated below.



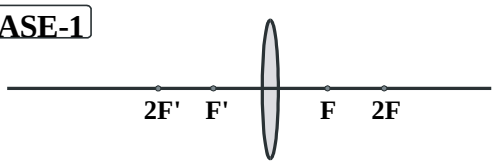
Convex Lens **Concave Lens**

- **Sign convention:**
  - ① Object distance is always positive.
  - ② Image distance is positive if the image is on the side of the lens where light emerges (from lens).
  - ③ Image distance is negative if the image is on the side of the lens where the light enters (the lens).
  - ④ The focal length of a convex or converging lens (or mirror) is positive.
  - ⑤ The focal length of a concave or diverging lens (or mirror) is negative.

Just as with concave mirrors, the characteristics of the image formed by a converging lens depend upon the location of the object. There are six "strategic" locations where an object may be placed. For each location, the image will be formed at a different place and with different characteristics.

We will illustrate the six different locations and label them as **CASE-1** to **CASE-6**.

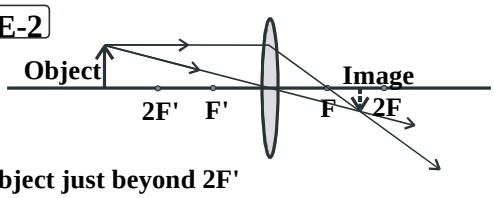
CASE-1



Object at infinity

No image

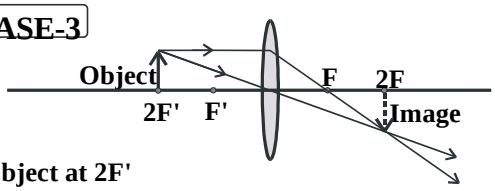
CASE-2



Object just beyond 2F'

Image is real, inverted, reduced, and located between F and 2F

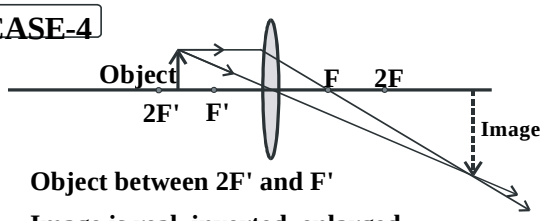
CASE-3



Object at 2F'

Image is real, inverted, same size as object, and located at 2F

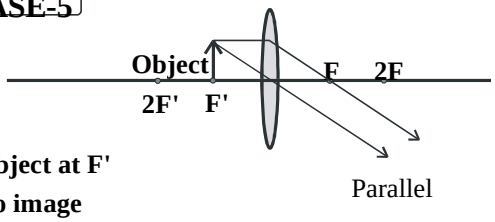
CASE-4



Object between 2F' and F'

Image is real, inverted, enlarged, and located beyond 2F

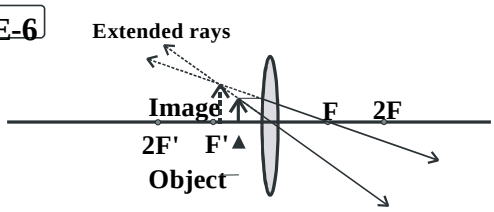
CASE-5



Object at F'

No image

CASE-6



Object within focal length

Image is virtual, upright, enlarged, and located on same side as object

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1. A lens that is ***thicker*** in the middle than at the ends is known as:

A **converging** lens or a **convex** lens.

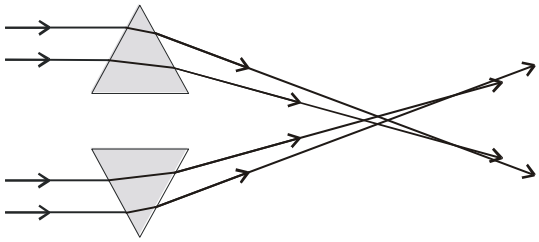
2. A lens that is ***thicker*** at the ends than in the middle is known as:

A **diverging** lens or a **concave** lens.

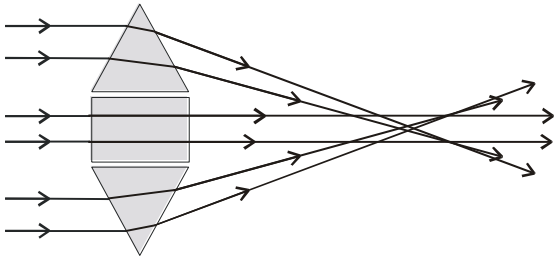
3. Trace the rays that emerge from the following glass mediums:

a)

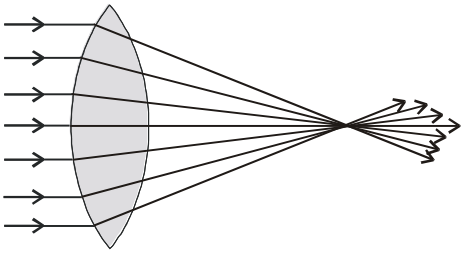
b)



