CHAPTER 5: LIGHT

In each of the following sentences, fill in the bracket the appropriate word or words given below.

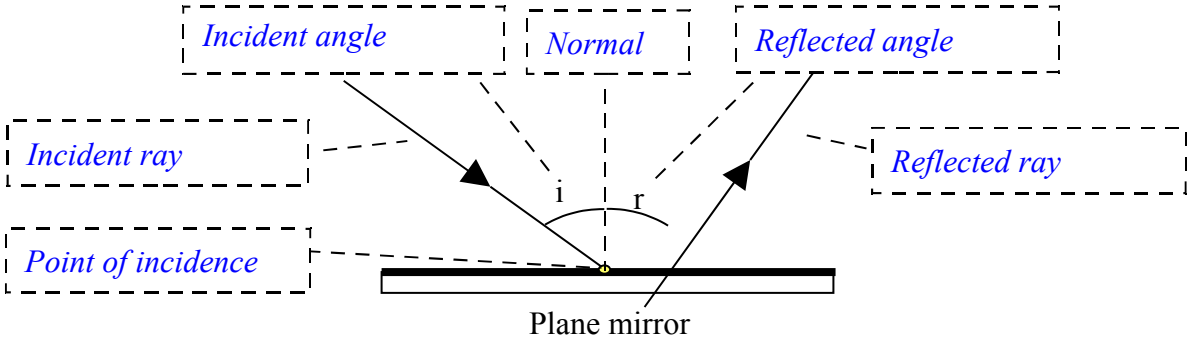
solid, liquid, gas, vacuum, electromagnetic wave, energy

1. Light is a form of (*energy*).
2. It travels in the form of (*Electromagnetic wave*)
3. In can travel through (*Solid, liquid, gas and vacuum*)
4. It travels fastest in the medium of (*vacuum*)
5. Light of different colours travels at the same speed in the medium of (*vacuum*)

Light allows us to see objects.
Light can be reflected or refracted.

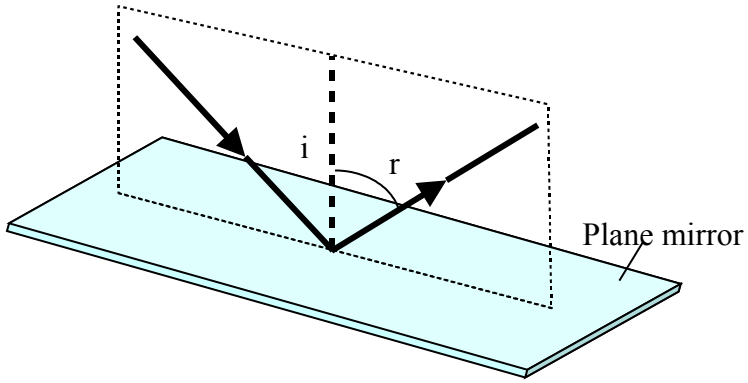
5.1 UNDERSTANDING REFLECTION OF LIGHT

Plane mirror and reflection: In the boxes provided for the diagram below, write the name of each of the parts indicated.



Laws of Reflection: State the laws of reflection.

(i) *The incident ray, the reflected ray and the normal to the point of incidence, all lie in the same plane.*

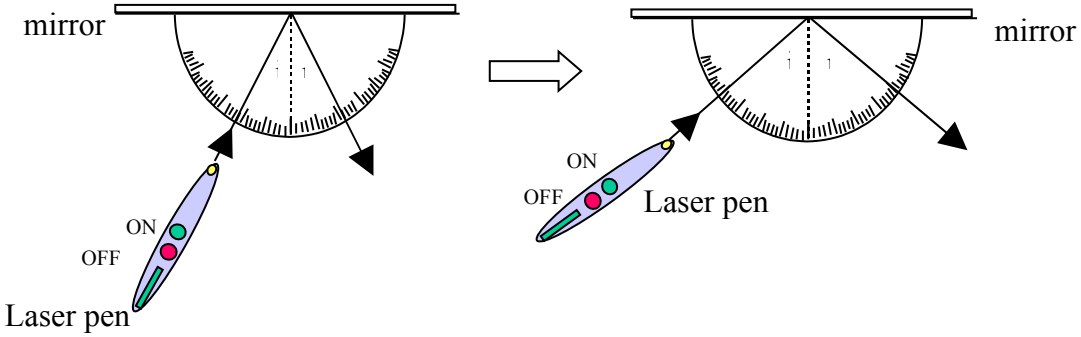


(ii) ……

The angle of incidence, i = The angle of reflection, r

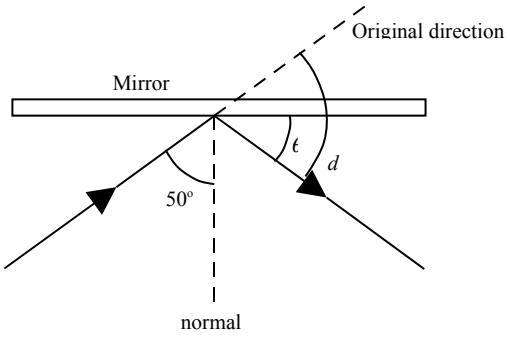
……
…..

Exercise 1. The diagram below shows how the relationship between incident angle and reflected angle can be investigated.
Fill in the values of the angles of reflection, *r* in the table below



*ir*10*10*20*20*30*30*40*40*50*50*

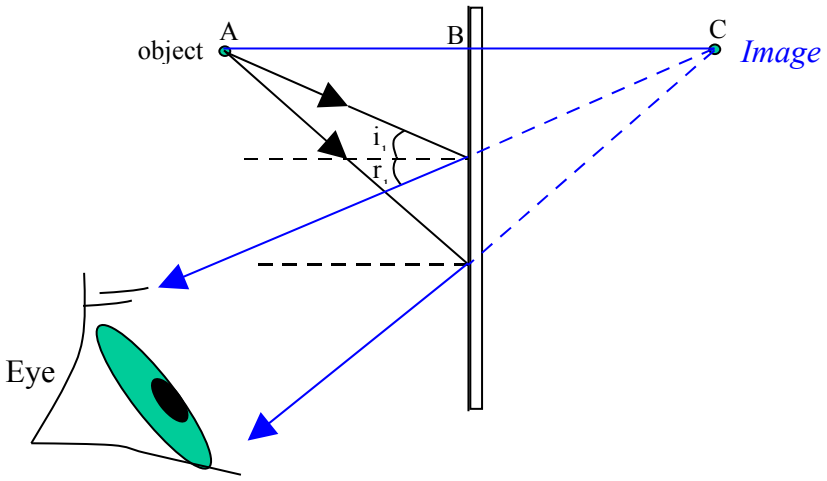
Exercise 2:



Based on the diagram on the left, calculate the angle, θ. Hence determine the angle of deviation, *d*.

$\theta = 40^o$
$d = 80^o$

<u>Image formed by a plane mirror</u>: Using the law of reflection, complete the ray diagram to determine the position of the image.



Perpendicular to the mirror

What can you say about the line joining object and image? ……

AB = BC

What can you say about the distances AB and BC? ……..

<u>Differences between real and virtual image</u>:

Real image	Virtual image
Can be caught on a screen	Cannot be caught on a screen
Formed by the meeting of real rays.	Form at a position where rays appear to be originating.

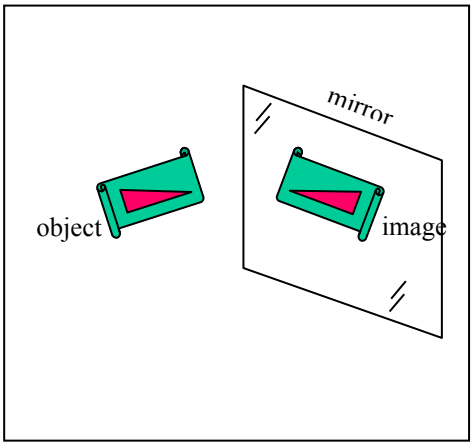
<u>Characteristics of image formed by plane mirror</u>: Observe the pictures below as well as using previous knowledge, list the characteristics.

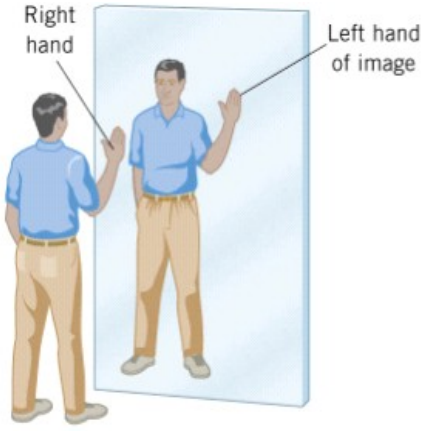
i) *virtual*

ii) *laterally inverted*

iii) *same size as object*

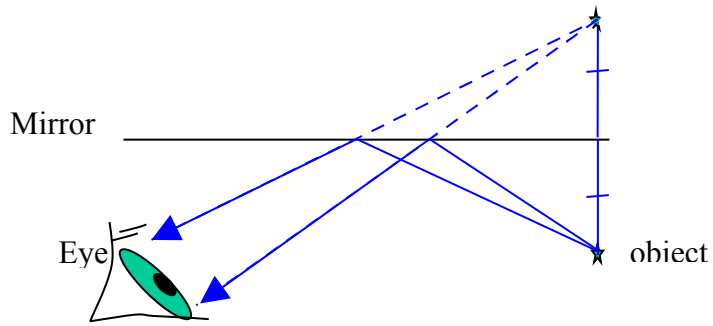
iv) *object distance = image distance*





Exercise 1:

Complete the ray diagram below consisting of 2 rays originating from the object, reflected and entering the eye such that the eye sees the image.



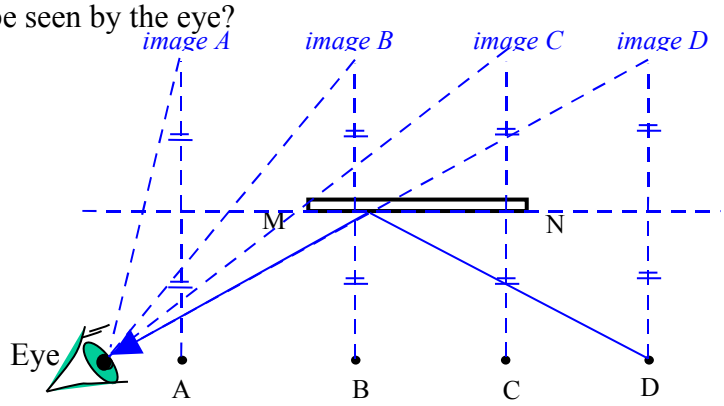
Exercise 2:

Ahmad is moving with speed 2 m s^{-1} towards a plane mirror. Ahmad and his image will approach each other at

1 m s^{-1}
2 m s^{-1}
3 m s^{-1}
4 m s^{-1}

Exercise 3:

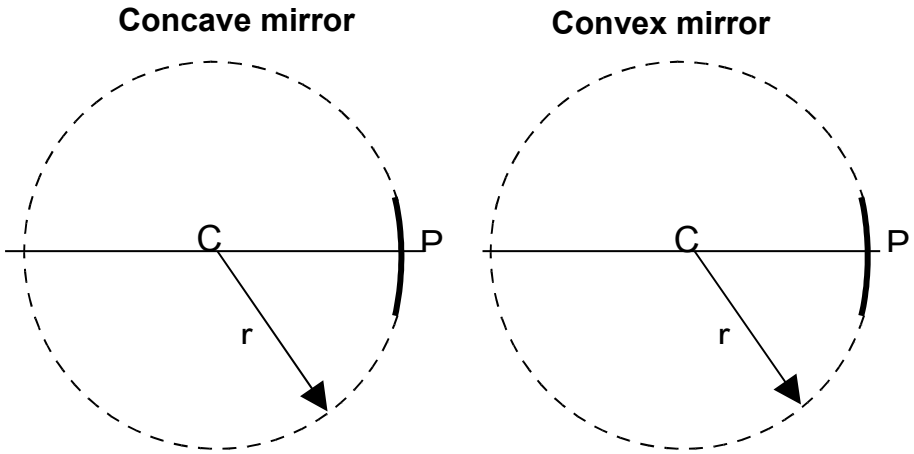
Four point objects A, B, C and D are placed in front of a plane mirror MN as shown. Between their images, which can be seen by the eye?



Only image D can be seen because the line joining image D to the eye cuts the actual mirror

ACTIVITY: Find out some of the uses of plane mirrors (application of reflection).

