GOMETRIC OPTICS
Example

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Geometric Optics Questions

Multiple Choice Questions:

1. The visible light has a wavelength of range _____.

a. **100–200 nanometres**
b. **250–300 nanometres**
c. **300–350 nanometres**
d. **400–700 nanometres**

2. What is the formula to find the refractive index?

a. **n=c-v**
b. **n=2cv**
c. **n = c/v**
d. **n = c+v**

3. Photons feature the property of _____.

a. **Wave only**
b. **Particle only**
c. **Both wave and particle**
d. **Neither wave nor particle**

4. The spectrum of visible light is emitted and absorbed in the form of _____.

a. **Protons**
b. **Photons**
c. **Electrons**
d. **Neutrons**

5. Separation of white light into different colours is known as _____.

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a. **Reflection**
b. **Refraction**
c. **Dispersion**
d. **Total internal reflection**

6. **The speed of light in a vacuum is represented by _____.**

a. **s**
b. **l**
c. **v**
d. **c**

7. **Bending of light when it passes from one medium to another is known as _____.**

a. **Reflection**
b. **Refraction**
c. **Dispersion**
d. **Total internal reflection**

8. **State true or false: The image formation in an optical system can be explained by geometric optics.**

a. **TRUE**
b. **FALSE**

9. **Which of the following changes when the light is reflected from the mirror?**

a. **speed**
b. **frequency**
c. **wavelength**
d. **Phase**

10. **For a concave mirror, what will be the minimum distance between a real object and its real image?**

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a. zero
b. f
c. 2f
d. 4f

11. Which of the following produces a virtual image which is larger than the object?
a. concave mirror
b. convex mirror
c. plane mirror
d. none of the

12. What will be the focal length of a spherical mirror?
a. same for all lights
b. maximum for white light
c. maximum for red light
d. maximum for blue light

13. The ratio between the sine of the angle of incidence and sine of the angle of refraction is constant for the light of a given colour and for the given pair of media
a. Snell's law
b. Prism law
c. Mirror law
d. Lens maker law

14. Consider the given four statements and choose the correct answer from the given
(1) A concave mirror is a diverging mirror
(2) Image formed by a concave mirror is generally real and inverted
(3) A convex mirror is a converging mirror
(4) Image formed by a convex mirror is always virtual, erect, and diminished

a. (1) and (2) only

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b. (1) and (3) only
c. (2) and (4) only
d. (3) and (4) only
e. None of the above/ More than one of the above

15. The colors in a Rainbow are formed by _____ phenomenon.
a. Reflection
b. Refraction
c. Diffusion
d. Dispersion

16. **What will be the power of a concave lens of focal length 5m?**
a. 5 D
b. -5 D
c. 0.2 D
d. -0.2 D

17. **The rearview mirrors of the vehicle should produce:**
a. **Inverted and diminished image**
b. **Enlarged and inverted image**
c. **Enlarged and erect image**
d. **Diminished, virtual and erect image**

18. **What is the velocity of light in a diamond if the refractive index of diamond with respect to vacuum is 2.5?**
a. 1.2×10^8 m/s
b. 5×10 m/s 8
c. 1.2×10^{10} m/s
d. 2.5×10 m/s

19. **Blue colour of the sky and the reddish appearance of the Sun at the sunrise or sunset is due to**
a. Interference
b. Reflection
c. Refraction
d. Scattering

20. **How does the focal length of a convex lens changes if mono chromatic red light is used instead of violet light?**
a. Focal length is increased when red light is used
b. Focal length is decreased when red light is used

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c. Focal length is remaining same when red light is used
d. Not depends on color of light.