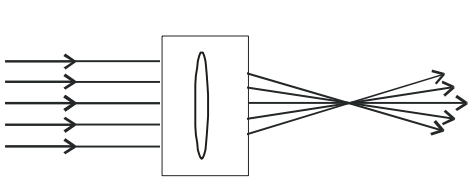
c)



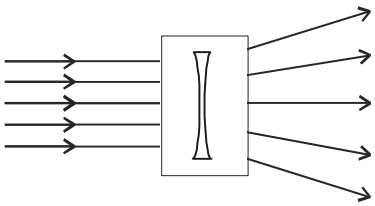
d)



4. For each case below, draw the appropriate lens that will produce the indicated rays.



(a)



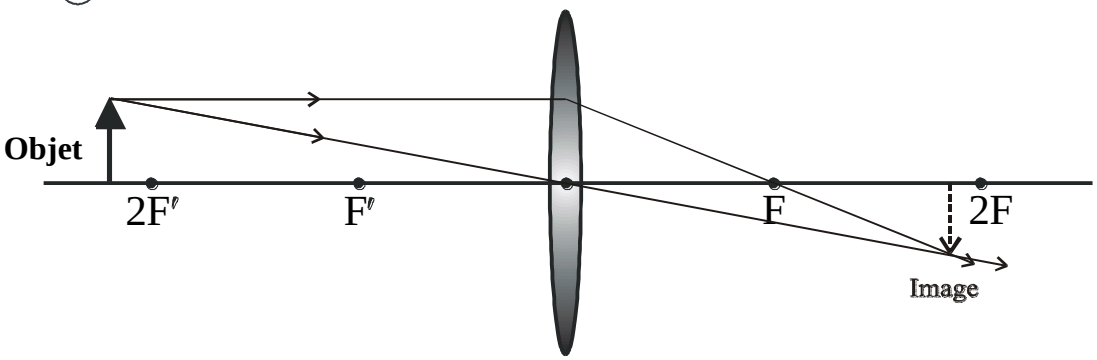
(b)

5. How is the image formed by a mirror different from the image formed by a lens?

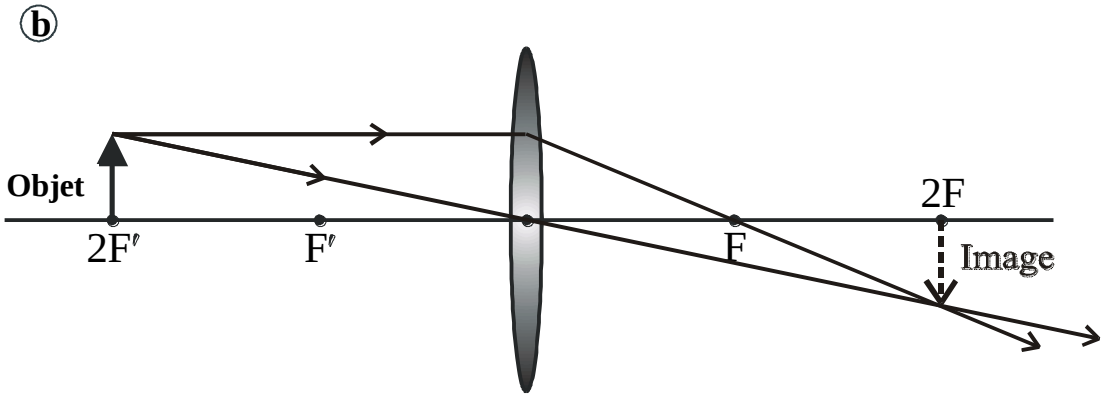
A mirror forms an image by reflection (reflected rays) whereas a lens forms an image by refraction (refracted rays).