Curved Mirrors:

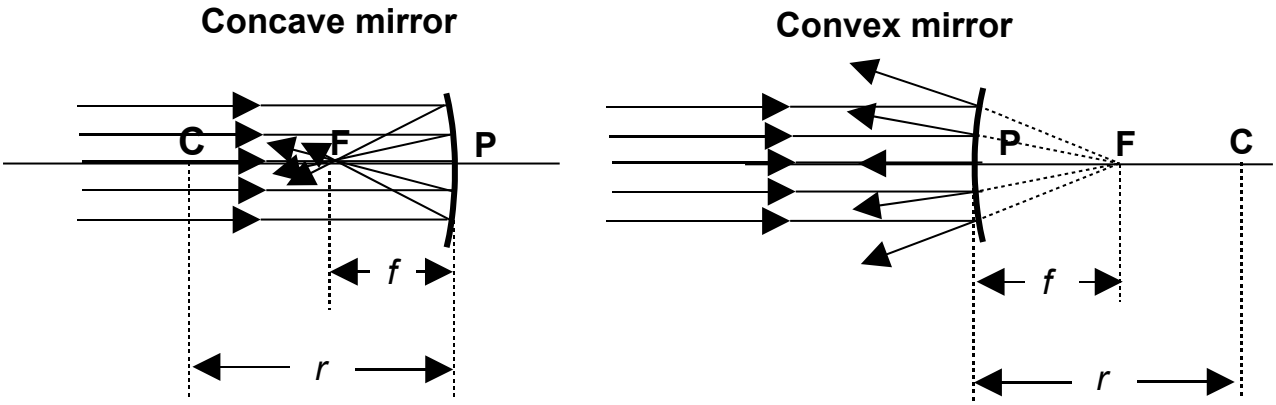


Terminology: Refer to the diagrams above and give the names for the following:

C = *Centre of curvature*
r = *Radius of curvature*
P = *Pole*
PC = *Principal axis*

Effect of curved mirrors on incident rays:

a) **Incident rays parallel to the principal axis**:



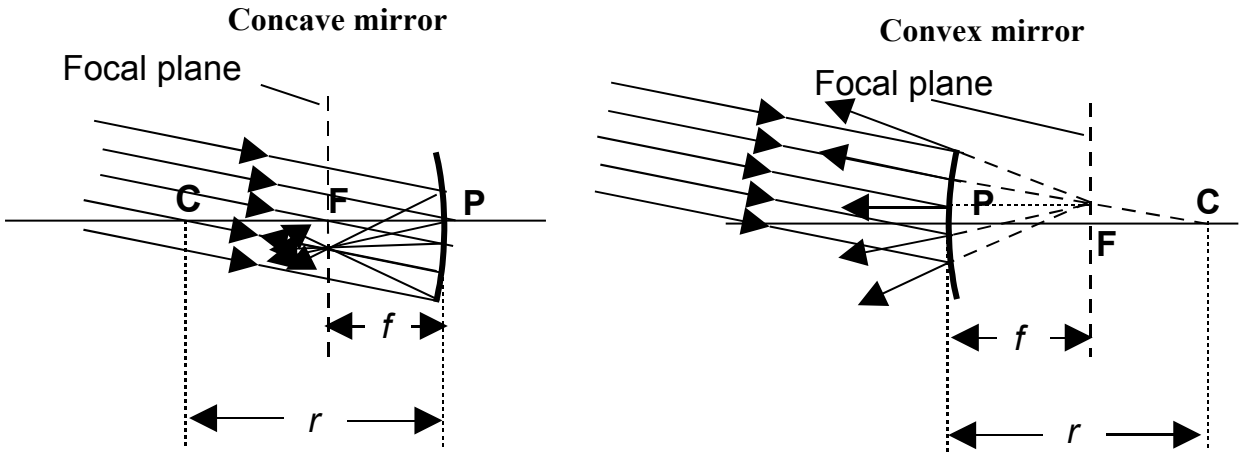
Study the diagrams above and fill in the blanks for the following sentences.

Rays parallel to the principal axis converge at the ……*Focal point*……, **F**
F is positioned at the ……*Mid point*….. between **C** and **P**
FP is named the ……*Focal length*…… which is denoted by ***f***.

Hence write an equation giving the relationship between *r* and *f*.

$r = 2f$

b) **Incident rays parallel to each other but not parallel to the principal axis**:



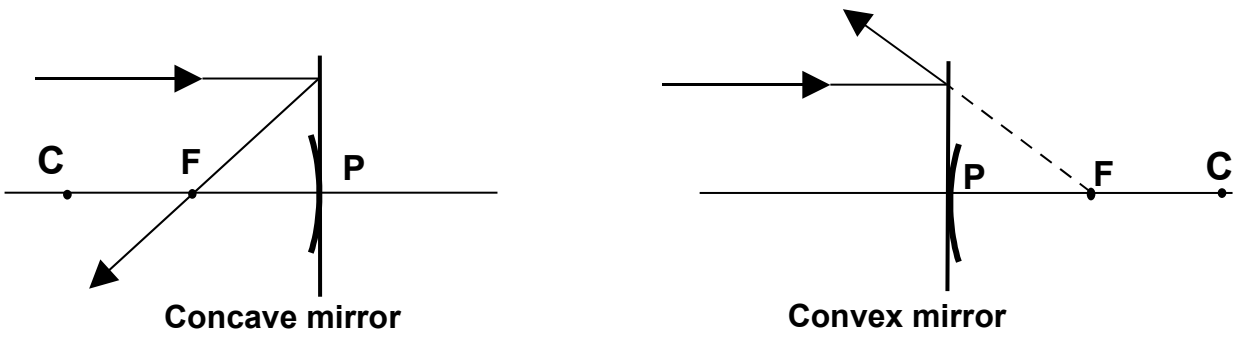
Study the diagrams above and fill in the blanks in the following sentences.

- Parallel rays converge at a point called ……*secondary focus*……
- The ray passing through **C** is reflected back along the line of the ……*secondary foci incident*……ray.
- The distance between the focal plane and the mirror is the ……*focal length*……*f*.

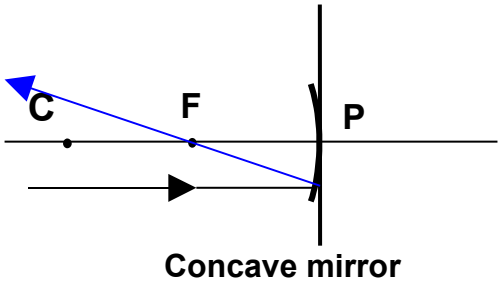
Image formed by curved mirror (ray diagram method)

Principle of drawing ray diagrams:

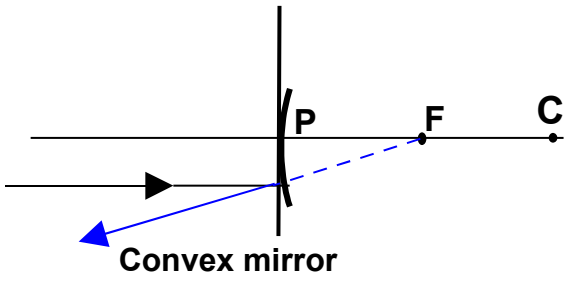
a. Rays parallel to the principal axis are reflected through the principal focus, F.



Exercise 1: Complete the ray diagrams below:

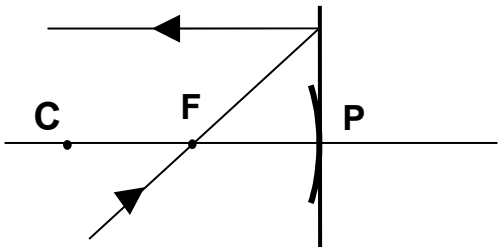


Concave mirror

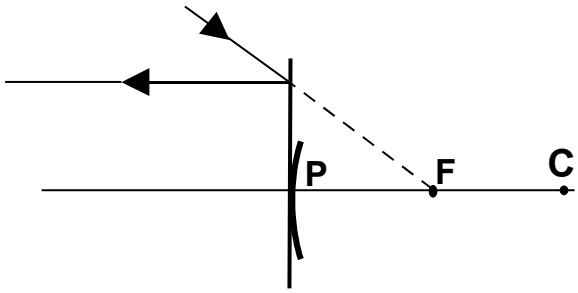


Convex mirror

b) **Rays passing through the principal focus are reflected parallel to the principal axis.**



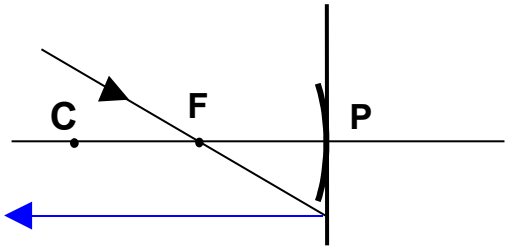
Concave mirror



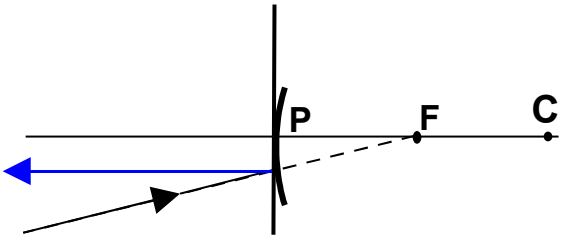
Convex mirror

Exercise 2:

a) Complete the ray diagrams below:

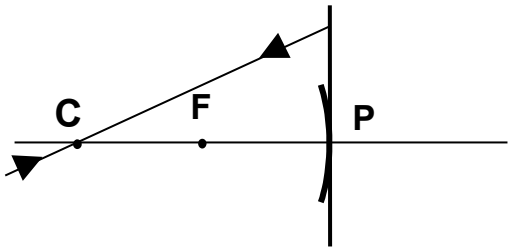


Concave mirror

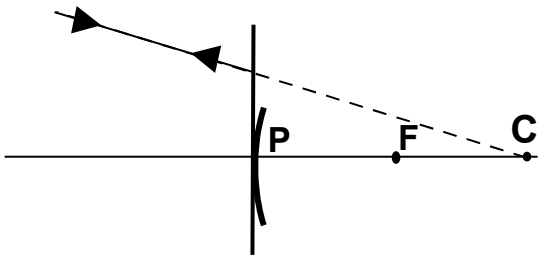


Convex mirror

b) Rays passing through the center of curvature are reflected directly back.

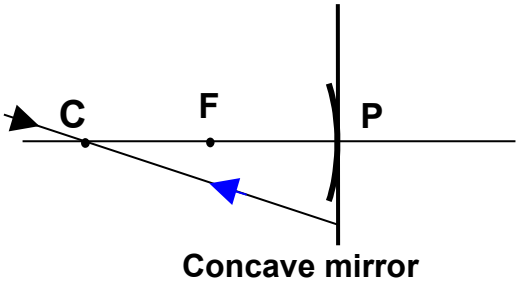


Concave mirror

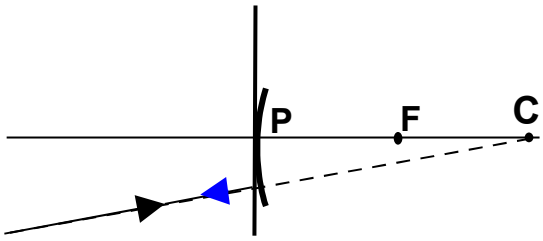


Convex mirror

Exercise 3: Complete the ray diagrams below:



Concave mirror



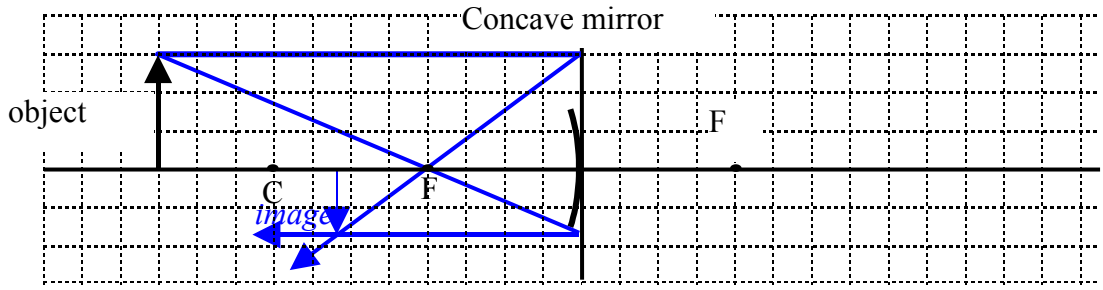
Convex mirror

Image formed by concave mirror:

Using the principles of construction of ray diagram, complete the ray diagrams for each of the cases shown below:

u = object distance ; ***v*** = image distance ; ***f*** = focal length ; ***r*** = radius of curvature

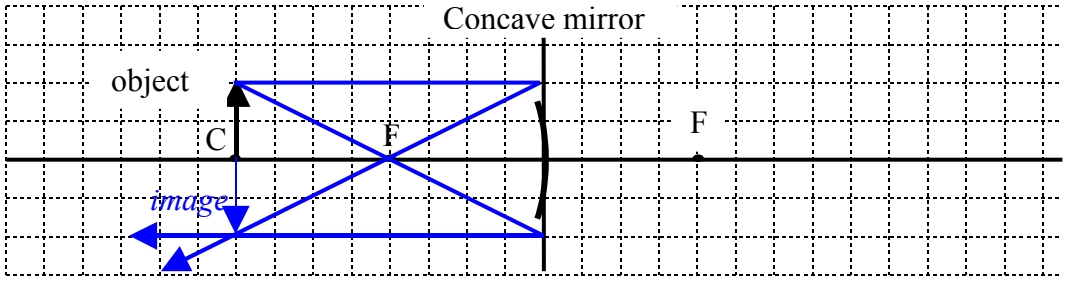
Case 1: *u* > 2*f*



Hence state the characteristics of image formed:

i) *diminished* ii) *real* iii) *inverted*

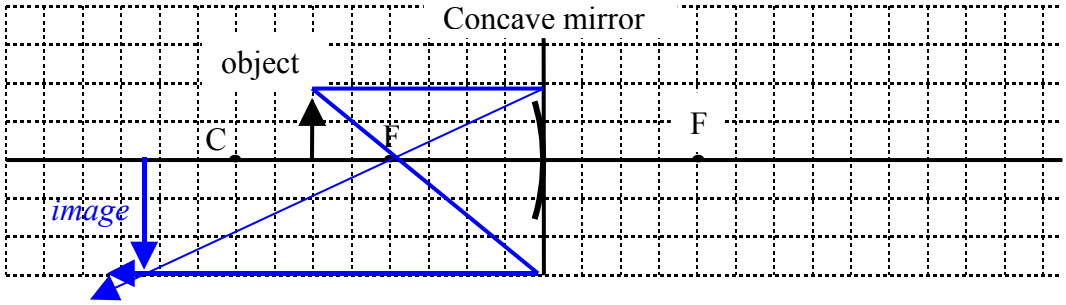
Case 2: *u* = 2*f* or *u* = *r*



Characteristics of image formed:

