Light-Reflection and Refraction

Case Study Based Questions

Case Study 1

A compound microscope is an instrument which consists of two lenses L1 and L2+ The lens L_1 called objective, forms a real, inverted and magnified image of the given object. This serves as the object for the second lens L2+ the eye piece. The eye piece functions like a simple microscope or magnifier. It produces the final, image, which is inverted with respect to the original object, enlarged and virtual. (CBSE 2021 Term-1)

Read the above passage carefully and give the answer of the following questions:

Q1. What types of lenses must be L1 and L2?

a. Both concave

b. Both convex

c. L-concave and L_2-convex

d. L-convex and L_2-concave

Q2. What is the value and sign of magnification (according to the new Cartesian sign convention) of the image formed by L_1?

a. Value = Less than 1 and Sign = Positive

b. Value = More than 1 and Sign = Positive

c. Value Less than 1 and Sign = Negative

d. Value More than 1 and Sign= Negative

Q3. What is the value and sign of (according to new Cartesian sign convention) magnification of the image formed by L_2?

a. Value Less than 1 and Sign Positive = Positive

b. Value = More than 1 and Sign = Positive

c. Value Less than 1 and Sign = Negative

d. Value More than 1 and Sign= Negative

Q4. If power of the eyepiece (L2) is 5 diopters and it forms an image at a distance of 80 cm from its optical centre, at what distance should the object be?

a. 12 cm
b. 16 cm
c. 18 cm
d. 20 cm

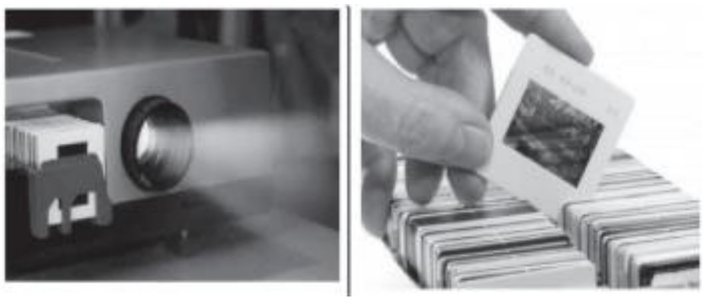
Answers

1. (b) Both convex

2. (d) Value = More than 1 and Sign = Negative

3. (b) Value = More than 1 and Sign = Positive

4. (b) 16 cm



The above images are that of a specialised slide projector. Slides are small transparencies mounted in sturdy frames ideally suited to magnification and projection, since they have a very high resolution and a high image quality. There is a tray where the slides are to be put into a particular orientation so that the viewers can see the enlarged erect images of the transparent slides. This means that the slides will have to be inserted upside down in the projector tray. To show her students the images of insects that she investigated in the lab, Mrs. Iyer brought a slide projector. Her slide projector produced a 500 times enlarged and inverted image of a slide on a screen 10 m away.

Read the above passage carefully and give the answer of the following questions:

Q1. Based on the text and data given in the above paragraph, What kind of lens must the slide projector have?

Q2. If v is the symbol used for image distance and u for object distance, then with one reason, state what will be the sign for in the given case?

Q3. A slide projector has a convex lens with a focal length of 20 cm. The slide is placed upside down 21 cm from the lens. How far away should the screen be placed from the slide projector's lens so that the slide is in focus?

Or

When a slide is placed 15 cm behind the lens in the projector, an image is formed 3 m in front of the lens. If the focal length of the lens is 14 cm, draw a ray diagram to show image formation. (not to scale) [CBSE SQP 2022-23]

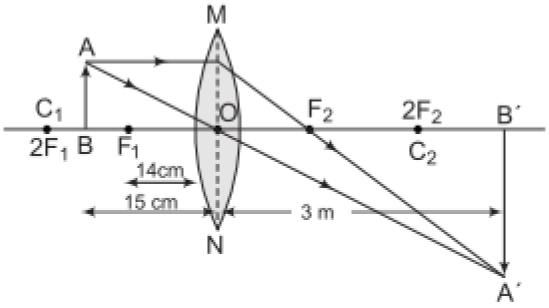
Answers

1. Convex lens

2. Negative as the image is real and inverted.

3. $1/f = 1/v - 1/-21$
$= 1/20 = 1/v - 1/u$
$= 1/v = 1/20 - 1/21$
$= (21-20)/420 = 1/420$
$v = 420$ cm

