CLASS 12 PHYSICS NCERT SOLUTIONS

NCERT Solutions for Class 12 Physics Chapter 9: Ray Optics and Optical Instruments – Free PDF Download

Chapter 9 covers ray (geometric) optics -- reflection at spherical mirrors, refraction at plane and curved surfaces, prisms, thin lenses, and the optical instruments (microscopes and telescopes) built from them. With 31 exercise questions, this is the longest chapter in the syllabus; these solutions work through eve...

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Chapter 9 covers ray (geometric) optics — reflection at spherical mirrors, refraction at plane and curved surfaces, prisms, thin lenses, and the optical instruments (microscopes and telescopes) built from them. With 31 exercise questions, this is the longest chapter in the syllabus; these solutions work through every one, using the mirror formula, lens formula, lens-maker's formula, and the magnifying-power formulas for optical instruments, each cross-checked numerically before publishing.

NCERT Exercise Solutions

9.1 A 2.5cm tall candle is placed 27cm in front of a concave mirror of radius of curvature 36cm. At what distance from the mirror should a screen be placed to obtain a sharp image? Describe the nature and size of the image.
Ans: $f=R/2=18$cm. Using $1/v+1/u=1/f$ with $u=-27$: $1/v=1/18-1/27$… solving gives $v=\mathbf{-54}$**cm**, so the screen should be placed **54cm** in front of the mirror. Magnification $m=-v/u=-2$, so the image is **real, inverted, and magnified (5.0cm tall)**.

9.2 A 4.5cm needle is placed 12cm away from a convex mirror of focal length 15cm. Give the location of the image and its magnification. Describe what happens as the needle moves farther from the mirror.
Ans: $f=+15$cm (convex), $u=-12$cm. $1/v=1/15+1/12=3/20 \Rightarrow v=\mathbf{+6.67}$**cm** (behind the mirror). $m=-v/u=+0.556$, so the image is **virtual, erect, and diminished, about 2.5cm tall**. As the needle moves farther away, the (still virtual, erect, diminished) image moves steadily closer to the focus and shrinks further, but never grows larger than the object and never becomes real.

9.3 A tank of water 12.5cm deep is viewed with a microscope focused on a needle at the bottom; the apparent depth is 9.4cm. What is the refractive index of water? If water is replaced with a liquid of refractive index 1.63 up to the same depth, by what distance would the microscope have to be moved to refocus?
Ans: μ=real depth/apparent depth$=12.5/9.4\approx\mathbf{1.33}$. With the new liquid, apparent depth$=12.5/1.63\approx7.67$cm — shallower than before by $9.4-7.67\approx\mathbf{1.73}$**cm**, so the microscope must be moved up (toward the surface) by about 1.7cm to refocus.

9.4 Figures show a ray going from air into glass at 60° incidence, and from air into water at 60° incidence. (a),(b) Find the refraction angle in each case. (c) Using these results, predict the refraction angle for a ray going from water into glass at 45° incidence.
Ans: (a) Air→glass ($n=1.5$): $\sin r=\sin60°/1.5 \Rightarrow r\approx\mathbf{35.3°}$. (b) Air→water ($n=1.33$): $\sin r=\sin60°/1.33 \Rightarrow r\approx\mathbf{40.6°}$. (c) Relative refractive index water-to-glass = $1.5/1.33\approx1.128$; $\sin r=\sin45°/1.128 \Rightarrow r\approx\mathbf{38.8°}$.

9.5 A small bulb is placed at the bottom of a tank filled with water to a depth of 80cm (μ=1.33). What is the area of the water surface through which light from the bulb can emerge?
Ans: Light can escape only within the cone defined by the critical angle, $\sin C=1/\mu=0.752 \Rightarrow C\approx48.75°$. Radius of the circle of illumination $r=h\times\tan C=80\times1.140\approx91.2$cm. Area$=\pi r^2\approx26149\text{cm}^2\approx\mathbf{2.61m^2}$.

9.6 A prism of angle 60° gives a minimum deviation of 40° in air. Find its refractive index. What angle of minimum deviation would this prism give if immersed in water (μ=1.33)?
Ans: $n=\sin((A+D_m)/2)/\sin(A/2)=\sin50°/\sin30°\approx\mathbf{1.53}$. Relative to water, $n_{rel}=1.53/1.33\approx1.152$; solving $\sin((A+D_m')/2)=n_{rel}\sin(A/2)=0.576$ gives $D_m'\approx\mathbf{10.3°}$ — a much smaller deviation, since the prism-water refractive-index contrast is far weaker than prism-air.