i) Same size ii) *real* iii) *inverted*

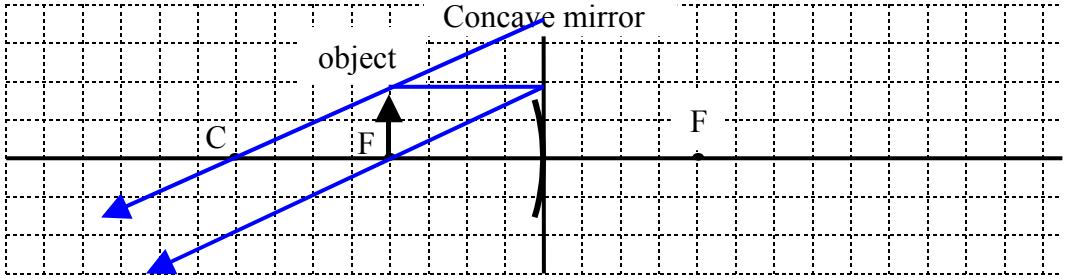
Case 3: $f < u < 2f$



Characteristics of image formed:

i) *magnified* ii) *real* iii) *inverted*

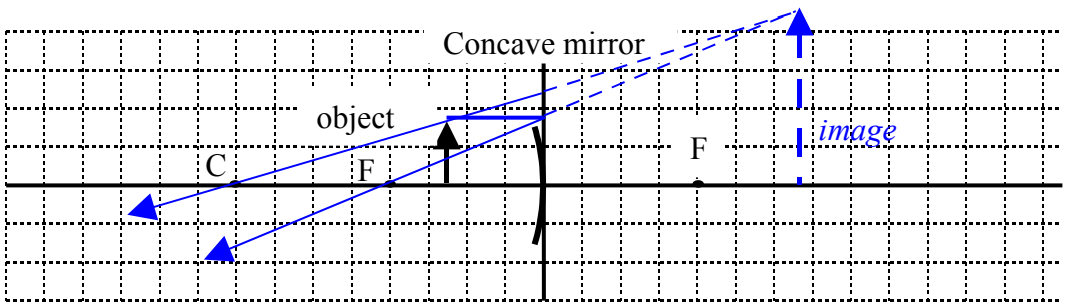
Case 4: $u = f$



Characteristics of image formed:

i) *Image at infinity*

Case 5: $u < f$

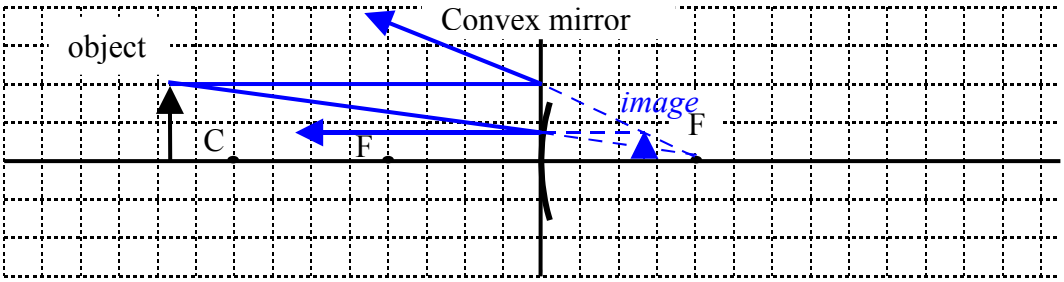


Characteristics of image formed:

i) *magnified* ii) *virtual* iii) *upright*

Image formed by convex mirror: (using construction of ray diagram).

u = object distance ; ***v*** = image distance ; ***f*** = focal length ; ***r*** = radius of curvature

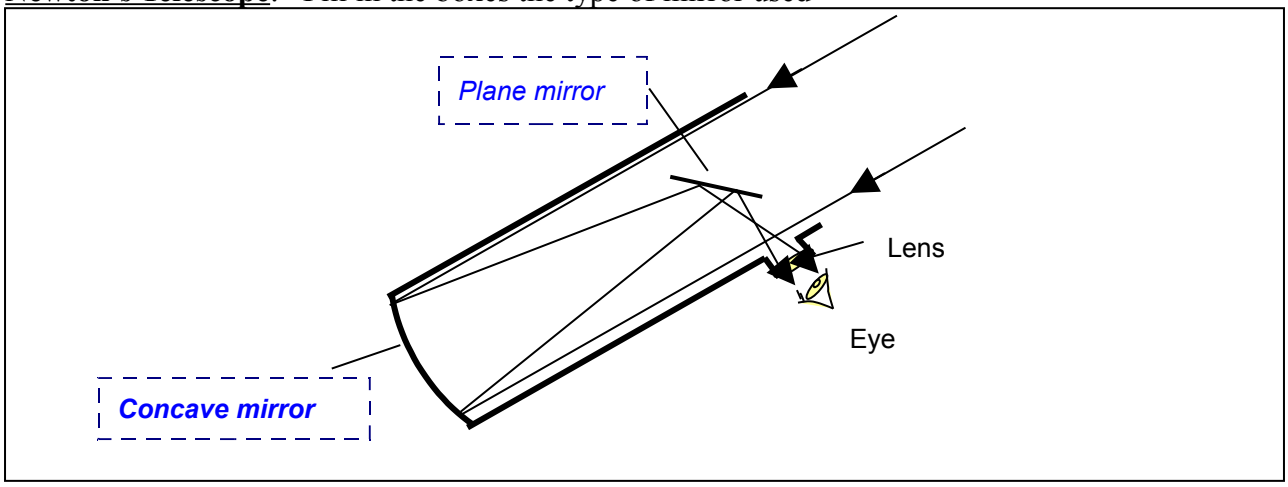


Characteristics of image formed:

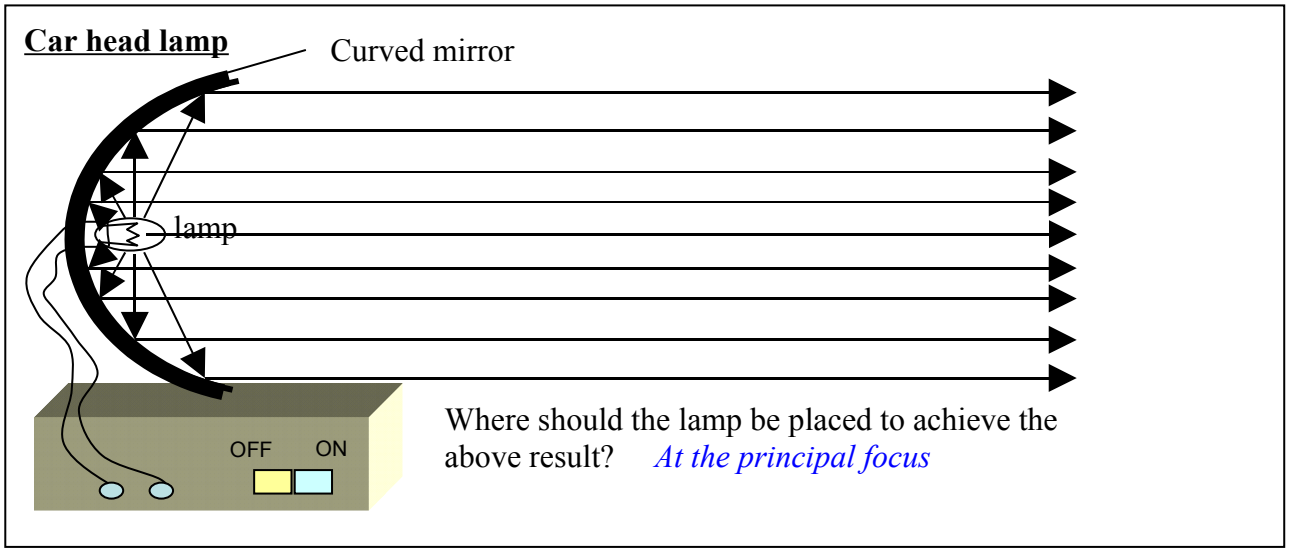
i) *diminished* ii) *virtual* iii) *upright*

Uses of curved mirrors:

Newton's Telescope: Fill in the boxes the type of mirror used

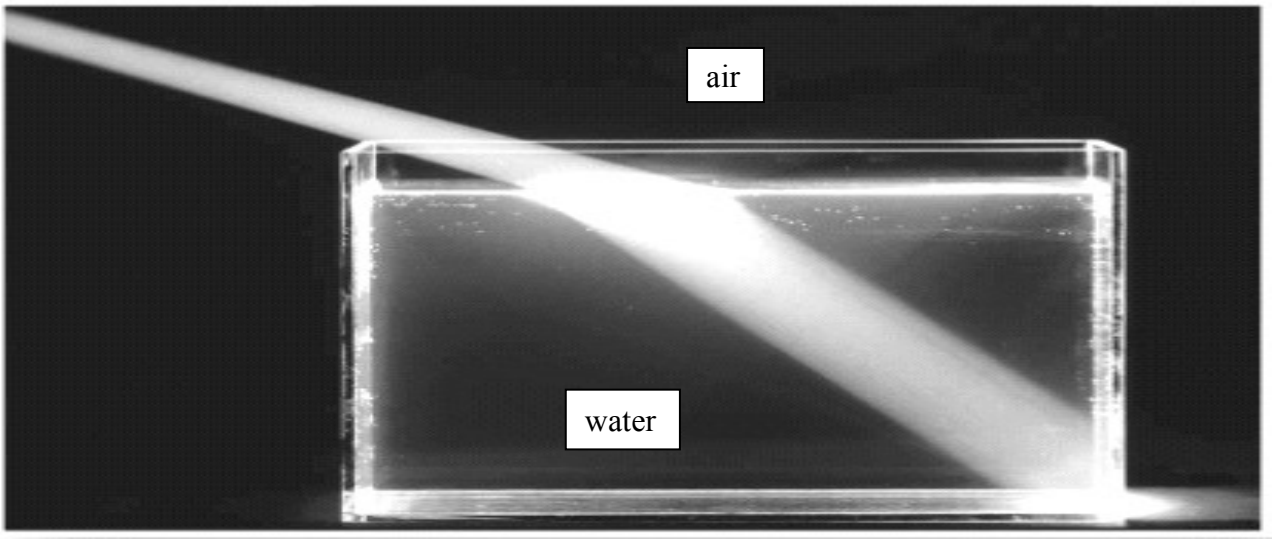


Car head lamp



Where should the lamp be placed to achieve the above result? *At the principal focus*

5.2 UNDERSTANDING REFRACTION OF LIGHT



What is the phenomenon which causes the bending of light in the picture above?

refraction

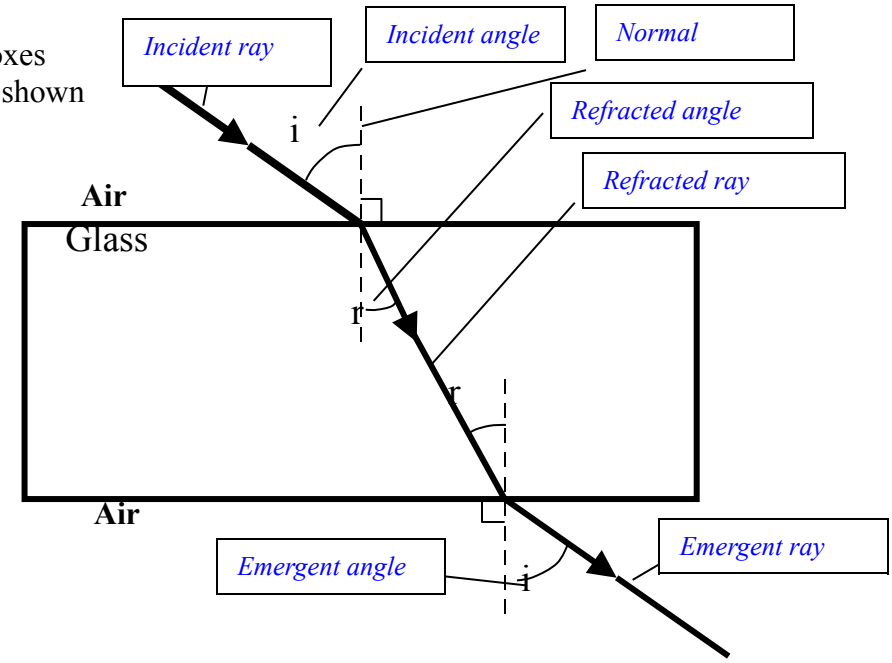
……
…

Why did this bending of light occur? (think in terms of velocity of light)

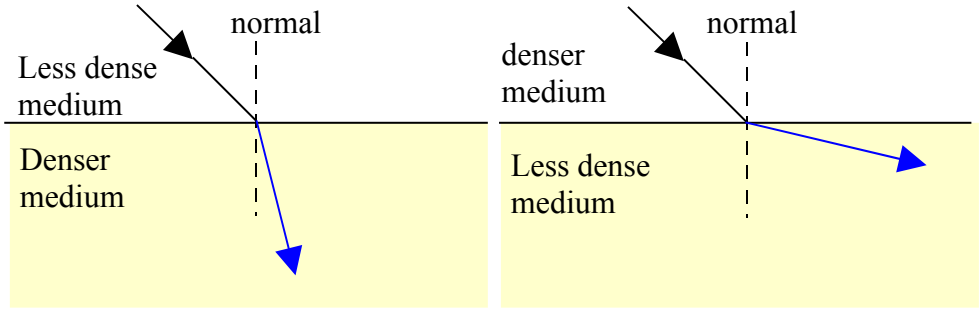
The velocity of light changes when it travels from one medium into another

……
…

<u>Refraction of light</u>:
Fill in each of the boxes
the name of the part shown



Direction of refraction:



Draw on the diagrams above the approximate directions the refracted rays.