Or



Case Study 3

Ravi wanted to fix the rear-view mirror of his scooter. He knows that rear-view mirror is an essential safety device in the vehicle and allows him to see objects at the backside of his vehicle.

He bought two mirrors M, and M2, out of which M_1 is curved inwards and M2 is curved outwards.

Read the above passage carefully and give the answer of the following questions:

Q1. Based on the given situation, which mirror should Ravi need to fix as his rear-view mirror and why?

Q2. Ravi did some preliminary experiment with mirror M_1 and found that magnification of the real image of an object placed at 10 cm in front of it is 3, at what distance is the image located?

Q3. What is the formula for magnification obtained with a mirror?

Q4. An object is placed at the centre of curvature of M_1. Find the distance between its image and pole.

Q5. An object is placed 60 cm in front of M_2. The image formed by the mirror is located 30 cm behind the mirror. What is the object's magnification?

Answers

1. M_2 because it gives an erect and diminished image.

2. Given, $m = -3$ (image is real), $u = -10$

We know that, $m = \frac{-v}{u} \Rightarrow -3 = \frac{-v}{-10}$

$\Rightarrow \quad v = -30$ cm

3. Magnification $(m) = \frac{\text{Height of image } (h_i)}{\text{Height of object } (h_o)}$

$= \frac{\text{Image distance } (-v)}{\text{Object distance } (u)}$

4. When object is at C of M, (concave mirror), image is formed at C, i.e., v=-C=-2f
Hence, distance between image and pole is 2f.

5. Given, $u = -60$ cm and $v = 30$ cm
We know that, $m = -v/u$

$$= \frac{-30}{-60}$$

$$= \frac{1}{2} \text{ or } +0.5$$

Case Study 4

The ability of a medium to refract light is expressed in terms of its optical density. Optical density has a definite connotation. It is not the same as mass density. On comparing two media, the one with the large refractive index is optically denser medium than the other. The other medium with a lower refractive index is optically rarer. Also the speed of light through a given medium is inversely proportional to its optical density.

Read the above passage carefully and give the answer of the following questions:

Q1. Determine the speed of light in diamond if the refractive index of diamond with respect to vacuum is 2.42. Speed of light in vacuum is 3 x 10^8 m/s.

Q2. Refractive indices of glass, water and carbon disulphide are 1.5, 1.33 and 1.62 respectively. If a ray of light is incident in these media at the same angle (say), then write the increasing order of the angle of refraction in these media.

Q3. The speed of light in glass is 2 x 10^8 m/s and in water is 2.25 x 10^8 m/s.
(i) Which one of the two is optically denser and why?
(ii) A ray of light is incident normally at the water- glass interface when it enters a thick glass container filled with water. What will happen to the path of the ray after entering the glass? Give reason.

Or

The absolute refractive indices of water and glass are 4/3 and 3/2 respectively. If the speed of light in glass is 2x 10^8 m/s, find the speed of light in (i) vacuum and (ii) water. [CBSE 2023]

Answers

1. Given, μ 2.42, c = 3 x 108 m/s

$$\text{Speed of light in diamond} = \frac{c}{\mu} = \frac{3 \times 10^8}{2.42}$$
$$= 1.24 \times 10^8 \text{ m/s}$$

2. Carbon disulphide, glass, water.

3. (i) Glass is denser than water because speed of light in glass is less than that of water.
(ii) A ray of light incident normally at the water- glass interface does not suffer any refraction and goes straight on entering the thick glass container filled with water. This is so because all parts of the light waves reach the interface at the same time, enter the glass at the same time and hence get slowed down at the same time.