6. For each ***convex*** lens illustrated below, draw the image.

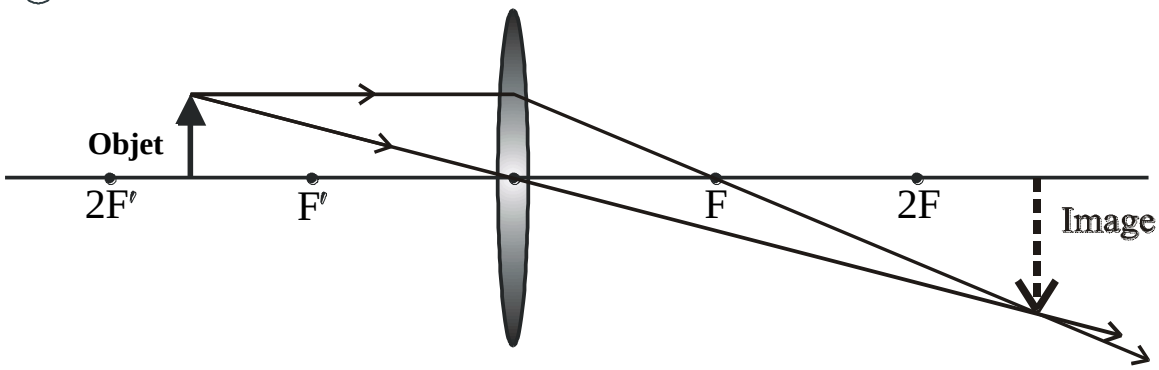
ⓐ



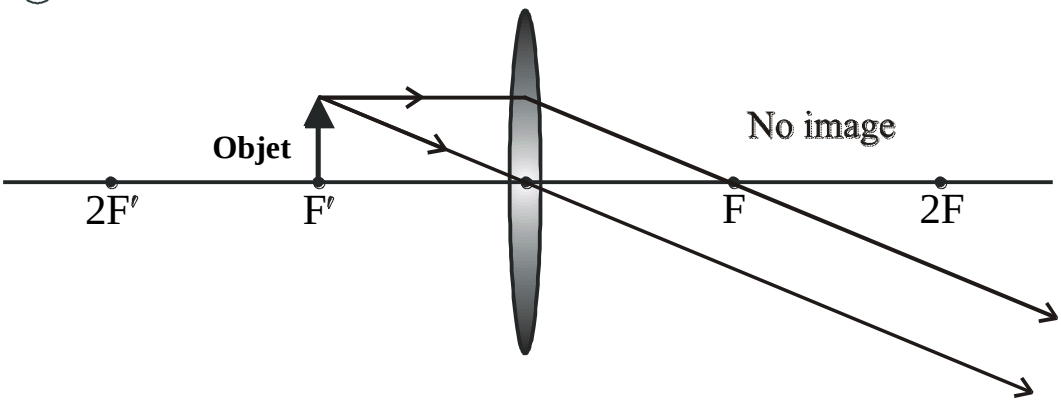
ⓑ



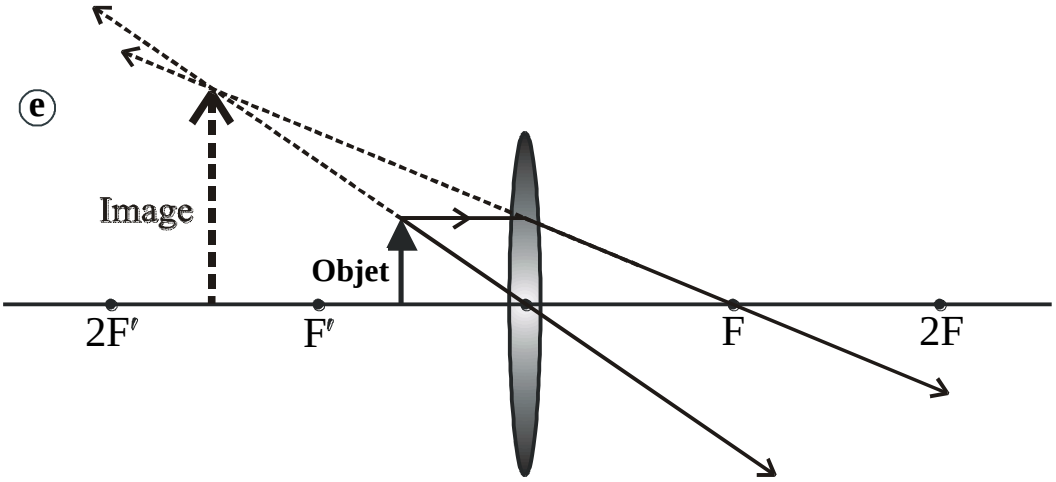
ⓒ



ⓓ

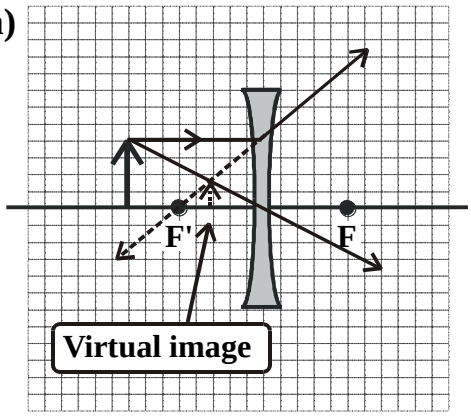


ⓔ

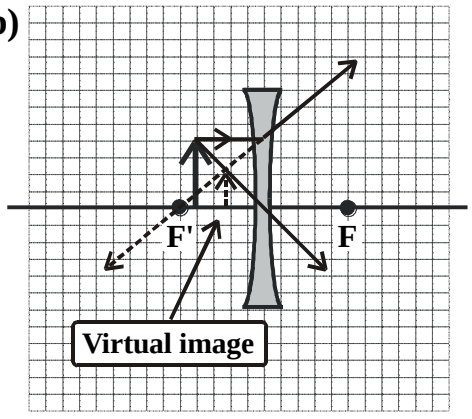


7. For each ***concave*** lens illustrated below, draw the image.

a)



b)