21. A glass lens is immersed in water. What will be the effect on the power of lens?
a. **increase**
b. **decrease**
c. **constant**
d. **not depends**

22. How does the magnifying power of a telescope change on increasing the linear diameter of its objective?
a. **Power increases on increases diameter**
b. **Power decreases on decreases diameter**
c. **Power remain constant on increases diameter**
d. **Power doesn't depend on diameter**

23. What is the magnification and focal length of a plane mirror?
a. **+1, ∞**
b. **+1, 0**
c. **–1, ∞**
d. **–1, 0**

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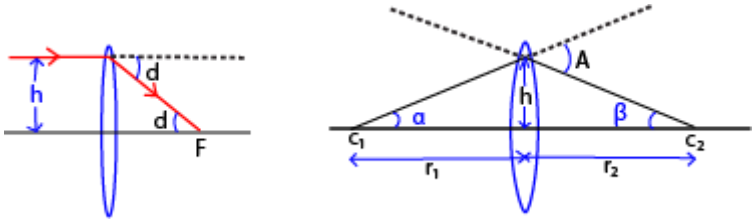
Geometrical optic revision questions and answers:

1. derive the relationship, for convex lens, where u is the object distance, v is the image distance and f is the focal length of the lens.

Solution

Consider in each case a ray incident on the same lens at a small height **h** above the principal axis as shown:



From Fig (i), the ray parallel and close to principal axis is converged to the focal point **F** and suffer a **small** deviation **d**

where **d** $\approx$ tan d $= \frac{h}{f}$ ---------- (i)

From Fig (ii), the ray from a point object **O** suffers the same small deviation **D** to give rise to a point image **I**.

From geometry, $d = \alpha + \beta$ where $\alpha \approx \tan\alpha = \frac{h}{u}$ and $\beta \approx \tan\beta = \frac{h}{v}$

$$d = \frac{h}{u} + \frac{h}{v} \quad \text{---------- (ii)}$$

Equating equations (i) and (ii) gives

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

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

2. State three possible reasons under which an image of real object may not be formed by a convex lens on the screen.

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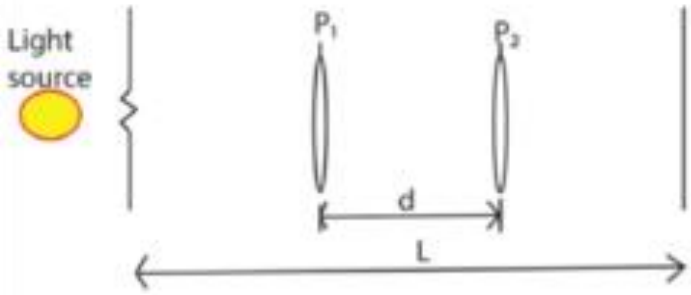
Solution

- When the object is placed between the lens and optical center.
- When the distance between the object and the screen is four times the focal length of the lens
- When the object is at the principal focus
- When the screen is between the lens and its principal focus.

3. Describe an experiment to determine the focal length of a convex lens fixed inside a short cylindrical tube

Solution
Illustration



- The tube is placed between an illuminated object and a screen a distance l slightly more than 4 times the approximate focal length of a lens to form a clear magnified image at the screen. The position of the front part P_1 is noted

- The tube is moved towards the screen until a clear diminished image is formed on the screen and position P_2 of the front part is noted

- The displacement, $d = P_2 - P_1$ is noted

The focal length, f of the lens $= \frac{l^2 - d^2}{4l}$

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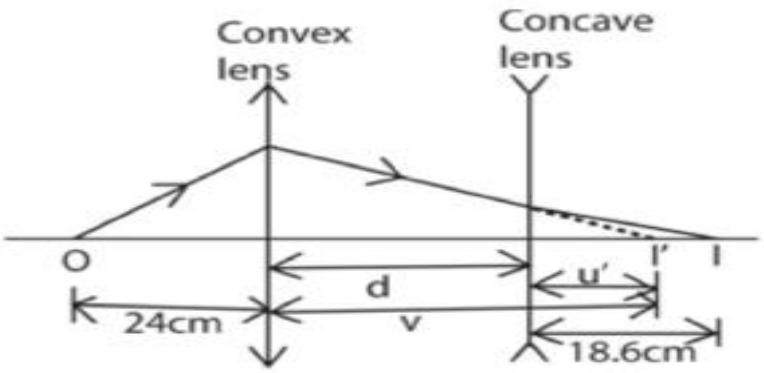
4. A convex lens of focal length 10cm is arranged coaxially with a concave lens of focal length 18cm. the lens system is used to focus an object placed 24cm from the convex lens on the side remote from the concave lens. the final image is formed on a screen placed 18.6cm from the concave lens. Calculate the; (i) separation between the lenses.