9.7 A double-convex lens is to be manufactured from glass of refractive index 1.55, with both faces of the same radius of curvature, to give a focal length of 20cm. What is the required

radius?

Ans: For an equi-convex lens, $1/f=(n-1)(2/R) \Rightarrow R=2(n-1)f=2\times0.55\times20=$**22cm**.

9.8 A beam of light converging to a point 12cm behind a lens is intercepted by that lens. Find the point to which the beam converges if the lens is (a) a convex lens of focal length 20cm, (b) a concave lens of focal length 16cm.

Ans: The unconverged beam represents a virtual object at $u=+12$cm in each case. (a) $1/v=1/20+1/12 \Rightarrow v=$**+7.5cm** — beam now converges 7.5cm behind the lens. (b) $1/v=-1/16+1/12 \Rightarrow v=$**+48cm** — beam converges 48cm behind the lens (farther out, since the concave lens diverges the beam somewhat before it can converge).

9.9 An object 3.0cm tall is placed 14cm in front of a concave lens of focal length 21cm. Describe the image produced.

Ans: $f=-21$cm, $u=-14$cm. $1/v=-1/21-1/14 \Rightarrow v=$**−8.4cm**. $m=v/u=+0.6$, so the image is **virtual, erect, diminished (1.8cm tall)**, formed 8.4cm from the lens on the same side as the object — as is always the case for a concave lens.

9.10 A convex lens of focal length 30cm and a concave lens of focal length 20cm are placed in contact. What is the focal length and nature of the combination?

Ans: $1/F=1/30-1/20=$**−1/60**, so $F=$**−60cm** — the combination acts as a single **diverging lens of focal length 60cm**.

9.11 A compound microscope has an objective of focal length 2.0cm and eyepiece of focal length 6.25cm, separated by 15cm. How far from the objective should an object be placed to obtain the final image (a) at the near point (25cm), (b) at infinity? What is the magnifying power in each case?

Ans: (a) For the eyepiece, $v_e=-25$, $f_e=6.25 \Rightarrow u_e=-5$cm, so the objective's image must form at $v_o=15-5=10$cm. Then $u_o=-2.5$cm — **the object should be placed 2.5cm from the objective**. $m_o=v_o/u_o=-4$, $m_e=1+25/6.25=5$, so magnifying power $M=m_om_e=$**−20** (magnitude 20). (b) $u_e=-f_e=-6.25$cm, $v_o=15-6.25=8.75$cm, $u_o\approx-2.59$cm — **object about 2.59cm from the objective**. $m_o\approx-3.375$, $m_e=25/6.25=4$, $M\approx$**−13.5**.

9.12 A small telescope has objective of focal length 8.0mm and eyepiece of focal length 2.5cm, arranged as a compound microscope, with the object placed 9.0mm from the objective, final image at the near point. Find the separation between the lenses and the magnifying power.

Ans: $f_o=0.8$cm, $u_o=-0.9$cm $\Rightarrow 1/v_o=1/0.8-1/0.9 \Rightarrow v_o=$**7.2cm**, $m_o=v_o/u_o=$**−8**. For the eyepiece, $v_e=-25$, $f_e=2.5 \Rightarrow u_e\approx-2.27$cm, $m_e=1+25/2.5=11$. Separation$=v_o+|u_e|\approx$**9.47cm**. Magnifying power $M=m_om_e=-8\times11=$**−88**.

9.13 A telescope has objective of focal length 144cm and eyepiece of focal length 6.0cm. What is the magnifying power, and the separation between the lenses, for the normal adjustment (final image at infinity)?

Ans: $M=f_o/f_e=144/6=$**24**. Separation$=f_o+f_e=$**150cm**.

9.14 A giant refracting telescope has an objective lens of focal length 15m and eyepiece of focal length 1.0cm. (a) What is the angular magnification? (b) What is the diameter of the moon's image formed by the objective, given the moon's diameter is 3.48×10^6m and its distance is 3.8×10^8m?

Ans: (a) $M=1500/1=$**1500**. (b) The moon subtends an angle $\theta=3.48\times10^6/3.8\times10^8\approx0.00916$ rad; the objective forms an image of size $f_o\times\theta=1500\times0.00916\approx$**13.7cm** in diameter.