Or

Given, $\mu_w = \frac{4}{3}$, $\mu_g = \frac{3}{2}$, $v_g = 2 \times 10^8$ m/s

We know that,

$$\text{Speed of light in medium} = \frac{c}{\mu}$$

where, c = speed of light in vacuum
μ = refractive index of medium

(i) $\therefore$ c = speed of light in glass × refractive index of glass

$$= v_g \times \mu_g$$
$$= 2 \times 10^8 \times \frac{3}{2}$$
$$= 3 \times 10^8 \text{ m/s}$$

(ii) $$\text{Speed of light in water} = \frac{c}{\text{refractive index of water}}$$
$$= \frac{c}{\mu_w}$$
$$= \frac{3 \times 10^8}{4/3}$$
$$= 2.25 \times 10^8 \text{ m/s}$$

Solutions for Questions 5 to 12 are Given Below

Case Study 5

Read the following and answer any four questions from 1(i) to 1(v).

The curved surface of a spoon can be considered as a spherical mirror. A highly smooth polished surface is called mirror. The mirror whose reflecting surface is curved inwards or outwards is called a spherical mirror. Inner part works as a concave mirror and the outer bulging part acts as a convex mirror. The center of the reflecting surface of a spherical mirror is called pole and the radius of the sphere of which the mirror is formed is called radius of curvature.

(i) When a concave mirror is held towards the sun and its sharp image is formed on a piece of carbon paper for some time, a hole is burnt in the carbon paper. What is the name given to the distance between the mirror and carbon paper?

(a) Radius of curvature
(b) Focal length
(c) Principal focus
(d) Principal axis

(ii) The distance between pole and focal point of a spherical mirror is equal to the distance between

(a) pole and center of curvature
(b) focus point and center of curvature
(c) pole and object
(d) object and image.

(iii) The focal length of a mirror is 15 cm. The radius of curvature is

(a) 15 cm
(b) 30 cm
(c) 45 cm
(d) 60 cm

(iv) The normal at any point on the mirror passes through

(a) focus
(b) pole
(c) center of curvature
(d) any point

(v) In a convex spherical mirror, reflection of light takes place at

(a) a flat surface
(b) a bent-in surface
(c) a bulging-out surface
(d) an uneven surface

Case Study 6

Read the following and answer any four questions from 2(i) to 2(v).

The spherical mirror forms different types of images when the object is placed at different locations.

When the image is formed on screen, the image is real and when the image does not form on screen, the image is virtual. When the two reflected rays meet actually, the image is real and when they appear to meet, the image is virtual.

A concave mirror always forms a real and inverted image for different positions of the object. But if the object is placed between the focus and pole, the image formed is virtual and erect.

A convex mirror always forms a virtual, erect and diminished image. A concave mirror is used as doctor's head mirror to focus light on body parts like eyes, ears, nose etc., to be examined because it can form erect and magnified image of the object. The convex mirror is used as a rear view mirrors in automobiles because it can form an small and erect image of an object.

(i) When an object is placed at the centre of curvature of a concave mirror, the image formed is

(a) larger than the object
(b) smaller than the object
(c) same size as that of the object
(d) highly enlarged.

(ii) No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be

(a) plane
(b) concave
(c) convex
(d) either plane or convex.

(iii) A child is standing in front of a magic mirror. She finds the image of her head bigger, the middle portion of her body of the same size and that of the legs smaller. The following is the order of combinations for the magic mirror from the top.

(a) Plane, convex and concave
(b) Convex, concave and plane
(c) Concave, plane and convex
(d) Convex, plane and concave

(iv) To get an image larger than the object, one can use

(a) convex mirror but not a concave mirror
(b) a concave mirror but not a convex mirror
(c) either a convex mirror or a concave mirror
(d) a plane mirror.

(v) A convex mirror has wider field of view because

(a) the image formed is much smaller than the object and large number of images can be seen.
(b) the image formed is much closer to the mirror
(c) both (a) and (b)
(d) none of these.