When light travels from a less dense medium to a denser medium, the ray is refracted **(toward/away from)** the normal at point of incidence.

When light travels from a more dense medium to a less dense medium, the ray is refracted **(toward/away from)** the normal at point of incidence.

Snell's law:

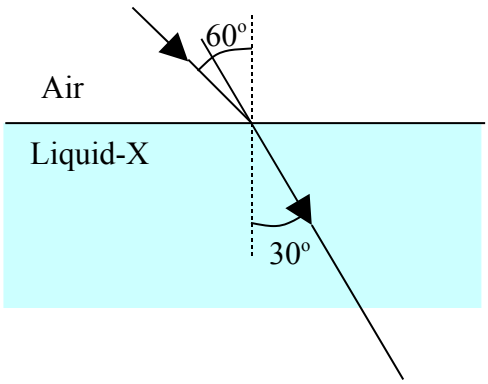
Snell's law states that ……*The ratio of* sin*(angle of incident) to* sin*(angle of refraction) is a constant*

$$i.e.\ \frac{\sin(incident\ \ angle)}{\sin(refracted\ \ angle)} = \text{constant}$$

What is the name and symbol of the constant? *Refractive index, n* ……..

Exercise 1:

Referring to the diagram on the right,
Calculate the refractive index of liquid-X.

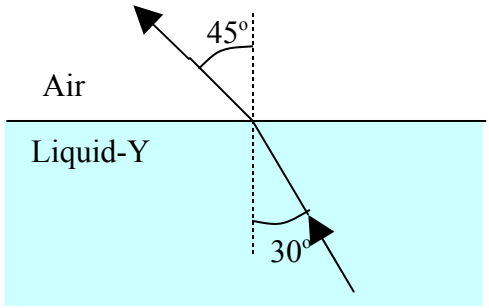


$$n = \frac{\sin(60^0)}{\sin(30^0)}$$

$= 1.732$

Exercise 2:

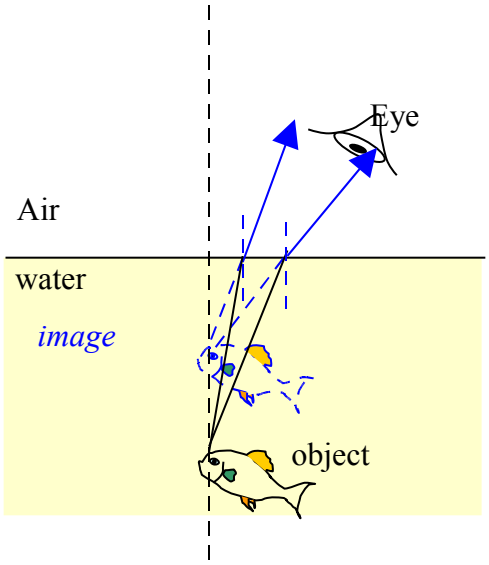
Referring to the diagram on the right,
Calculate the refractive index of liquid-Y.



n = 1.414

Exercise 3:

On the diagram to the right, draw two rays which originate from the fish to show how a person observing from above the surface of the water is able to see the image of the fish at an apparent depth less than the actual depth of the fish.



Exercise 4:
An equation that gives the relationship between apparent depth, real depth and the refractive index of water for the diagram above is

$$n = \frac{\text{real depth}}{\text{apparent depth}}$$

If the fish is at an actual depth of 4 m and the refractive index of water is 1.33, what is the apparent depth of the image?

Apparent depth = 3 m

5.3 UNDERSTANDING TOTAL INTERNAL REFLECTION OF LIGHT

Critical angle and total internal reflection:

Figures a, b and c show rays being directed from liquid-Y which is denser than air towards the air at different angles of incident,θ.

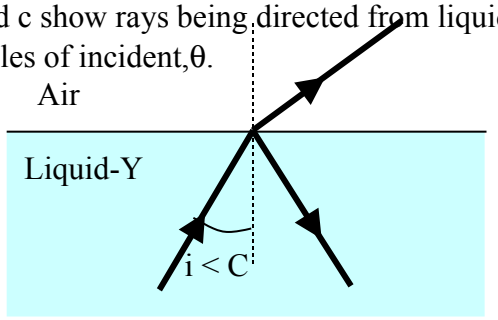


Figure a

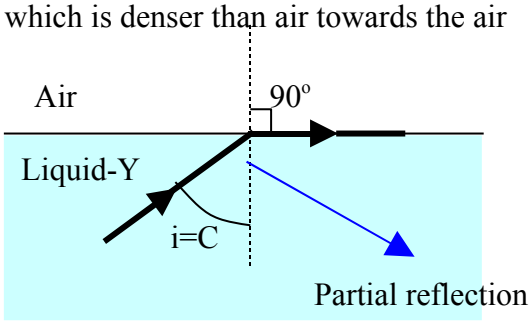


Figure b

Among the figures a, b and c, only Figure a has a complete ray diagram.

(i) Complete the ray diagrams for Figure b and Figure c.

(ii) The angle, *C* is called *Critical angle* .....

(iii) The phenomenon which occurs in Figure c yang is called *Total internal reflection* .....

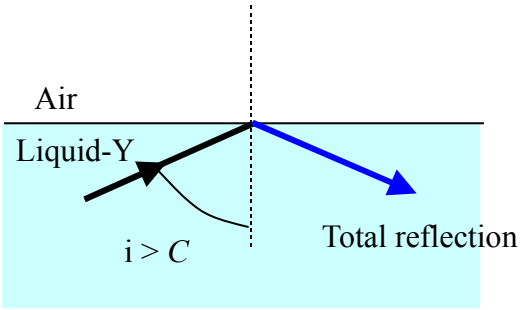


Figure c

(iv) State 2 conditions which must be satisfied in order for the phenomenon you mentioned in (iii) to occur.

Light must travel from denser medium to less dense medium
.....

The angle of incident must be greater than the critical angle
.....

Exercise 1:

Referring to figure d and using Snell's law, write an equation that gives the relationship between the critical angle, *C*, the refracted angle and the refractive index of liquid-Y

$$n = \frac{1}{\sin(C)}$$

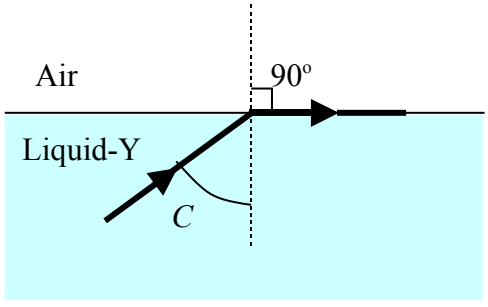


Figure d

Exercise 2:

Referring to Figure e, determine the refractive index of liquid-Z

$$n = \frac{1}{\sin(30^0)}$$

$= 2$

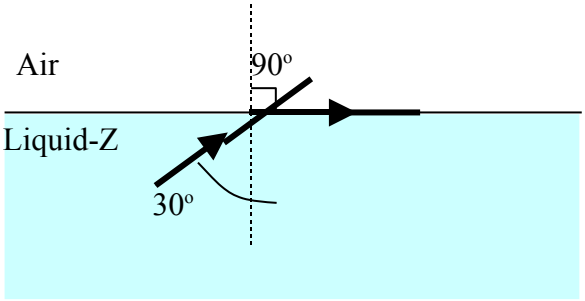
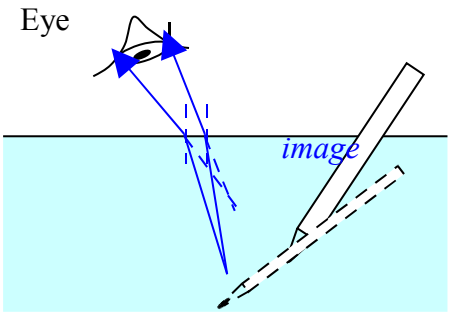


Figure e

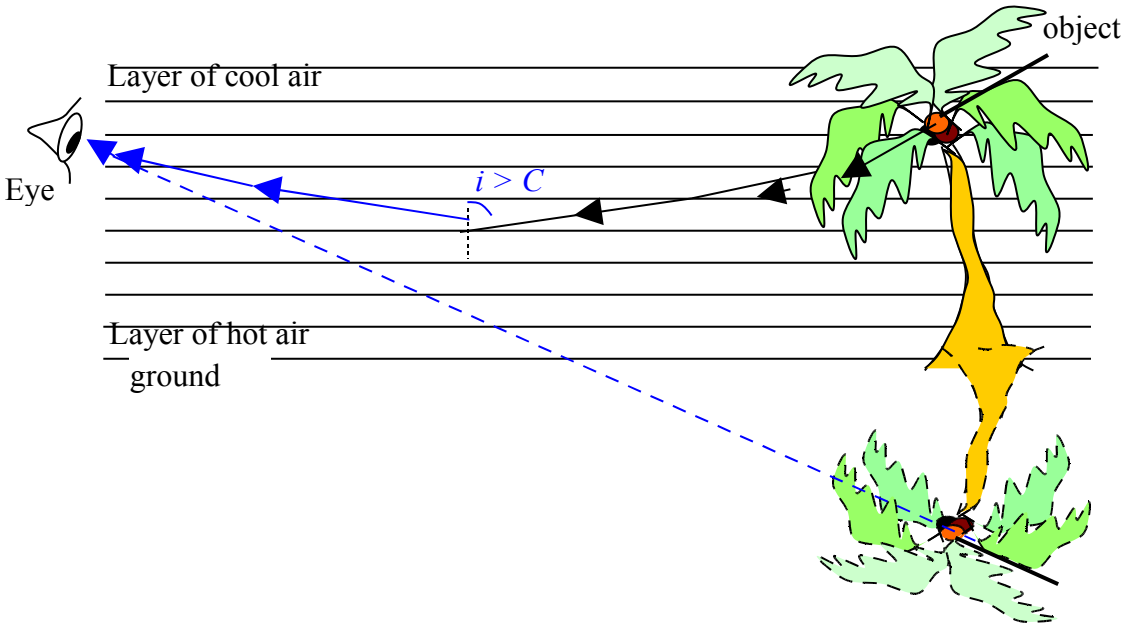
Exercise 3:

Explain why a pencil partially immersed in water looks bent.(Use a ray diagram).



Exercise 4:

Complete the path of the ray in the diagram below and explain how a mirage is formed.



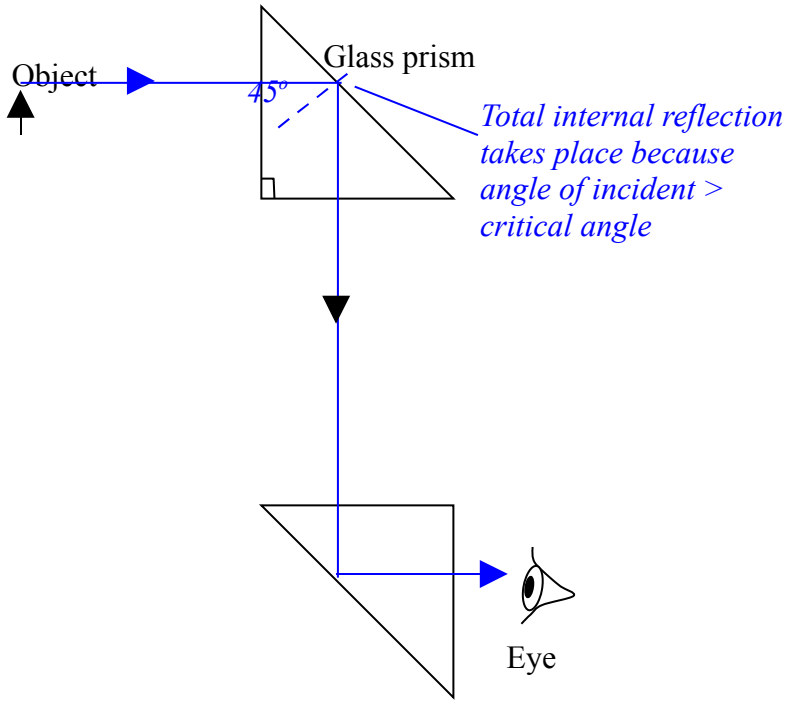
During the day, the ground is heated by the sun. The layer of air near the ground is hotter than the layers above. Hot air is less dense than cool air. Therefore ray from object is refracted away from

the normal. When angle of incident becomes larger than the critical angle, total internal reflection occurs. Thus a mirage is formed.

Image
(mirage)

Exercise 5:

Completing the ray diagram below, to show how a periscope works: (critical angle of glass = 42°)

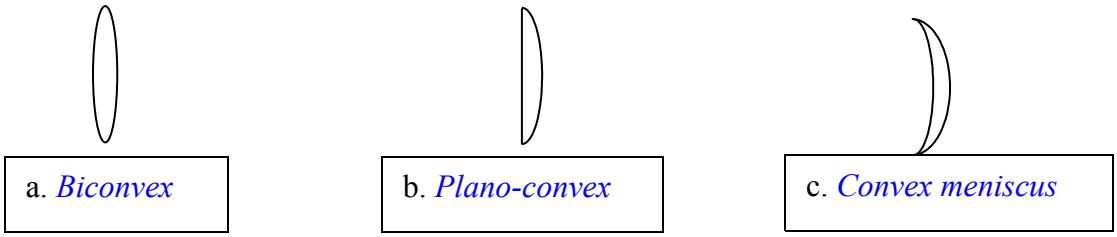


5.4 UNDERSTANDING LENSES

Thin Lenses :

Types of lenses : Name the types of lenses shown below.