9.15 Using the mirror formula, show algebraically that: (a) an object between f and 2f produces a real image beyond 2f for a concave mirror; (b) a convex mirror always produces a virtual image,

regardless of object distance; (c) the virtual image in a convex mirror is always diminished, and between the pole and focus; (d) a concave mirror gives a virtual, enlarged image only when the object is between the pole and focus.
Ans: (a) With $f<u<2f$ (both negative, mirror formula $1/v=1/f-1/u$), substituting u between f and 2f gives v also negative but larger in magnitude than 2f — a short algebraic check with $u=1.5f$ gives $v=3f$, confirming the real, magnified image lies beyond 2f. (b) For a convex mirror f is positive; with u always negative (real object), $1/v=1/f-1/u$ is always positive, so v is always positive (behind the mirror) — always virtual. (c) Since $v<f$ always in that case, $|v|<|u|$ follows from the formula, so $m=-v/u$ is always less than 1 in magnitude — the image is always diminished, lying between the pole and focus. (d) For a concave mirror (f negative) with u between 0 and f (i.e. $|u|<|f|$), the formula gives v positive (behind the mirror, virtual) and $|v|>|u|$, so the image is virtual and enlarged — this is exactly the magnifying-mirror configuration (e.g. a shaving mirror).

9.16 Looking through a 15cm thick glass slab (n=1.5) held between a pin and the eye, at a distance of 50cm, the pin appears displaced. By how much, and in which direction?
Ans: Apparent shift$=t(1-1/n)=15\times(1-1/1.5)=15\times1/3=$**5cm**, and the pin appears **shifted 5cm closer to the eye** (the slab makes objects appear nearer than they are).

9.17 A light pipe (optical fiber) has core refractive index 1.68. (a) With cladding of refractive index 1.44, what is the range of angles of the incident ray (from air, at the flat end) for which total internal reflection inside the pipe is possible? (b) What is the range if there is no cladding, with the outer surface in contact with air?
Ans: (a) Critical angle at core-cladding interface: $\sin C=1.44/1.68\Rightarrow C\approx59.0°$. The numerical-aperture condition gives $\sin(i_{max})=\sqrt{(n_1^2-n_2^2)}=\sqrt{(1.68^2-1.44^2)}\approx0.863\Rightarrow i_{max}\approx$**59.9°** — so total internal reflection is assured for all angles of incidence from **0° up to about 60°.** (b) Without cladding (outer medium air, n=1): $\sqrt{(1.68^2-1^2)}\approx1.35$, which exceeds 1 — meaning $\sin(i_{max})$ would need to exceed 1, which is impossible, so **total internal reflection occurs for all angles of incidence (0° to 90°)** at the entry face.

9.18 A screen is placed 3m from an object; a convex lens, when placed between them, produces a sharp image on the screen for two lens positions separated by some distance. What is the maximum possible focal length of the lens for this to work at all?
Ans: By the displacement method, a real image can only be formed on a fixed screen (object-screen distance D) if $D\geq4f$, so the largest possible focal length is $f_{max}=D/4=300/4=$**75cm**.

9.19 A convex lens is placed between an object and a screen fixed 90cm apart. The lens produces a sharp image for two positions separated by 20cm. Find the focal length of the lens.
Ans: By the displacement (Bessel) method, $f=(D^2-d^2)/4D=(90^2-20^2)/(4\times90)=(8100-400)/360\approx$**21.4cm**.

9.20 A convex lens (f=30cm) and a concave lens (f=−20cm), 8.0cm apart, are used together. An object of height 1.5cm is placed 40cm from the convex lens. (a) Find the focal length of the combination — does it depend on which side the light enters from? (b) Find the size and nature of the final image.
Ans: (a) Using $1/F=1/f_1+1/f_2-d/(f_1f_2)=1/30-1/20-8/(30\times(-20))=$**−1/300**, so F=**−300cm**. Swapping f_1 and f_2 in the formula leaves it unchanged, so **the effective focal length of a two-lens combination does not depend on which side the light enters from**. (b) Convex lens: $u=-40$, $f=30\Rightarrow v_1=120$cm, $m_1=-3$. This image is a virtual object for the concave lens at $u_2=120-8=+112$cm; $1/v_2=-1/20+1/112\Rightarrow v_2\approx-24.3$cm, $m_2\approx-0.217$. Total magnification $m_1m_2\approx$**+0.65**, so the final image is **erect** (since the product of two negative magnifications is positive) relative to the object, with height $1.5\times0.65\approx$**0.98cm**, formed about 24.3cm from the concave lens on the side facing the convex lens.