Case Study 7

Read the following and answer any four questions from 3(i) to 3(v).

The relation between distance of an object from the mirror (u), distance of image from the mirror (v) and the focal length (F) is called mirror formula. This formula is valid in all situations for all spherical mirrors for all positions of the object. The size of image formed by a spherical mirror depends on the position of the object from the mirror. The image formed by a spherical mirror can be bigger than the object, equal to the object or smaller than the object. The size of the image relative to the object is given by the linear magnification (m). Thus, the magnification is given by the ratio of height of image to the height of object. If magnification is negative, image is real and if it is positive, image is virtual.

(i) What is the position of an image when an object is placed at a distance of 20 cm from a concave mirror of focal length 20 cm?

(a) 5 cm (b) 20 cm (c) 10 cm (d) infinity

(ii) Which of the following ray diagrams is correct for the ray of light incident on a concave mirror as shown in figure?

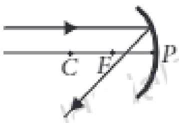


Figure *A*

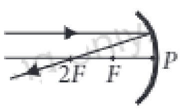


Figure *B*

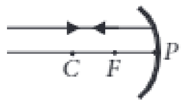


Figure *C*

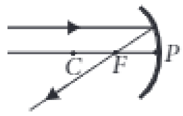


Figure *D*

(a) Figure *A* (b) Figure *B* (c) Figure *C* (d) Figure *D*

(iii) If the magnification of an image is –2, the characteristic of image will be

(a) real and inverted (b) virtual and enlarged (c) virtual and inverted (d) real and small

(iv) The mirror formula holds for

(a) concave mirror (b) convex mirror (b) plane mirror (d) all of these

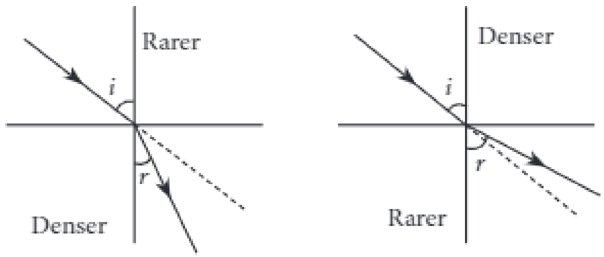
(v) A parallel beam of light is made to fall on a concave mirror. An image is formed at a distance of 7.5 from the mirror. The focal length of the mirror is

(a) 15 cm (b) 7.5 cm (c) 3.75 cm (d) 10 cm

Case Study 8

Read the following and answer any four questions from 4(i) to 4(v).

When the rays of light travels from one transparent medium to another, the path of light is deviated. This phenomena is called refraction of light. The bending of light depends on the optical density of medium through which the light pass.



The speed of light varies from medium to medium. A medium in which the speed of light is more is optically rarer medium whereas in which the speed of light is less is optically denser medium. Whenever light goes from one medium to another, the frequency of light does not change however, speed and wavelength change. It concluded that change in speed of light is the basic cause of refraction.

(i) When light travels from air to glass, the ray of light bends

(a) towards the normal (b) away from normal (c) anywhere (d) none of these

(ii) A ray of light passes from a medium *A* to another medium *B*. No bending of light occurs if the ray of light hits the boundary of medium *B* at an angle of

(a) 0° (b) 45° (c) 90° (d) 120°

(iii) When light passes from one medium to another, the frequency of light

(a) increases (b) decreases (c) remains same (d) none of these

(iv) When light passes from glass to water, the speed of light

(a) increases (b) decreases

(c) remains same (d) first increases then decrease

(v) The bottom of pool filled with water appears to be _________ due to refraction of light.

(a) shallower (b) deeper (c) at same depth (d) empty

Case Study 9

Read the following and answer any four questions from 5(i) to 5(v).