(i)

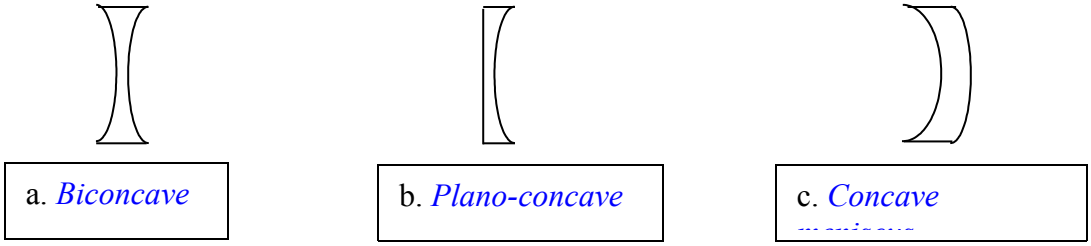


a. *Biconvex*

b. *Plano-convex*

c. *Convex meniscus*

(ii)

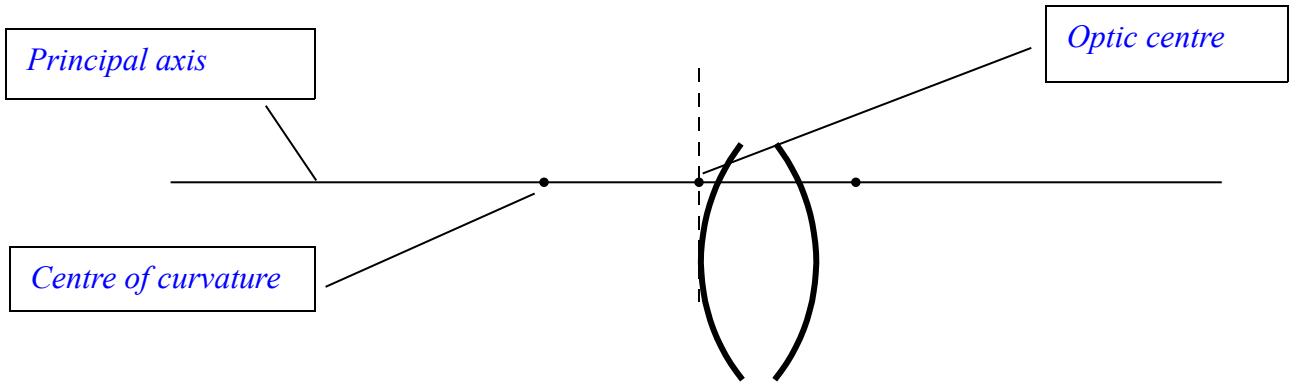


a. *Biconcave*

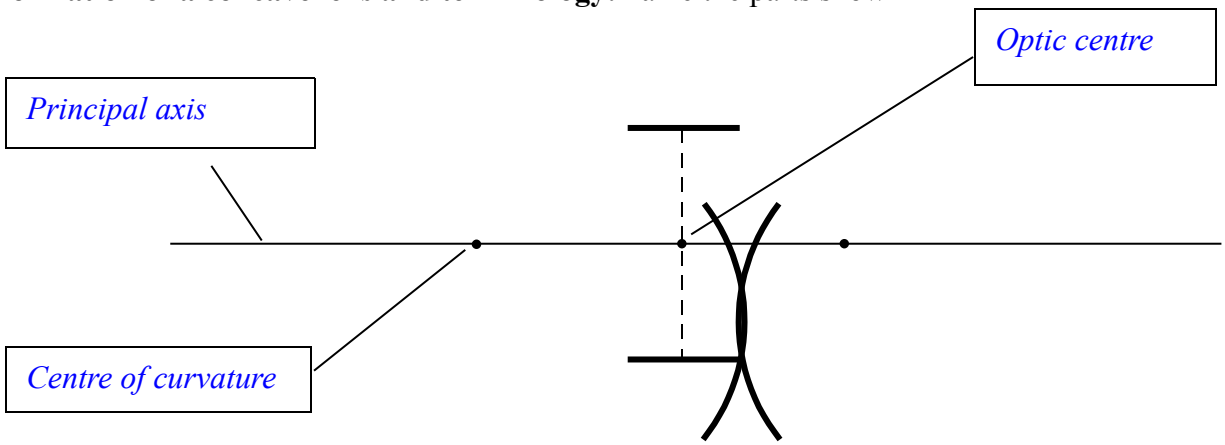
b. *Plano-concave*

c. *Concave*

Formation of a convex lens and terminology: name the parts shown



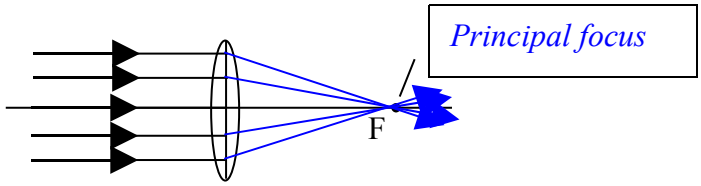
Formation of a concave lens and terminology: name the parts shown



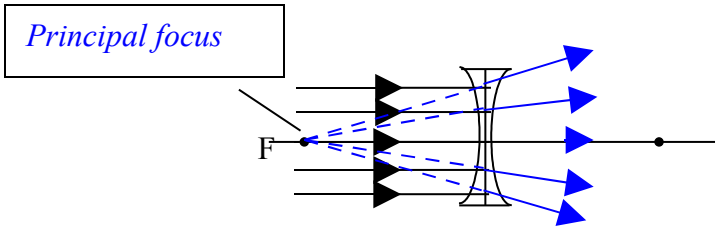
Refraction of rays parallel to the principal axis of a convex lens:

Draw in the following diagrams the paths of the rays after passing through the lens.
Write in the boxed provided, the name of the point or line shown.

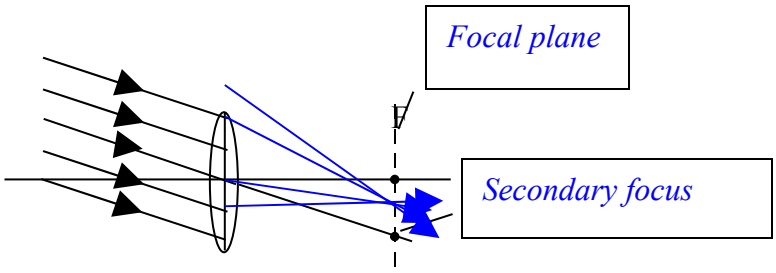
i)



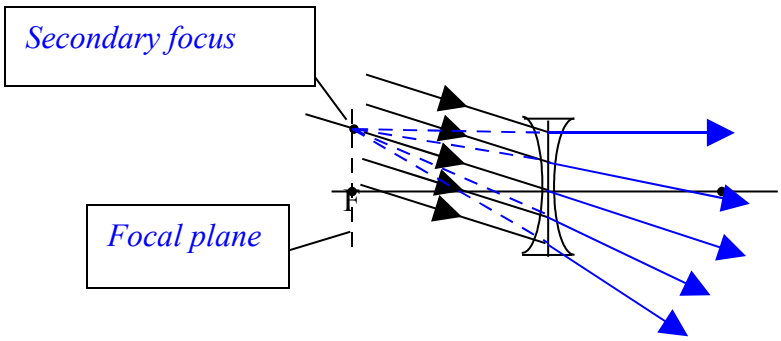
ii)



iii)

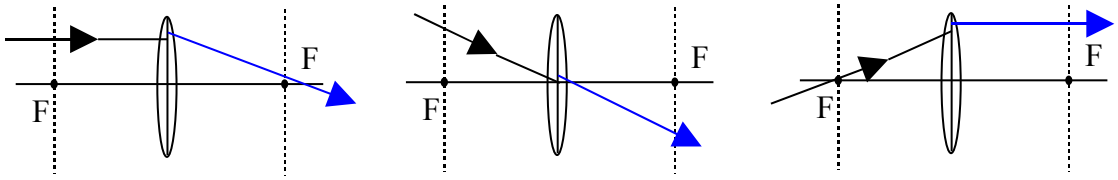


iv)

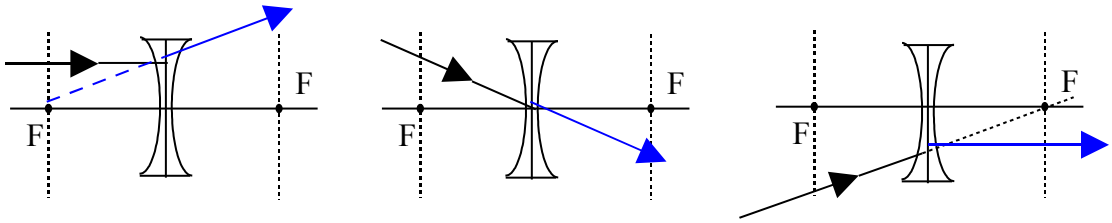


Principles of constructing ray diagrams: Complete the path of each ray after passing through the lens

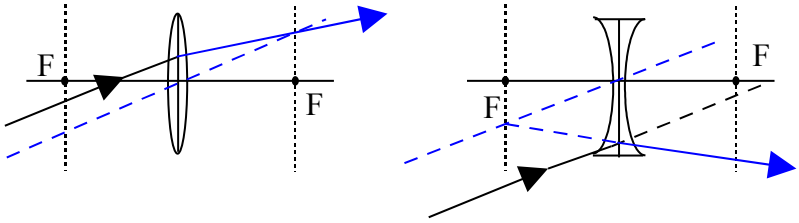
i) ii) iii)



iv) v) vi)



vii) viii)



Exercise 1:

State the meaning of each of the following terms:

i) Focal length , f : *The distance between optic centre and the principal focus*

ii) Object distance, u : *The distance between the object and optic centre*

iii) Image distance, v : *The distance between the image and the optic centre*

Exercise 2:

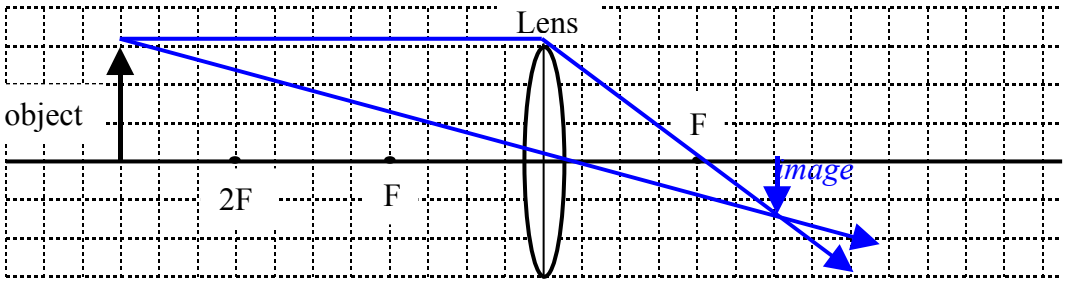
Describe how you would estimate the focal length of a convex lens in the school lab.

Place the lens facing the window on the far side of the lab. Adjust the distance of a screen behind the lens until a sharp image of the window is formed. Measure the focal length (distance between the lens and the image).

Characteristics of image formed by a convex lens : (Construction of ray diagram method)

Construct ray diagrams for each of the following cases and state the characteristics of the image formed.

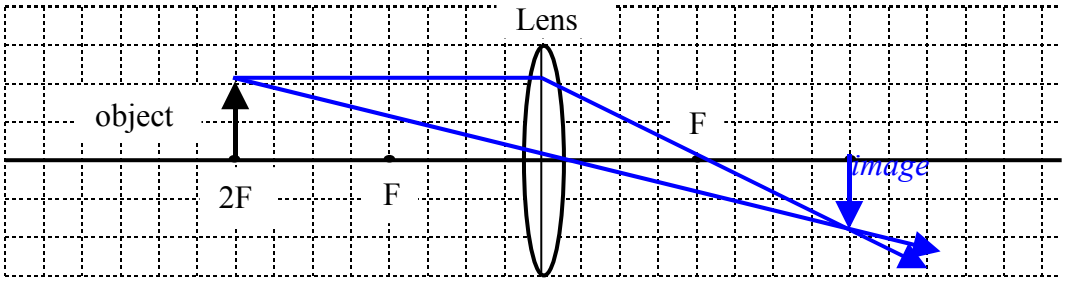
i) **Case 1** : $u > 2f$ where u = object distance ; and f = focal length of lens.