Solution



Let the separation between the lenses be d.

For convex lens

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

$$\frac{1}{10} = \frac{1}{24} + \frac{1}{v}\ ; v = 17.14cm$$

For concave lens

$$\frac{1}{-18} = \frac{1}{u'} + \frac{1}{18.6}\ , u' = -9.15cm \text{ (-ve because object is virtual)}$$

Separation, d = v-u' = 17.14 − 9.15 = 7.99cm

(ii) Magnification (03marks)

$$M = M_1 \times M_2$$

$$= \frac{v}{u} \times \frac{v'}{u'}$$

$$= \frac{17.14}{24} \times \frac{18.6}{9.15} = 1.45$$

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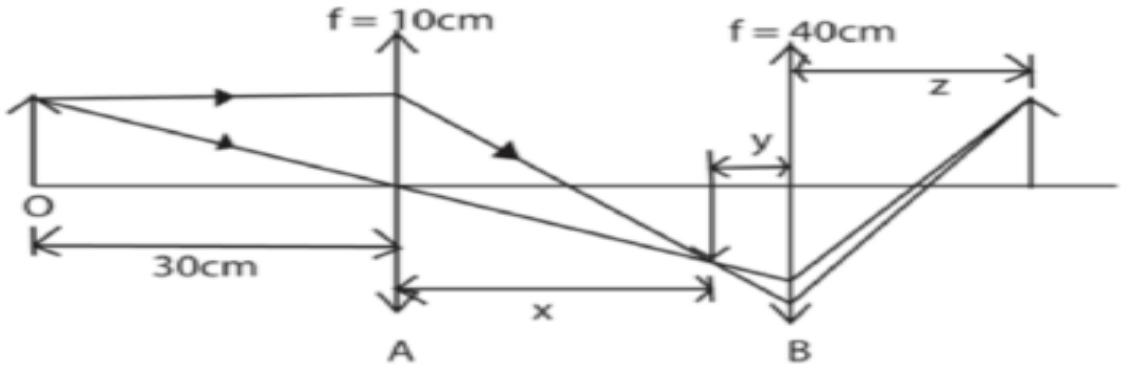
5. A small object is placed at a distance of 30.0cm from a converging lens of focal length 10.0cm. Calculate the distance from the first lens where a second converging lens of focal length 40.0cm must be placed in order to produce an erect image of the same size as the object.

Solution



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

$$\frac{1}{10} = \frac{1}{30} + \frac{1}{x}; \; x = 15cm$$

Magnification, $M_1 = \frac{v}{u} = \frac{15}{30} = \frac{1}{2}$

Magnification, $M_2 = \frac{z}{y}$

But $m = M_1 \times M_2$

$$1 = \frac{1}{2} \times \frac{z}{y}; \; z = 2y$$

Action of second lens

$$\frac{1}{40} = \frac{1}{y} + \frac{1}{2y}; \; y = 60cm$$

Position = x + y= 15 + 60 = 75cm from the first lens

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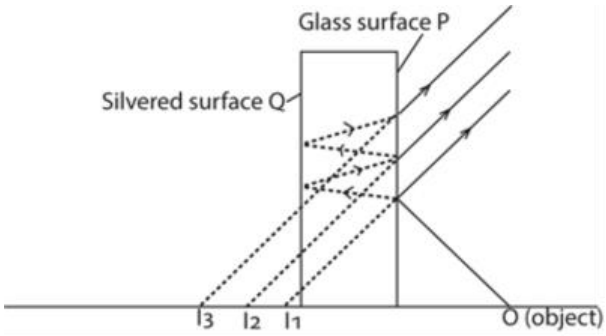
6. Explain with the aid of a diagram how thick plane mirror forms multiple images

Formation of multiple images in thick plane mirror



Solution

Multiple images are formed due to partial reflection and refraction at the non-silvered surface of the mirror.