The refraction of light on going from one medium to another takes place according to two laws which are known as the laws of refraction of light. These laws are

1. The ratio of sine of angle of incidence to the sine of angle of refraction is always constant for the pair of media in contact.

$$\frac{\sin i}{\sin r} = \mu = \text{constant}$$

This constant is called refractive index of the second medium with respect to the first medium. Refractive index is also defined as the ratio of speed of light in vacuum to the speed of light in medium.

2. The incident ray, refracted ray and normal all lie in the same plane.

This law is called Snell's law of refraction.

(i) When light travels from air to glass,

(a) angle of incidence > angle of refraction (b) angle of incidence < angle of refraction

(c) angle of incidence = angle of refraction (d) can't say

(ii) When light travels from air to medium, the angle of incidence is 45° and angle of refraction is 30°. The refractive index of second medium with respect to the first medium is

(a) 1.41 (b) 1.50 (c) 1.23 (d) 1

(iii) In which medium, the speed of light is minimum?

(a) Air (b) Glass (c) Water (d) Diamond

(iv) If the refractive index of glass is 1.5 and speed of light in air is 3×10^8 m/s. The speed of light in glass is

(a) 2×10^8 m/s (b) 2.9×10^8 m/s (c) 4.5×10^8 m/s (d) 3×10^8 m/s

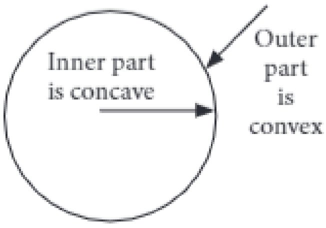
(v) Refractive index of *a* with respect to *b* is 2. Find the refractive index of *b* with respect to *a*.

(a) 0.4 (b) 0.5 (c) 0.25 (d) 2.

Case Study 10

Read the following and answer any four questions from 6(i) to 6(v).

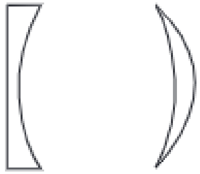
A lens is a piece of any transparent material bounded by two curved surfaces. There are two types of lenses convex lens and concave lens.



Convex lens is made up of a transparent medium bounded by two spherical surfaces such that thicker at the middle and thinner at the edges. Concave lens is also made up of a transparent medium such that thicker at the edge and thinner at the middle. The mid point of the lens is called optical centre.
A point on the principal axis, where the incident parallel rays meet or appears to come out after refraction is called focus.
A convex lens converges a parallel beam of light to other side whereas concave lens spreads out.

(i) Which of the following lenses would you prefer to use while reading small letters found in dictionary?
(a) A convex lens of focal length 50 cm
(b) A concave lens of focal length 50 cm
(c) A convex lens of focal length 5 cm
(d) A concave lens of focal length 5 cm

(ii) Which type of lenes are shown in given figure (i) and (ii).



(i) (ii)

(a) Plano concave, concavo convex
(b) Plano convex, convexo concave
(c) Double concave, concave convex
(d) Convexo concave, double convex

(iii) A small bulb is placed at the focal point of a converging lens. When the bulb is switched on, the lens produces
(a) a convergent beam of light
(b) a divergent beam of light
(c) a parallel beam of light
(d) a patch of coloured light.

(iv) The part of lens through which the refraction takes place is called
(a) aperture (b) centre of curvature (c) principal axis (d) focus

(v) A water drop acts as a
(a) convex lens (b) concave lens (c) double concave lens (d) none of these

Case Study 11

Read the following and answer any four questions from 7(i) to 7(v).
The lenses forms different types of images when object placed at different locations. When a ray is incident parallel to the principal axis, then after refraction, it passes through the focus or appears to come from the focus. When a ray goes through the optical centre of the lens, it passes without any deviation.
If the object is placed between focus and optical center of the convex lens, erect and magnified image is formed. As the object is brought closer to the convex lens from infinity to focus, the image moves away from the convex lens from focus to infinity. Also the size of image goes on increasing and the image is always real and inverted. A concave lens always gives a virtual, erect and diminished image irrespective to the position of the object.