Characteristics of image:

Diminished, real and inverted

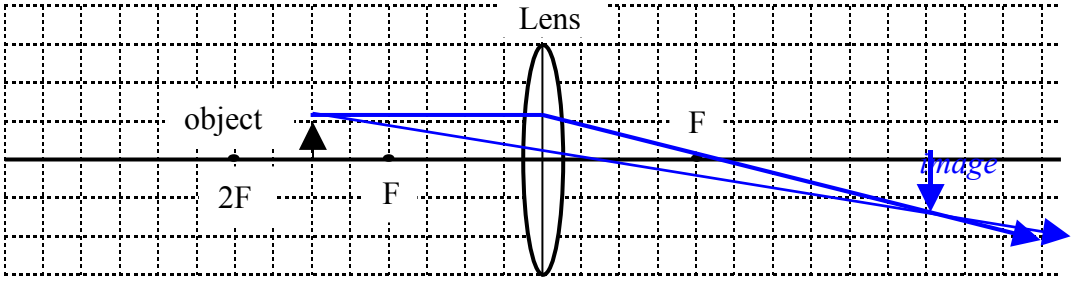
ii) **Case 2** : $u = 2f$



Characteristics of image:

Same size, real and inverted

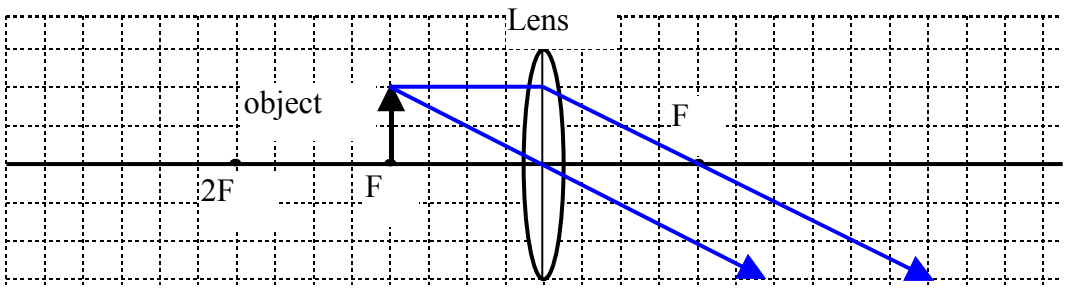
iii) **Case 3** : $2f > u > f$



Characteristics of image:

Magnified, real and inverted

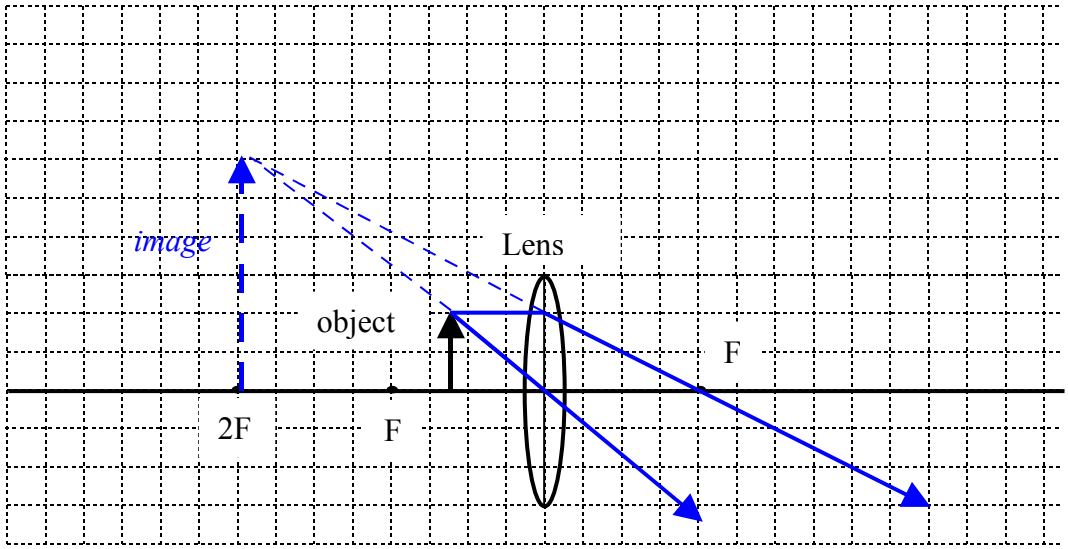
iv) Case 4 : $u = f$



Characteristics of image:

Image at infinity

v) Case 5 : $u < f$



Characteristics of image:

Magnified, virtual, upright

Exercise:

In each of the following statements below, fill in the space provide one of the following conditions.
($u > 2f$ / $2f = u$ / $2f > u > f$ / $u > f$ / $u < f$)

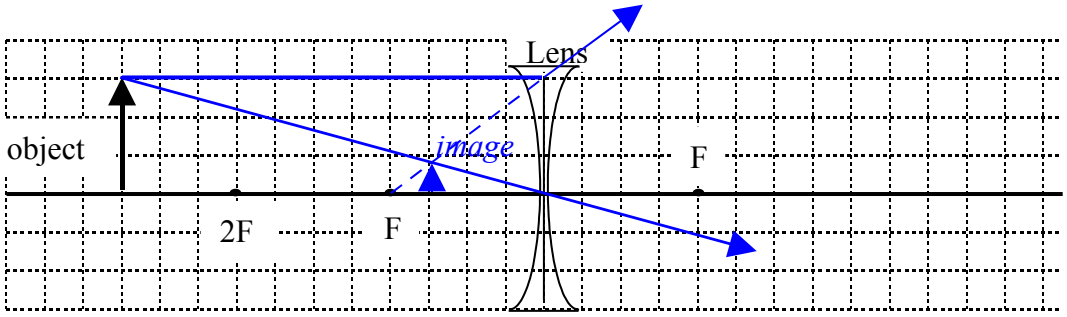
i) To obtain a real image, the object must be placed at a distance u such that … *$u > f$* ……

ii) To obtain a virtual image, the object must be placed at a distance u such that *$u < f$* ……

Characteristics of image formed by concave lens : (by construction of ray diagrams)

Construct a ray diagram for each of the following and state the characteristics of the image formed

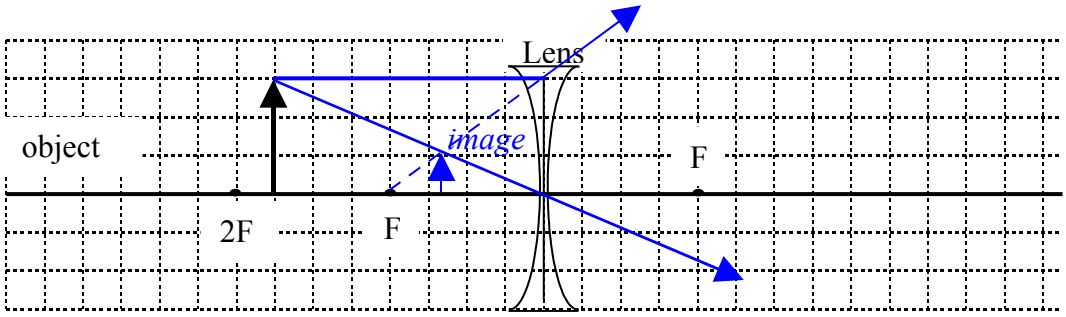
i)



Characteristics of image:

Diminished, virtual, upright

ii)



Characteristics of image :

Diminished, virtual, upright

Note: Image formed by a concave lens is always diminished, virtual and on the same side of the lens as the object.

Power of a lens (*p*)

The power of the lens is given by:

$$\text{Power of lens} = \frac{1}{\textit{focal length}}$$

Sign convention (for focal length) and the S.I. unit for power of a lens.

- The focal length of a convex lens is (positive/negative)
- The focal length of a concave lens is (positive/negative)
- The S.I. unit for the power of a lens is…*Dioptre*…and its symbol is…*D*…
- When calculating the power of a lens, the unit of the focal length must be in (m/cm)

Exercise 1 : A concave lens has a focal length of 10 cm. What is its power?

$$p = \frac{1}{f} = -\frac{1}{0.1} = \text{-10 D}$$

Exercise 2 : The power of a lens is + 5 D. State whether it is a convex lens or a concave lens and calculate its focal length.

Convex lens.

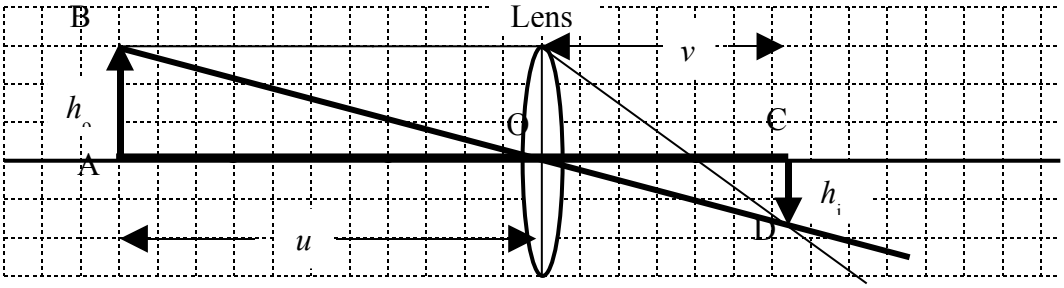
$f = 20$ cm

Linear Magnification (*m*) :

Definition: **Linear magnification** = $\frac{\text{height of image}}{\text{height of object}}$

$$m = \frac{h_i}{h_0}$$

Based of the definition above and the ray diagram below, derive an expression for the relationship between linear magnification, ***m***, the object distance, ***u*** and the image distance, ***v***.



The triangles, ABO and DCO are similar triangles.

Therefore, $\frac{h_i}{h_0} = \frac{v}{u}$

Therefore, $m = \frac{v}{u}$

Lens formula :

The relationship between the object distance, u, image distance, v, and the focal length, f, of a lens is given by

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

- This lens formula is valid for both convex and concave lenses.

When using the **lens formula**, the '**real is positive sign convention**' must be followed.

The rules stated in this sign convention are:

1) *The focal length of a convex lens is positive while the focal length of a concave lens is negative*

2) *Object distance is positive for real object*

3) *Image distance is positive for real image: image distance is negative for virtual image*

Application of the lens formula:

Exercise 1. An object is placed 10 cm in front of a converging lens of focal length 15 cm. Calculate the image distance and state the characteristics of the image formed.

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$
$$\frac{1}{10}+\frac{1}{v}=\frac{1}{15}$$
$$\frac{1}{v}=\frac{1}{15}-\frac{1}{10}$$

v = - 30 cm

Image is virtual

Exercise 2 : An object is placed 30 cm in front of a converging lens of focal length 25 cm.
a) Find the position of the image, and state whether the image is real or virtual.
b) Calculate the linear magnification of the image.

$$\frac{1}{30}=\frac{1}{v}+\frac{1}{25}$$

v = 150 cm ; Image is real

m = v/u

m = 150/30

m = 5

Latihan 3 : An object is placed 30 cm in front of a diverging lens of focal length 20 cm. Calculate the image distance and state whether the image is real or virtual.

$$\frac{1}{30}+\frac{1}{v}=-\frac{1}{20}$$

v = - 12 cm ; image is virtual

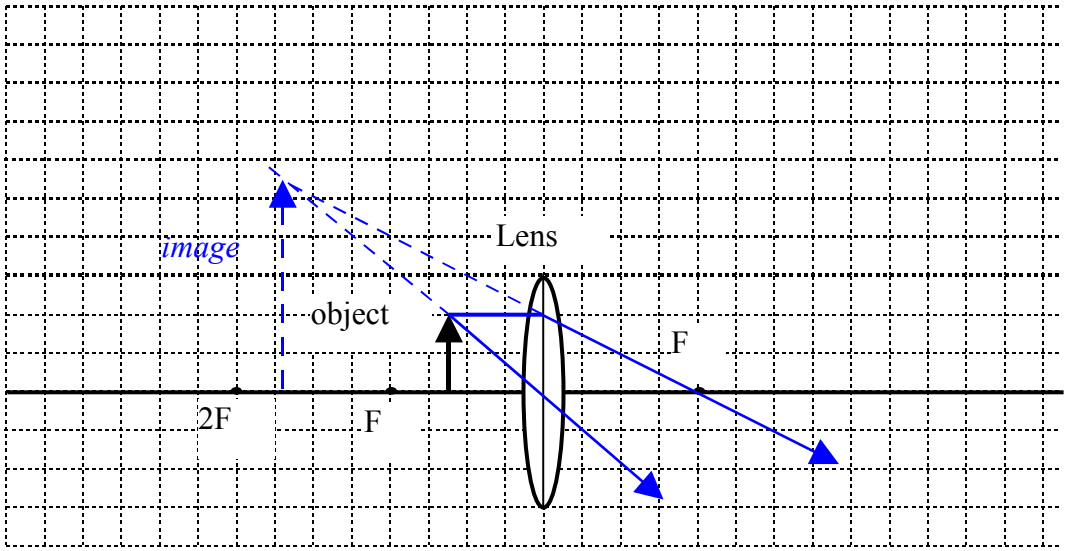
Lenses and optical instruments :

1. Magnifying glass (simple microscope):

A lens acts as a magnifying glass when the object is placed as in case 5 on page 23.

i) A magnifying glass consists of a (**converging / diverging**) lens.
ii) The object must be placed at a distance (**more than *f* / same as f / less than *f* / between *f* and 2*f* / more than 2*f***) in order for the lens to act as a magnifying glass.
iii) The characteristics of the image formed by a magnifying glass are yang (**real / virtual**) ; (**inverted / upright**) ; (**magnified /diminished**) ; (**on the same side as the object / on the opposite side of the object**).
iv) Greater magnification can be obtained by using a lens which has (**long / short**) focal length.

Complete the ray diagram below to show how a magnifying glass produces an image of the object.



Exercise 1 : A magnifying glass produces an image with linear magnification = 4. If the power of the lens is +10 D, find the object distance and image distance.

$4 = \frac{v}{u}$ $\quad \therefore v = 4u$

$10 = \frac{1}{f}$ $\quad \therefore f = 10 \text{ cm}$

$\frac{1}{u} + \frac{1}{4u} = \frac{1}{10}$

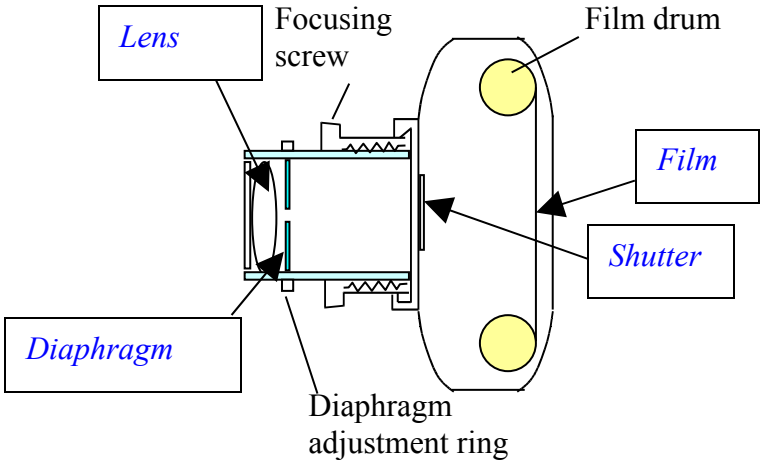
$\therefore u = 12.5 \text{ cm}$

v = 50 cm

Exercise 2: Which of the following lenses with their powers given below makes the magnifying glass with the highest power of magnification?