- İmage I_1 is formed by reflection on the glass surface P
- The image I_2 (the brightest is formed by reflection of the most light on the silvered surface Q
- Others by partial refraction

7. Find the power of a lens of focal length 15 cm

Solution

$$\text{Power of lens} = \frac{1}{f(m)} = \frac{1}{0.15} = 6.67D$$

8. A compound microscope consists of two thin lenses, an objective of focal length 1.0cm and eye piece of focal length 5.0cm. The objective forms an image of an

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object placed in front of it at a point 16.0cm away. If the final image is formed at the near point of the eye, calculate the
(i) Separation of the lenses and (ii) magnifying power of the instrument

Solution

Consider the eyepiece lens, using $\frac{1}{f} = \frac{1}{u} + \frac{1}{V}$

$\frac{1}{5} = \frac{1}{u_e} + \frac{1}{-25}$; $u_e = 4.17m$

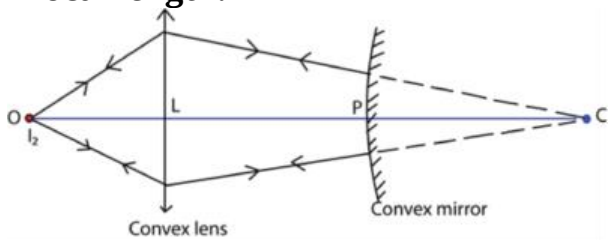
Separation of lenses = $v_0 + u_e = 16.0 + 4.17 = 20.17cm$

$$M = (\frac{-D}{f_e} - 1)(\frac{v}{f_0} - 1) = (\frac{-25}{5} - 1)(\frac{1}{1} - 1) = -90$$

8. Describe how the focal length of a convex mirror can be measured using a convex lens of known focal length

Solution

Determination of the focal length of a convex mirror can be measured using a convex lens of known focal length.



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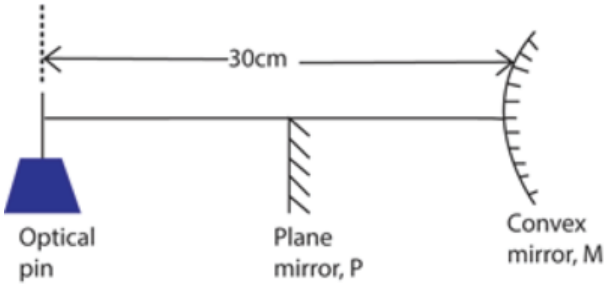
- The apparatus is arranged as shown above
- An object, O is placed in front of a convex lens L and its image formed at C
- The distance LC is measured and recorded.
- The convex mirror whose focal length, f, is required is placed is placed between L and C with its reflecting surface facing the lens.
- The lens is then moved along the axis, OC until a converging beam incident normally on the mirror forms its image at O
- Distance LP is measured

PC = LC – LP thus, f can be determined from

$$f = \frac{PC}{2}$$

9.The plane mirror, P, in the figure below is adjusted to a position20cm from optical pin, the image of the pin in P coincides with its image in M. Calculate the focal length of the convex mirror.



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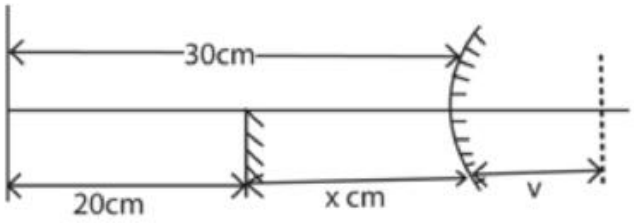
Solution



$v = 20 - x$

$= 20 - (30\text{-}20) = 10\text{cm}$

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

$= \frac{1}{30} + \frac{1}{-10}$

$f = 15\text{cm}$

10. A concave lens of focal length 15.0cm is arranged coaxially with a concave mirror of focal length 10.0cm, a distance of 4.0cm apart. An object is placed 20.0cm in from of the lens on the side remote from the mirror. Find the distance of the final image from the lens.