9.21 A prism of angle 60° is made of material of refractive index 1.524. What is the minimum angle of incidence at the first face for which the emergent ray just grazes the second face (i.e. the ray does not emerge from the second face for smaller angles of incidence)?

Ans: Critical angle $C=\sin^{-1}(1/1.524)\approx41.0°$. For the ray to just fail to emerge, the refraction angle at the second face must equal C, so $r_2=41.0°$ and $r_1=A-r_2=60-41.0=19.0°$. Then $\sin i=n\sin r_1=1.524\times\sin19.0°\approx0.497\Rightarrow i\approx$ **29.8°** — this is the minimum angle of incidence for the ray to emerge from the second face at all; for any smaller i, the ray undergoes total internal reflection inside the prism instead.

9.22 A card sheet with squares of area $1mm^2$ is viewed through a magnifying glass of focal length 9cm, held close to the eye. What is the magnification when the image is formed (a) at infinity, (b) at the near point (25cm)? What is the area of each square as seen through the lens in each case?
Ans: (a) $m=D/f=25/9\approx$**2.78**; apparent area$=2.78^2\approx$**$7.72mm^2$**. (b) $m=1+D/f=1+25/9\approx$**3.78**; apparent area$\approx3.78^2\approx$**$14.3mm^2$**.

9.23 (a) At what distance should the lens from Exercise 9.22 (f=9cm) be held from the object for maximum magnifying power? (b) What is the magnification in this case? (c) Is this magnification equal to the magnifying power here? Explain.
Ans: (a) Maximum magnifying power occurs with the image at the near point: $1/u=1/v-1/f=-1/25-1/9\Rightarrow u\approx$**−6.62cm** — the lens should be held about 6.6cm from the object. (b) $m=v/u=-25/-6.62\approx$**3.78** (matches the 1+D/f value from 9.22(b), as expected). (c) **Yes —** magnification (image height/object height) equals magnifying power (ratio of angles subtended at the eye) precisely because the image is deliberately formed at the near point, the same distance used to define the eye's unaided angular reference; they coincide only in this specific configuration.

9.24 What object distance (from the Exercise 9.22 lens) would make the virtual image of each $1mm^2$ square have an area of $6.25mm^2$? Would the squares be seen distinctly if the eye is held very close to the lens?
Ans: Required linear magnification$=\sqrt{6.25}=2.5$. Setting $v=2.5u$ in $1/v-1/u=1/9$ gives $u=$**−5.4cm** (object 5.4cm from the lens), with image at $v=$**−13.5cm**. Since this image distance (13.5cm) is **less than the eye's near point (25cm)**, an eye held close to the lens **would not be able to focus on it distinctly** — the image is too close for the unaided eye to accommodate.

9.25 (a) Why can't the magnifying power of a simple microscope be increased indefinitely just by using lenses of smaller and smaller focal length? (b) Why do both the objective and the eyepiece of a compound microscope need small focal lengths? (c) When viewing through a compound microscope, does it matter much whether the eye is held close to the eyepiece or a short distance away? (d) Why must both objective and eyepiece have sufficiently large apertures? (e) Why does a telescope's eyepiece need a large focal length, while a compound microscope's eyepiece needs a small one?
Ans: (a) A real lens develops significant spherical and chromatic aberration at very short focal lengths, degrading image quality faster than the magnifying power gain is useful — practical simple microscopes rarely exceed about 9–10×. (b) Since magnifying power $M=m_o\times m_e$, and each factor grows as its respective focal length shrinks ($m_o\propto1/f_o$ roughly, $m_e=1+D/f_e$), small focal lengths for both lenses are needed to reach high overall magnification within a reasonably compact instrument. (c) Not much — moving the eye a short distance from the eyepiece mainly shifts the exit pupil and can narrow the field of view slightly, but the magnifying power itself is essentially unchanged as long as all the emergent light still enters the eye. (d) A large enough aperture is needed to collect sufficient light (for a bright enough image) and to reduce diffraction-limited blurring, which would otherwise limit how much detail the magnification can actually resolve. (e) A telescope's eyepiece works with an already-large real image formed by a long-focal-length objective, so a comparatively larger eyepiece focal length still gives a comfortable, high magnifying power ($M=f_o/f_e$) without excessive aberration; a microscope's objective image is small and close, so its eyepiece needs a short focal length simply to achieve any worthwhile magnification ($m_e=1+D/f_e$) at all.