(i) The location of image formed by a convex lens when the object is placed at infinity is
(a) at focus (b) at $2F$ (c) at optical center (d) between F and $2F$

(ii) When the object is placed at the focus of concave lens, the image formed is
(a) real and smaller (b) virtual and inverted (c) virtual and smaller (d) real and erect

(iii) The size of image formed by a convex lens when the object is placed at the focus of convex lens is
(a) small (b) point in size (c) highly magnified (d) same as that of object

(iv) When the object is placed at $2F$ in front of convex lens, the location of image is
(a) at F
(b) at 2 F on the other side
(c) at infinity
(d) between F and optical center

(v) At which location of object in front of concave lens, the image between focus and optical centre is formed
(a) anywhere between centre and infinity
(b) at F
(c) at $2F$
(d) infinity

Case Study 12

Read the following and answer any four questions from 8(i) to 8(v).

The relationship between the distance of object from the lens (u), distance of image from the lens (v) and the focal length (f) of the lens is called lens formula. It can be written as $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$.

The size of image formed by a lens depends on the position of the object from the lens. A lens of short focal length has more power whereas a lens of long focal length has less power. When the lens is convex, the power is positive and for concave lens, the power is negative.

The magnification produced by a lens is the ratio of height of image to the height of object as the size of the image relative to the object is given by linear magnification (m).

When, m is negative, image formed is real and when m is positive, image formed is virtual. If $m < 1$, size of image is smaller than the object. If $m > 1$, size of image is larger than the object.

(i) An object 4 cm in height is placed at a distance of 10 cm from a convex lens of focal length 20 cm. The position of image is
(a) – 20 cm (b) 20 cm (c) –10 cm (d) 10 cm

(ii) In the above question, the size of image is
(a) 16 cm (b) 8 cm (c) 4 cm (d) 2 cm

(iii) An object is placed 50 cm from a concave lens and produces a virtual image at a distance of 10 cm infront of lens. The focal length of lens is
(a) –25 cm (b) –12.5 cm (c) 12.5 cm (d) 10 cm

(iv) A convex lens forms an image of magnification –2 of the height of image is 6 cm, the height of object is
(a) 6 cm (b) 4 cm (c) 3 cm (d) 2 cm

(v) A concave lens of focal length 5 cm, the power of lens is
(a) 20 D (b) –20 D (c) 90 D (d) –5 D

HINTS & EXPLANATIONS

5. **(i)** **(b)**: The focal length of a concave mirror is the distance between its pole and principal focus.

(ii) **(b)**

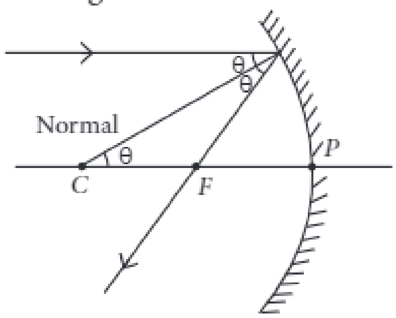
(iii) **(b)**: Given that, $f = 15$ cm

Radius of curvature of a spherical mirror is given as

$R = 2F$

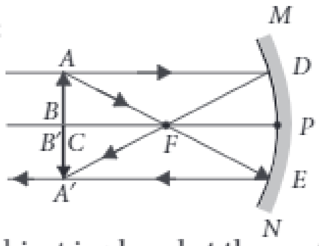
$\therefore \quad R = 2 \times 15 = 30$ cm

(iv) **(c)**: In a spherical mirror, normal drawn at any point passes through the centre of curvature.



(v) (c)

6. (i) (c):



When the object is placed at the centre of curvature of concave mirror, the image formed is real, inverted and of the same size as that of the object.

(ii) (d): The image is erect in a plane mirror and also in a convex mirror, for all positions of the object.

(iii) (c): As the image of head is bigger, the upper portion of magic mirror is concave. The middle portion of the image is of same size, so, middle portion of magic mirror is plane. Now, the image of legs looks smaller, therefore, the lower portion of magic mirror is convex.