Solution

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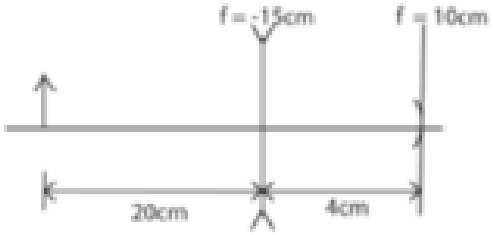


Action of concave lens

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-15} - \frac{1}{20}$$

$$v = \frac{-60}{7} = -8.6\text{cm}$$

Action of concave mirror

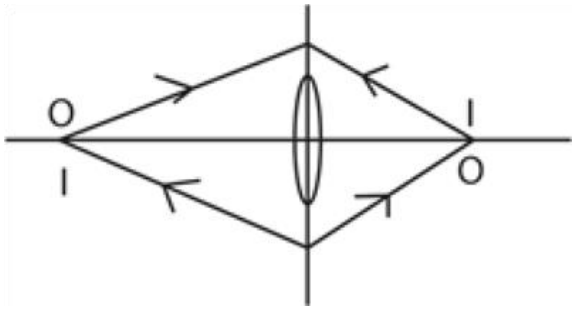
u = 8.6 + 4 = 12.6cm, f = 10

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{10} - \frac{1}{12.6}; \; u = 48.5\text{cm}$$

Distance of image from the lens = 48.5- (20 + 4) =24.5 cm on the side remote to the mirror

11. Explain what is meant by conjugate points.

Solution



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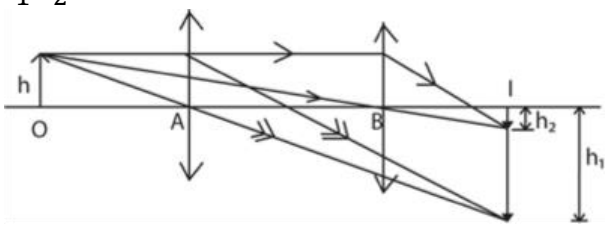
These are two points, O and I. each on the opposite side of a convex lens such that an object and its image at these points are interchangeable.

12. A converging lens forms an image of height, h_1 on a screen of an object O of height, h. When the lens is displaced towards the screen, an image of height, h_2 is formed on the screen.

(i) Sketch a ray diagram to show the formation of the images on the screen.

(ii) show that $h = \sqrt{h_1 h_2}$



(ii)

O and I are conjugate points with respect to the lens

OB = AI and OA = BI

At point A, linear magnification, $Ma = \frac{AI}{OA} = \frac{h_1}{h}$ ..... (i)

At point B, linear magnification, $Mb = \frac{BI}{OB} = \frac{h_2}{h}$ ..... (ii)

But AI = OB

$$\frac{h}{h_1} = \frac{h_2}{h}$$

$$h^2 = h_1 h_2$$

$$h = \sqrt{h_1 h_2}$$

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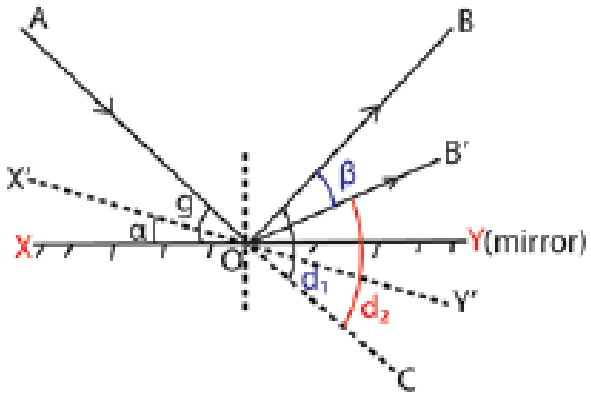
13. A ray of light is incident on a plane mirror. The mirror is then turned through an angle α keeping the direction of the incident ray constant. If a reflected ray turned through angle β, find the relationship between α and β.

Solution

Let XY be the initial position of the mirror with ray AO making a glancing angle g. By keeping the direction of the incident ray fixed, the mirror is rotated through an angle **α** to a new position X'Y' as shown.