A. – 5 D B. –25 D C. +5 D D. +25 D.

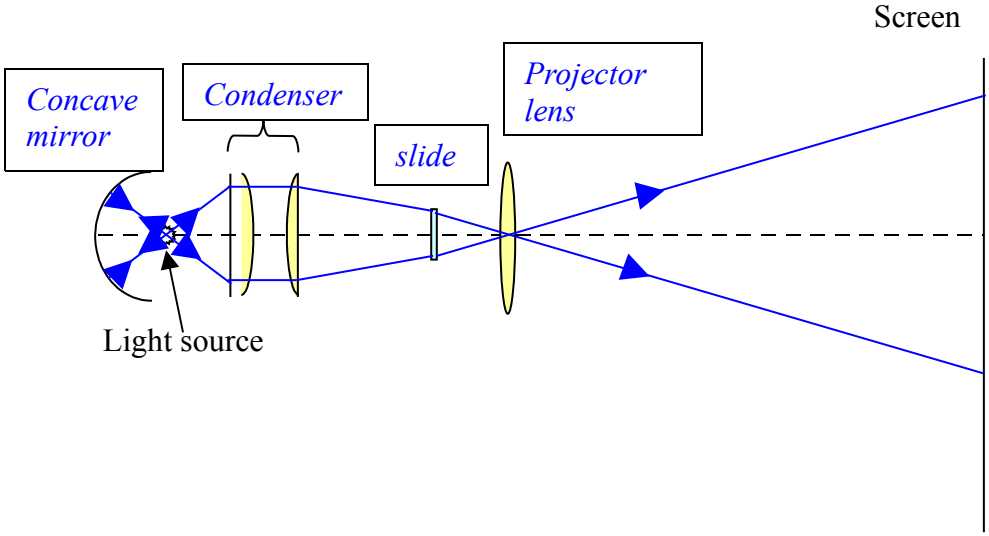
2. Simple camera : The diagram below shows the structure of a simple camera. In the boxes provided, write the names of the parts shown.



For each of the parts you have named, state its function.

Lens: to focus a sharp image onto the film
Film: to record the image
Diaphragm: to adjust the size of the aperture (control the brightness of image).
Shutter: to open and shut the camera so that the film is exposed only for a short time.

3. Slide projector : The diagram below shows the structure of a simple projector. In the boxes provided, write the names of the parts shown

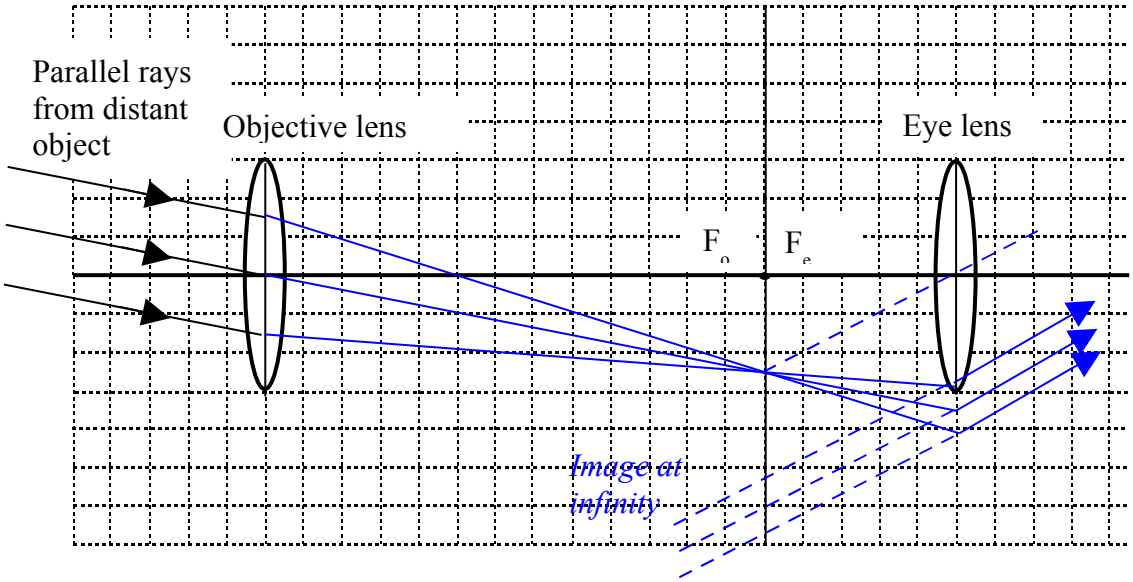


Complete the ray diagram above to explain how the slide projector works.

4. Astronomical telescope :

Making of the astronomical telescope.

- The astronomical telescope consists of 2 (**converging / diverging**) lenses.
- The objective lens has focal length, f_o and the eye lens has focal length, f_e where ($f_o < f_e$ / $f_o > f_e$).
- The lenses are arranged such that the distance between the objective lens and the eye lens is ($f_o - f_e$ / $f_o + f_e$ / $f_o \times f_e$ / f_o / f_e).



Complete the ray diagram above to show how the astronomical telescope works.

Characteristics of image formed by an astronomical telescope:

- The first image formed by the objective lens is (virtual/real ; upright/inverted ; diminished/magnified).
- The final image is (virtual/real ; upright/inverted ; diminished/magnified).
- The final image is located at (F_o / F_e / **infinity**).

Magnifying Power (M) :

$$M = \frac{f_0}{f_e}$$

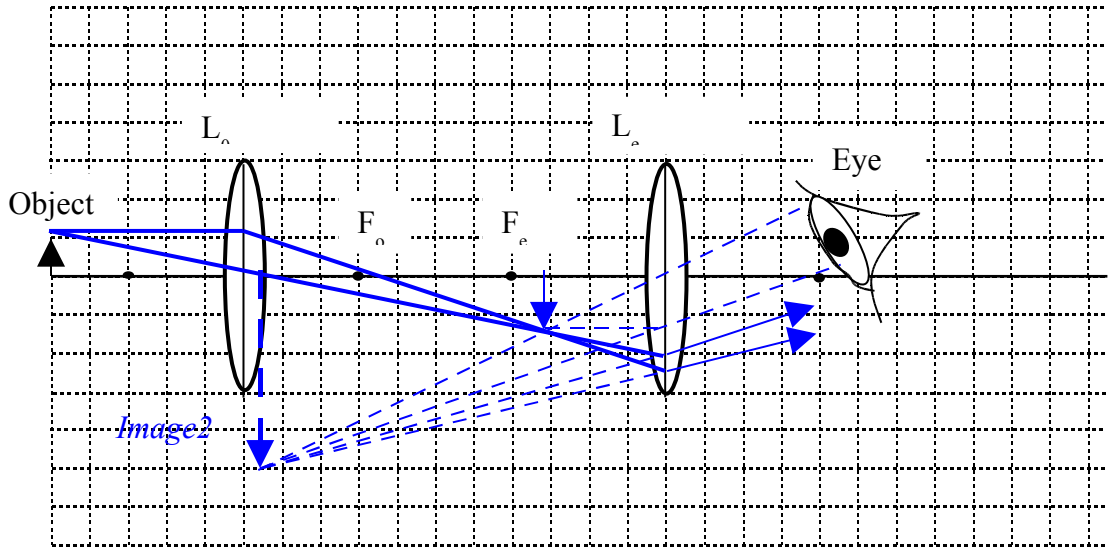
Exercise:

An astronomical telescope with high power of magnification can be built using eye lens of (long / short) focal length and objective lens of (long / short) focal length.

5. The compound microscope :

Structure of the compound microscope:

- A compound microscope consists of 2 (converging / diverging) lenses
- The focal length of the eye lens is (long / short) and the focal length of the objective lens is (long / short).
- The objective lens is arranged such that the object distance, u is ($u = f_o$ / $f_o < u < 2f_o$ / $u = 2f_o$).
- The eye lens is used as a (magnifying / diverging / projector) lens.
- The total length, s, between both lenses is ($s = f_o + f_e$; $s > f_o + f_e$)



Complete the ray diagram above to show how the compound microscope works.

Characteristics of image formed by compound microscope:

- The first image formed by the objective lens is (real/virtual ; diminished/magnified ; upright/inverted).
- The final image is (real/virtual ; diminished/magnified ; upright/inverted).

Exercise 1 (a) : A compound microscope consists of two lenses of focal lengths 2 cm and 10 cm. Between them, which is more suitable as the eye lens? Explain your answer.

The 10 cm lens is used as the eye lens because it will make a shorter microscope.

(b): How would you arrange the lenses in (a) to make an astronomical telescope?

Use the 10 cm lens as the objective lens and the 2 cm lens as the eye lens.

Reinforcement:

Part A:

1. Between the following statements about reflection of light, which is **not** true?

   A. All light energy incident on a plane mirror is reflected.
   B. The angle of incidence is always the same as the angle of reflection.
   C. The incident ray, the reflected ray and the normal to the point of incidence, all lie on the same plane.
   D. The speed of the reflected ray is the same as the speed of the incident ray.

2. A boy stands in front of a plane mirror. He observes the image of some letterings printed on his shirt. The letterings on his shirt is as shown in Figure 1.

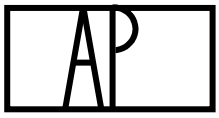
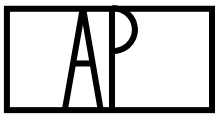


Figure 1

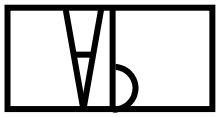
Between the following images, which is the image observed by the boy?

A

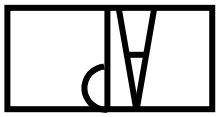


B

C



D



3. Figure 2 shows an object, O placed in front of a plane mirror. Between the positions A, B, C and D, which is the position of the image?

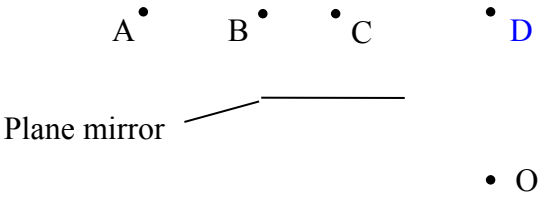


Figure 2

4. A student is moving with a velocity of 2 m s^{-1} towards a plane mirror. The distance between the student and his image will move towards each other at the rate

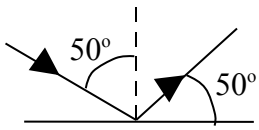
   A. 2 m s^{-1} B. 3 m s^{-1} C. 4 m s^{-1} D. 5 m s^{-1} E. 6 m s^{-1}

5. The table below shows the characteristics of the images formed by a concave mirror for various positions of the object. All symbols used have the usual meanings. Which of them is **not true**?

	Position of object	Characteristics of image
A	$u > 2f$	Diminished, inverted, real
B	$f < u < 2f$	Magnified, inverted, real
C	$u = f$	Same size, inverted, real
D	$u < f$	Maginfied, upright, virtual

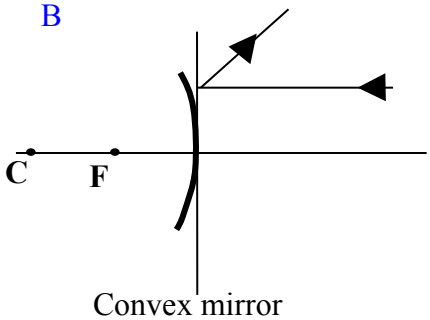
6. Which of the following ray diagram is correct?

A



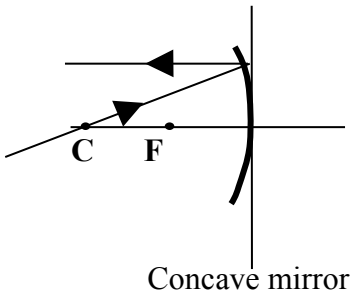
Plane mirror

B



Convex mirror

C



Concave mirror

7. The depth of a swimming pool appears to be less than its actual depth. The light phenomenon which causes this is

A. Reflection
B. Refraction
C. Diffraction
D. Interference

8. The critical angle in glass is 42°. What is the refractive index of glass?

A. 1.2 B. 1.3 C. 1.4 D. 1.5 E. 1.6

9. Which of the following are the characteristics of an image formed by a magnifying glass?

A. Magnified, virtual, inverted
B. Diminished, real, upright
C. Magnified, virtual, upright
D. Diminished, virtual, inverted

10. A student is given three convex lenses of focal lengths 2 cm, 10 cm and 50 cm. He wishes to construct a powerful astronomical telescope. Which of the following arrangements should he choose?

	Focal length of objective lens / cm	Focal length of eye lens / cm
A	50	2
B	10	10
C	2	50
D	50	10

Part B

1.

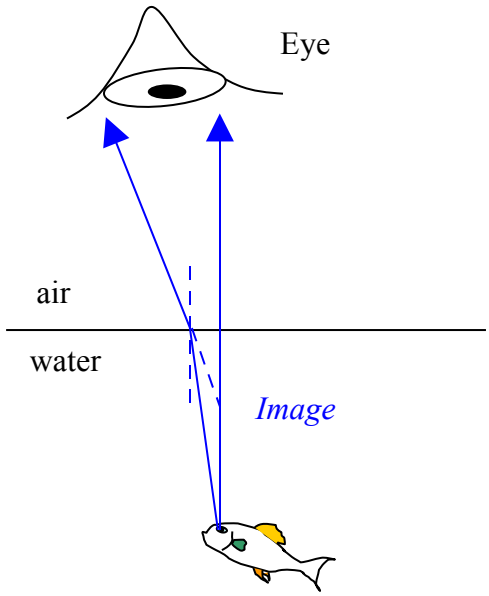


Figure 3

Figure 3 shows the eye of a person looking at a fish.

a) Sketch a ray diagram consisting of 2 rays originating from the eye of the fish to show why the image of the fish is seen closer to the surface.

b) The fish is at a depth of 2 m. If the refractive index of water is 1.33, calculate the apparent depth of the fish.