8. An object that is 7 cm high is placed 20 cm in front of a ***convex*** (converging) lens whose focal length is 15 cm. Determine the characteristics of the image:

$h_o = 7\text{ cm}$ $\quad h_i = ?$ $\quad f = 15\text{ cm}$

$d_o = 20\text{ cm}$ $\quad d_i = ?$

$\because \dfrac{1}{f} = \dfrac{1}{d_i} + \dfrac{1}{d_o}$

or $\dfrac{1}{d_i} = \dfrac{1}{f} - \dfrac{1}{d_o} = \dfrac{1}{15\text{ cm}} - \dfrac{1}{20\text{ cm}} \quad \therefore\ d_i = 60\text{ cm}$

$\because \dfrac{h_i}{h_o} = -\dfrac{d_i}{d_o} \quad \therefore\ h_i = -\dfrac{(60\text{ cm})(7\text{ cm})}{20\text{ cm}} = -21\text{ cm}$

$\because M = \dfrac{h_i}{h_o} = \dfrac{-21\text{ cm}}{7\text{ cm}} = -3$

Negative sign indicates inversion

Type: Real (real or virtual)

Location: 60 cm

Magnification: -3

Height: 21 cm

Attitude: Inverted (upright or inverted)

9. An object whose height is 4 cm is placed 50 cm from a ***concave*** (diverging) lens. If the focal length of the lens is 30 cm, determine the characteristics of the image:

$h_o = 4\text{ cm}$ $\quad h_i = ?$ $\quad f = -30\text{ cm}$

$d_o = 50\text{ cm}$ $\quad d_i = ?$

Reference (sign) is negative

$\because \dfrac{1}{f} = \dfrac{1}{d_i} + \dfrac{1}{d_o}$

or $\dfrac{1}{d_i} = \dfrac{1}{f} - \dfrac{1}{d_o} = \dfrac{1}{-30\text{ cm}} - \dfrac{1}{50\text{ cm}} \quad \therefore\ d_i = -18.75\text{ cm}$

$\because \dfrac{h_i}{h_o} = -\dfrac{d_i}{d_o} \quad \therefore\ h_i = -\dfrac{(-18.75\text{ cm})(4\text{ cm})}{50\text{ cm}} = 1.5\text{ cm}$

$\because M = \dfrac{h_i}{h_o} = \dfrac{1.5\text{ cm}}{4\text{ cm}} = 0.375$

Type: **Virtual** (real or virtual)

Location: **18.75 cm**

Magnification: **0.375**

Height: **1.5 cm**

Attitude: **Upright** (upright or inverted)

10. An object that is 5 cm high is placed 70 cm in front of a ***convex*** (converging) lens whose focal length is 20 cm. Determine the characteristics of the image:

$\mathbf{h_o = 5\text{ cm}}$ $\quad \mathbf{h_i = ?}$ $\quad \mathbf{f = 20\text{ cm}}$

$\mathbf{d_o = 70\text{ cm}}$ $\quad \mathbf{d_i = ?}$

$\because \dfrac{\mathbf{1}}{\mathbf{f}} = \dfrac{\mathbf{1}}{\mathbf{d_i}} + \dfrac{\mathbf{1}}{\mathbf{d_o}}$

or $\dfrac{\mathbf{1}}{\mathbf{d_i}} = \dfrac{\mathbf{1}}{\mathbf{f}} - \dfrac{\mathbf{1}}{\mathbf{d_o}} = \dfrac{\mathbf{1}}{\mathbf{20\text{ cm}}} - \dfrac{\mathbf{1}}{\mathbf{70\text{ cm}}} \quad \therefore\ \mathbf{d_i = 28\text{ cm}}$

$\because \dfrac{\mathbf{h_i}}{\mathbf{h_o}} = -\dfrac{\mathbf{d_i}}{\mathbf{d_o}} \quad \therefore\ \mathbf{h_i = -\dfrac{(28\text{ cm})(5\text{ cm})}{70\text{ cm}} = -2\text{ cm}}$

$\because \mathbf{M = \dfrac{h_i}{h_o} = \dfrac{-0.2\text{ cm}}{5\text{ cm}} = -0.04}$

Negative sign indicates inversion

Type: **Real** (real or virtual)

Location: **28 cm**

Magnification: **-0.4**

Height: **2 cm**

Attitude: **Inverted** (upright or inverted)