Case 1 (mirror in position XY)

Glancing angle = g

Deviation $d_1 = 2g$…… (i)

Case 2**(mirror in position X'Y')**

Glancing angle = $(g - \alpha)$

Deviation $d_2 = 2(g - \alpha)$ …..(ii)

$\beta = d_1 - d_2$

$= 2g - 2(g - \alpha)$

$= 2g-2g + 2\alpha$

$= 2\alpha$

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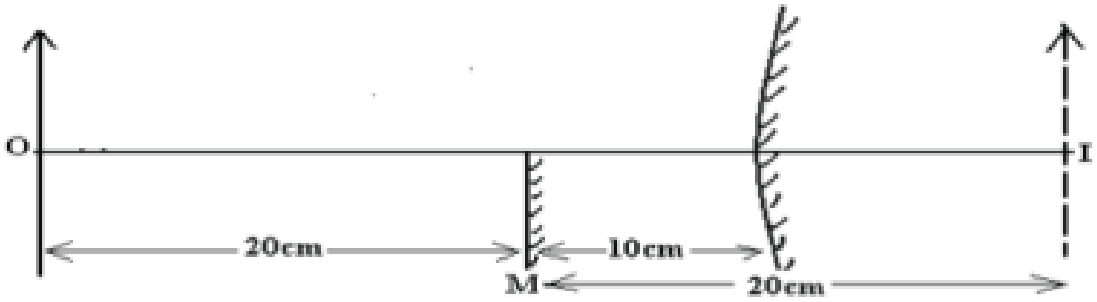
14. A plane mirror is placed 10cmin front of a convex mirror so that it covers about half of the convex mirror surface. A pin placed 20cm in front of the plane mirror gives an image which coincides with that of the pin in the convex mirror. Find the focal length of the convex mirror.

Solution



Consider the action of a convex mirror

u = 30cm and v = - (20 - 10) = -10cm "The image formed is virtual "

Using the lens formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ give

Image distance v of the lens = $\frac{fu}{u-f} = \frac{-10\,x\,30}{30-10} = -15cm$

15. Explain how chromatic and spherical aberration are minimized in a reflecting telescope

Solution

Correction of chromatic aberration

- Use **lenses** made of low-dispersion glasses, especially those containing fluorite

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- By using combination of lenses of opposite nature (convex & concave) or chromatic doublet such that the dispersion produced by one lens is reversed by another.
- Placing the eye close to the lens such that images due to different colours subtend the same angle at the eye.

Means of reduction of spherical aberration

- Using lenses with an aspheric surface
- Using lens of small aperture.
- Using a stopper such that only light incident on the middle of the lens pass, but this method reduces the brightness of the image since it reduces the amount of light energy passing through the lens.

16. State four applications of total internal reflection

Solution

- in radio broadcasting
- determination of refractive index if material
- in optical fiber transmission
- in refracting prisms in binoculars and periscopes

17. The figure below is a glass convex lens in air with surfaces A and B having radii of curvature 10cm and 15cm respectively. if the refractiv index of the glass 1.5. Calculate the power of the lens

Solution

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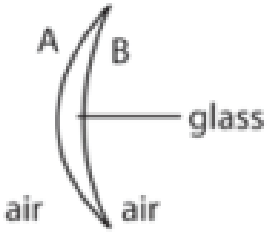
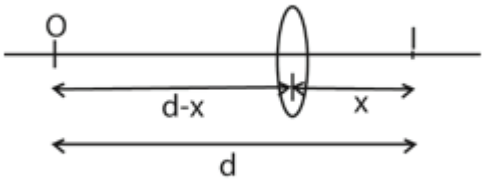


r_1= 10cm = 0.1m, r_2 = -15cm = -0.15m

Using $\frac{1}{f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right) = (1.5-1)\left(\frac{1}{0.1} + \frac{1}{0.15}\right) = 1.67D$

18. Derive the expression for the least possible distance between the object and its real image

Solution



u = d-x v = x

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

$\frac{1}{f} = \frac{1}{d-x} + \frac{1}{x} = \frac{d}{dx-x^2}$

$x^2 - dx + fd = 0$

$x = \frac{d \pm \sqrt{d^2-4fd}}{2}$

for real roots, $d^2 > 4fd$ or $d > 4f$

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19. Give the properties of lenses in achromatic combination.