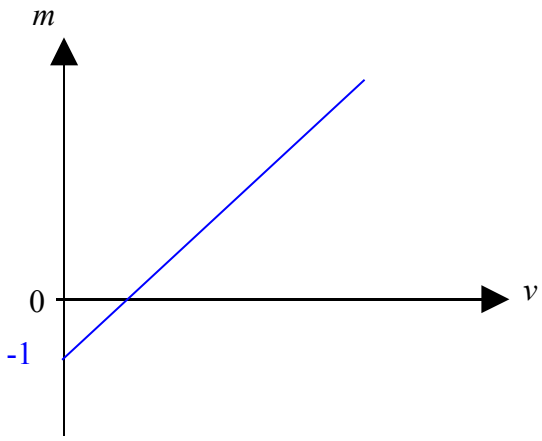
$$n = \frac{\text{real depth}}{\text{apparent depth}}$$

$$1.33 = \frac{2}{\text{apparent depth}}$$

Apparent depth = 1.5 m

2. a) Starting with the lens formula, $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$, derive an equation that gives the relationship between liner magnification, ***m*** and the image distance, ***v***. Hence sketch the graph of *m* against *v* on the axes provided below.

$$\frac{v}{u}+\frac{v}{v}=\frac{v}{f}$$
$$m+1=\frac{v}{f}$$
$$m=\frac{1}{f}v-1$$



(b) State the value of *m* at the point of intersection of the graph with the vertical axis.

-1

(c) Describe how you would determine the focal length of the lens using the graph.

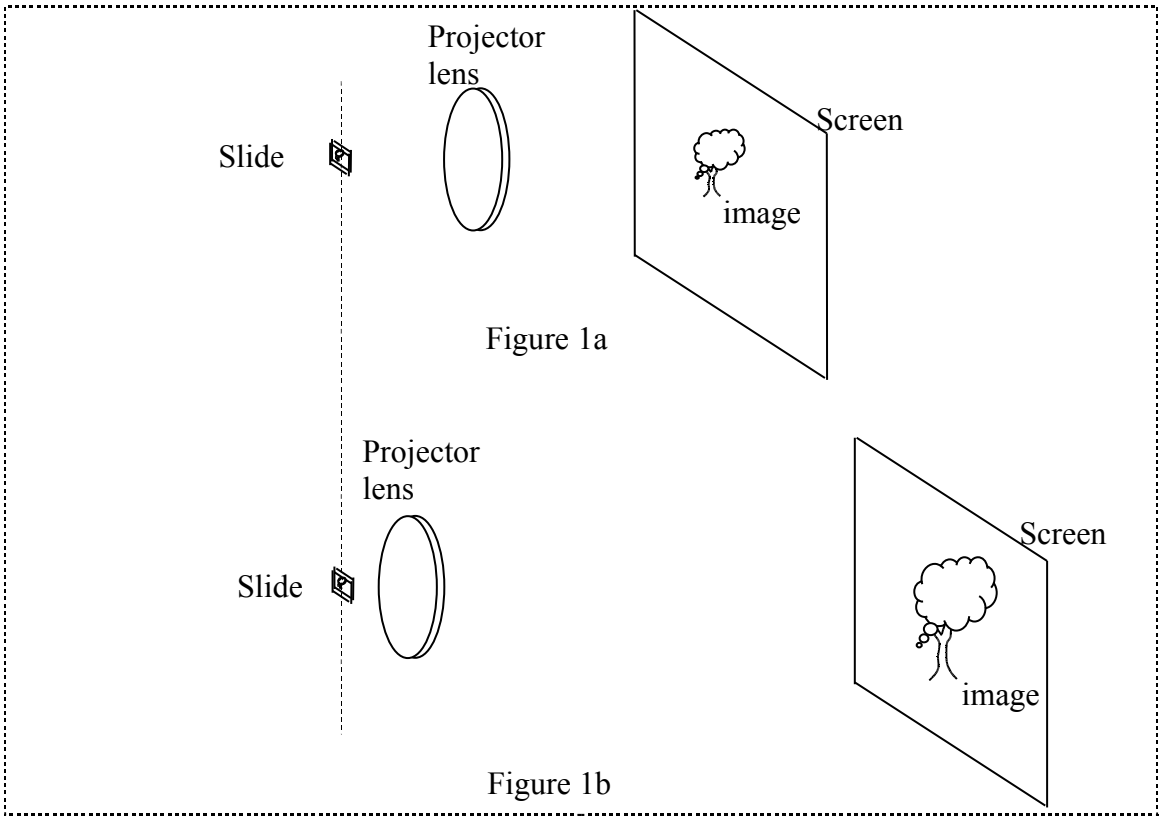
The gradient of the graph gives the value of 1/f

Therefore $f=\frac{1}{\text{gradient of graph}}$

Part C

1.

A student used a slide projector to project a picture onto the screen. Figure 1a and 1b show the relative positions of the slide, projector lens and the screen.
It is observed that when the screen is moved further away (Figure 1b), the lens of the projector has to be moved nearer to the slide to obtain a sharp image.



Based on your observations and knowledge of lenses;

a) make **one** suitable inference.

The image distance is dependent on the object distance

b) state an appropriate hypothesis that could be investigated.

The greater the object distance, the smaller the image distance

c) describe how you would design an experiment to test your hypothesis using a convex lens, filament bulb and other apparatus.
In your description, state clearly the following:

(i) aim of the experiment

To investigate the relationship between object distance and image distance for a convex lens.

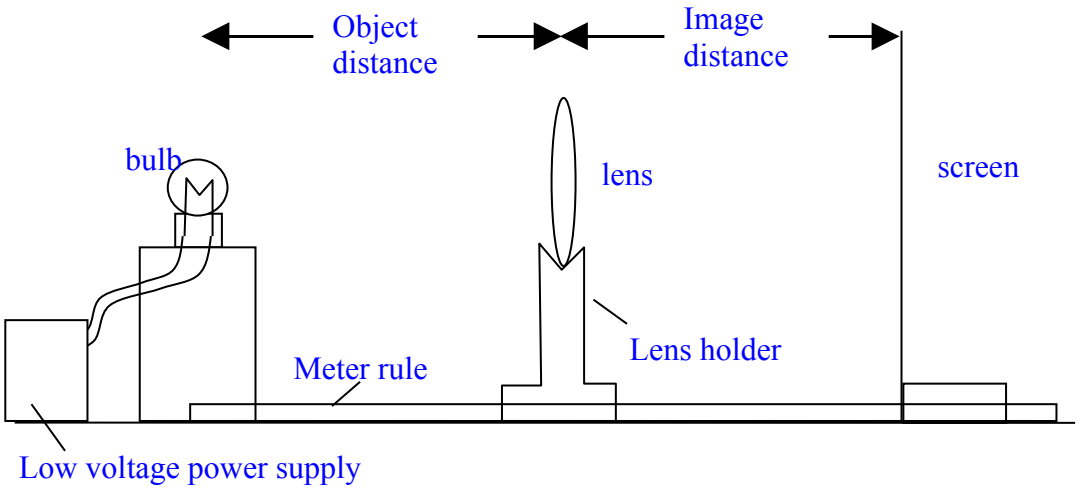
(ii) variables in the experiment

Manipulated variable: *object distance.*
Response variable: *image distance.*
Fixed variable: *focal length of lens*.

(iii) List of apparatus and materials

Apparatus: *light bulb, convex lens of focal length 10 c , white screen, metre rule, low voltage power supply and lens holder*

(iv) Arrangement of the apparatus



(v) The procedure of the experiment, which includes the method of controlling the manipulated variable and the method of measuring the responding variable

Procedure:
1. Arrange the apparatus as shown in the diagram above.
2. Adjust the bulb so that the object distance (filament), *u* is 35 cm from the lens.
3. Light up the electric bulb, adjust the screen position until a sharp image of the filament is formed on the screen. Record the image distance, *v*.
4. Repeat steps 2 and 3 for objects distances of, *u* = 30cm, 25 cm, 20 cm, and 15 cm.

(vi) The way you tabulate the data

Object distance, *u* /cm	Image distance, *v* /cm
35.0	
30.0	
25.0	
20.0	
15.0	

(vii) The way you would analyse the data

Plot the graph of v against u

2.

A student carried out an experiment to investigate the relationship between object distance, u, and image distance, v, for a convex lens. The student used various values of u and recorded the corresponding values of v. The student then plotted the graph of uv against $u + v$ as shown in Figure 2.

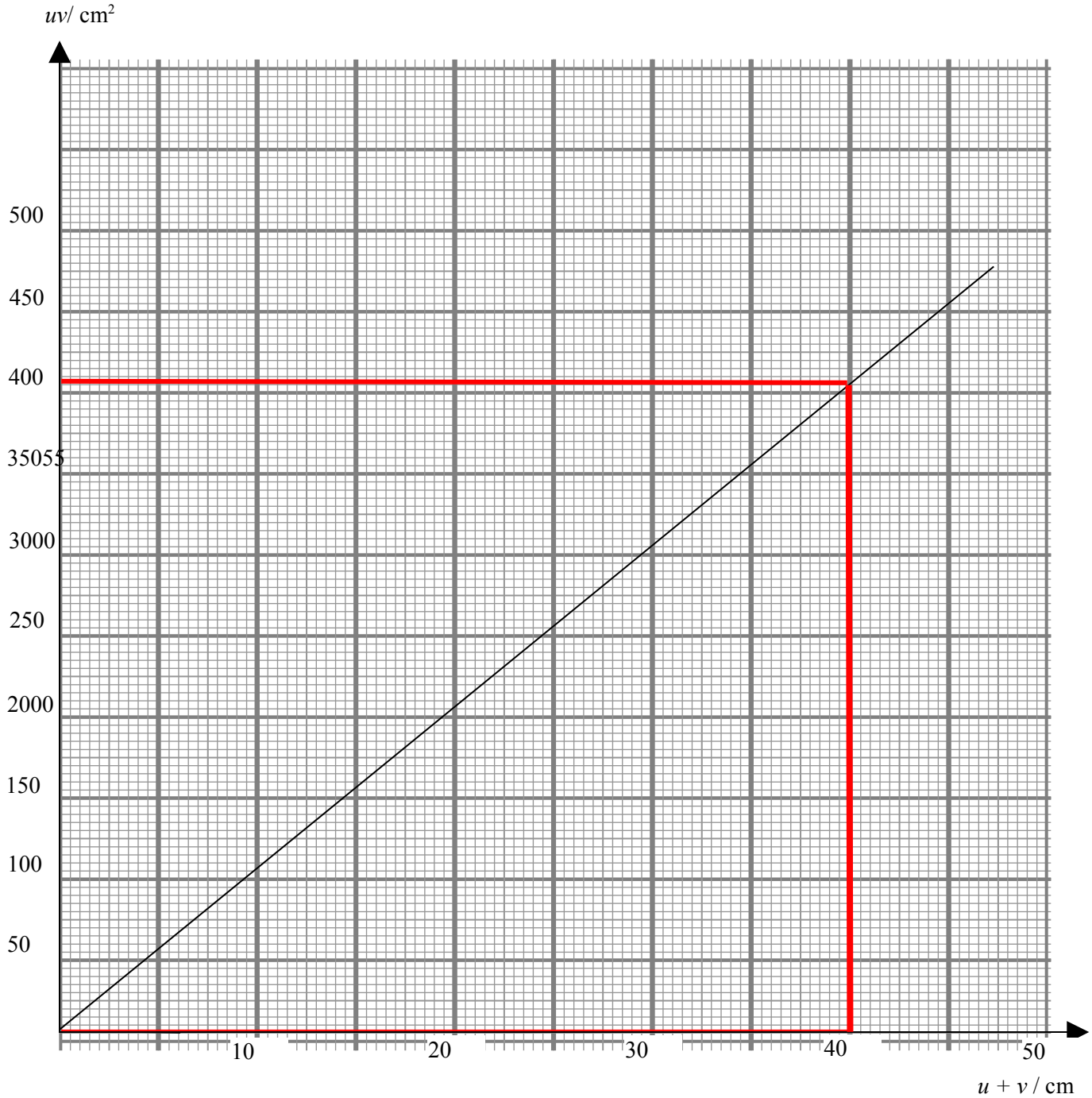


Figure 2

a) Based on the graph in Figure 2,

(i) state the relationship between uv and $u + v$

uv is directly proportional to (u + v)

.....

[*1 mark*]

(ii) determine the value of $u + v$ when the value of uv = 400 cm^2. Show on the graph how you obtained the value of u + v.

40 cm

From the value of $u + v$ obtained, calculate the image distance, v when u = 20 cm.

20 + v = 40
v = 20 cm

[*3 marks*]

(iii) calculate the gradient of the graph. Show clearly on the graph how you obtained the values needed for the calculation.

Gradient = 400/40
= 10 cm

[*3 marks*]

b) Given that the relationship between u, v and focal length, f of the convex lens used, is represented by the equation

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Derive an equation which gives the relationship between uv and $(u + v)$.

$$\frac{v+u}{uv} = \frac{1}{f}$$

$$uv = f(u+v)$$

[*2 marks*]

c) Using the equation derived in (b), and the value of gradient calculated in (a)(iii), determine the focal length of the lens used in the experiment.

The gradient = f
Therefore f = 10 cm

[*2 marks*]

d) State one precaution taken to ensure the accuracy of the experiment.

The object (lamp), lens and the screen must be arranged in a straight line perpendicular to the screen .....[*1 mark*]