9.26 A compound microscope with objective focal length 1.25cm and eyepiece focal length 5cm

is desired to give an overall magnifying power of 30. How far from the objective should the object be placed, and what should the lens separation be, if the final image forms at the near point?

Ans: $m_e=1+25/5=6$, so $|m_o|=30/6=5$ ($m_o=-5$, since the objective's image is real and inverted). Solving $1/v_o-1/u_o=1/f_o$ with $v_o=-5u_o$: $u_o=$**-1.5cm** (object 1.5cm from the objective), giving $v_o=7.5$cm. For the eyepiece, $u_e\approx-4.17$cm, so the lens separation$=v_o+|u_e|\approx$**11.7cm**.

9.27 A telescope has objective focal length 140cm and eyepiece focal length 5.0cm. What is the magnifying power when the final image is (a) at infinity (normal adjustment), (b) at the near point?

Ans: (a) $M=f_o/f_e=140/5=$**28**. (b) $M=(f_o/f_e)(1+f_e/D)=28\times(1+5/25)=28\times1.2=$**33.6**.

9.28 For the telescope of Exercise 9.27: (a) What is the separation between the objective and eyepiece in normal adjustment? A 100m tall tower is 3km away. (b) What is the height of its image formed by the objective alone? (c) What is the final image height if the final image forms at the near point?

Ans: (a) Separation$=f_o+f_e=140+5=$**145cm**. (b) The tower subtends $\theta=100/3000\approx0.0333$ rad; objective's image height$=f_o\times\theta=140\times0.0333\approx$**4.67cm**. (c) The eyepiece further magnifies this by $m_e=1+25/5=6$ when the final image is at the near point: $4.67\times6\approx$**28.0cm**.

9.29 A Cassegrain telescope uses a large concave primary mirror (radius of curvature 220mm) and a small convex secondary mirror (radius of curvature 140mm), 20mm apart. For a distant (essentially infinite) object, where does the final image form?

Ans: Primary's focal length $f_1=110$mm; parallel rays would converge 110mm behind it, but the secondary mirror (20mm in front of that point) intercepts them first — a virtual object for the secondary at $u=110-20=+90$mm. Secondary's focal length $f_2=+70$mm (convex); $1/v=1/70-1/90\Rightarrow v=$**+315mm** — the final image forms **315mm behind the secondary mirror**, i.e. through a hole at the centre of the primary mirror, which is exactly how a real Cassegrain telescope is built.

9.30 The mirror of a galvanometer, mounted vertically, deflects a light beam through 3.5° when a current passes through the coil. A screen is placed 1.5m from the mirror. Find the displacement of the light spot on the screen.

Ans: A mirror rotation of θ deflects the reflected ray by $2\theta=7°$.
Displacement$=D\times\tan(2\theta)=150\times\tan7°\approx$**18.4cm**.

9.31 An equi-convex lens (refractive index 1.50) is placed on a liquid layer resting on a plane mirror. By the auto-collimation method (moving a needle until its own inverted image coincides with it), the equilibrium distance is 45.0cm with the liquid present, and 30.0cm with the liquid removed. Find the refractive index of the liquid.

Ans: Without the liquid, the auto-collimation distance equals the lens's own focal length: $f_{lens}=$**30cm**. Since the lens is equi-convex with $n=1.5$, its radius of curvature is $R=2(n-1)f_{lens}=30$cm (each surface). With the liquid present, the combined system (lens + the liquid, which forms a plano-concave lens between the lens's lower surface and the mirror) has focal length 45cm: $1/45=1/30+1/f_{liq}\Rightarrow f_{liq}=$**$-90$cm**. Applying the lens-maker's formula to this plano-concave liquid lens ($R_1=-30$cm, $R_2=\infty$): $1/(-90)=(n_{liq}-1)\times(-1/30)\Rightarrow n_{liq}-1=1/3$ $\Rightarrow n_{liq}\approx$**1.33**.

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