Solution

- One lens should be concave and the other convex
- The lenses should be of different materials
- The dispersion caused by the concave lens should be completely cancelled by the convex lens.
- The radii of curvature of concave and convex lenses should be numerically equal

19. Find the maximum angle of refractive index when a light ray is refracted from glass ($\mu\mu$=1.50) to air

Solution

When light ray travels from glass to air then total internal reflection takes place. In this refracted angle is more than 90° for reflection to occur. Thus, maximum angle is 90°.

20. Lenses are constructed by a material of refractive index 1.50. The magnitude of the radii of curvature are 20cm and 30cm. Find the focal length of the possible lenses with the above specification.

Solution

There are four types of lenses: We know that,

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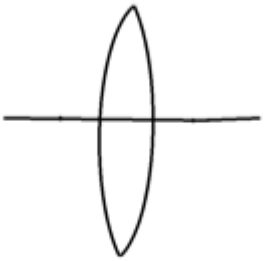
$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R1} - \frac{1}{R2}\right]$$

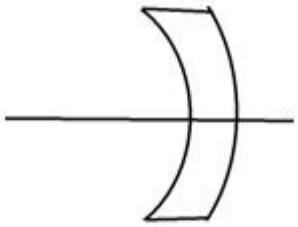
(1) If R1=+ve and R2= -ve



$$\frac{1}{f} = (15 - 1)\left[\frac{1}{20} - \frac{1}{-30}\right]$$

$$f = 24cm$$

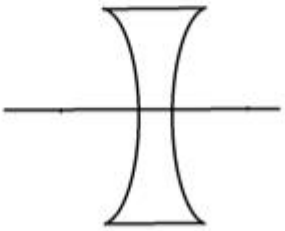
(2) If R1=-ve and R2= -ve



$$\frac{1}{f} = (15 - 1)\left[\frac{1}{-20} - \frac{1}{-30}\right]$$

$$f = -120cm$$

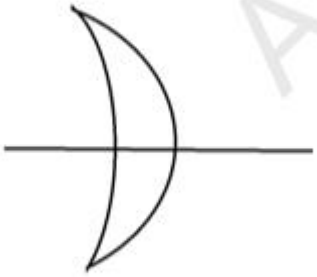
(3) If R1=-ve and R2= +ve



$$\frac{1}{f} = (15 - 1)\left[\frac{1}{-20} - \frac{1}{30}\right]$$

$$f = -24cm$$

(4) If R1=+ve and R2= +ve



$$\frac{1}{f} = (15 - 1)\left[\frac{1}{20} - \frac{1}{30}\right]$$

$$f = 120cm$$

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Practice Questions:

1. What is light?
2. Explain the electromagnetic spectrum.
3. What is wave-particle duality?
4. Explain refraction through a glass prism.
5. What are the various optical properties of light?
6. State the laws of refraction of light.
7. What is meant by the following:
   I. total internal reflection
   II. critical angle
8. Briefly explain why an observer sees a spectrum of colors through rain drops when it is raining on a sunny day
9. Name one defect of the image formed by a lens and explain how the defect is minimized in practice.
10. Explain the following
    i. total internal reflection
    ii. Formation of mirages
11. State two differences between real and virtual images
12. Define the following as applied to a converging lens;
    i. Principal focus
    ii. center of curvature
13. Draw a sketch ray diagram showing formation of the image of a finite size real object by a concave lens
14. With the aid of a sketch ray diagram explain spherical aberration in a concave lens, and state how it is minimized.
15. Explain the following as applied to lenses.
    i. chromatic aberration

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ii. spherical aberration

16. Explain why the rays from the sun can still be seen shortly after sunset

17. Define the following terms as applied to a concave lens:

i. principal focus'

ii. radii of curvature

18. Define refractive index.