(iv) (b)

(v) (c)

7. (i) (d): When an object is placed at the focus of a concave mirror, the image is formed at infinity.

(ii) (d): When a light ray parallel to the principal axis is incident on a concave mirror, it passes through the principal focus after reflection. Therefore, figure D is correct.

(iii) (a): If m is negative, the image will be real and inverted.

(iv) (d)

(v) (b): The distance of object from mirror = ∞

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

$\frac{1}{\infty}-\left(-\frac{1}{7.5}\right)=\frac{1}{f}$

$f = 7.5$ cm

8. (i) (a): When, a ray of light travels from air to glass, it bends towards the normal.

(ii) (c): No bending of light occurs when light is incident normally or perpendicularly on a boundary of two media since angle of incidence and angle of refraction both are zero.

(iii) (c): When light goes from one medium to other medium, its frequency does not change.

(iv) (a): The speed to light increases when light passes from glass to water as water is optically rarer medium.

(v) (a): The bottom of a pool of water appears to be less deep than it actually is due to refraction.

9. (i) (a): According to Snell's law of refraction,

$\frac{\sin i}{\sin r} > 1$ or $\sin i > \sin r$

or $i > r$.

(ii) (a): As, ${}_1\mu^2 = \frac{\sin i}{\sin r}$

$\frac{\sin 45°}{\sin 30°} = \frac{1/\sqrt{2}}{1/2} = 1.41$

(iii) (d): As diamond has maximum value of refractive index, therefore it has minimum speed of light in medium.

(iv) (a): As, $\mu_{glass} = 1.5$, $c = 3 \times 10^8$ m/s

$\therefore \quad \mu = \frac{c}{v}$ or $1.5 = \frac{3\times10^8}{v}$

$v = 2 \times 10^8$ m/s

(v) (b): Given, refractive index of a with respect to b is ${}^b\mu_a = 2$

$\therefore$ Refractive index of b with respect to a is

$\frac{1}{{}^b\mu_a} = {}^a\mu_b = \frac{1}{2} = 0.5$

10. (i) (c): Convex lens is used as magnifying glass. For better performance its focal length should be small.

(ii) (a) (iii) (c)

(iv) (a): A aperture is the area of the lens available for refraction.

(v) (a): Water droplets behave like a convex lens only as refraction takes place on outer surface.

11. (i) (a): When an object is placed at infinity of convex lens, image will be formed at focus F.

(ii) (b): Virtual and inverted image is formed, when object is placed at focus of the concave lens.

(iii) (c): When object is placed at focus of a convex lens, highly enlarged or magnified image is formed.

(iv) (b): When an object is placed at distance $2F$ in front of a convex lens, then the image formed is at a distance $2F$ on the other of the lens.

(v) (a): Image if formed between focus and optical centre when the object is placed anywhere between optical centre and infinity.

12. (i) (a): Given, $f = 20$ cm, $u = -10$ cm

Using, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\frac{1}{20} = \frac{1}{v} - \left(-\frac{1}{10}\right) \Rightarrow v = -20 \text{ cm}$$

(ii) (b): As, $m = \frac{v}{u} = \left(\frac{-20}{-10}\right) = 2$

$\therefore \quad m = \frac{h_2}{h_1}$

$$2 = \frac{h_2}{4} \Rightarrow h_2 = 8 \text{ cm}$$

(iii) (b): Here $u = -50$ cm, $v = 10$ cm, $f = ?$

Using, $\frac{1}{f} = \frac{1}{10} - \frac{1}{50} \Rightarrow f = -12.5$ cm

(iv) (c): Here, $m = -2$

$h_2 = -6$ cm

$h_1 = ?$

As, $m = \frac{h_2}{h_1} \Rightarrow -2 = \frac{-6}{h_2} \Rightarrow h_1 = 3$ cm

(v) (b): As $P = \frac{1}{f}$ $(\because f = 5 \text{ cm})$

$$P = \frac{-1}{0.05 \text{ m}} = -20 \text{ D}$$