CBSE CLASS X

Science (086)

ANSWER KEY

AI-generated question paper

Code: HK1NWI	Questions: 74	Maximum Marks: 203	Generated: 2026-06-25 18:02

SELECTIONS USED

Subject	Science
Lessons	9 Light – Reflection and Refraction
Level of understanding	Thorough understanding
Question selection	Curated chapter coverage (~5 questions per section + 8 synthesis)
Model	claude-sonnet-4-6

Composition — Difficulty: 5 straightforward · 46 medium · 23 deep | Types: 59 Short · 6 Long · 5 Very short · 4 MCQ

Q1. medium | thorough-understanding | § Introduction **[3]**

A small opaque ball is held in the path of a parallel beam of light and casts a shadow on a screen. When the ball is replaced by one that is much smaller (comparable in size to the wavelength of light), a bright spot is observed at the centre of the shadow instead of a dark region. (i) What does the formation of a sharp shadow by the larger ball tell us about the nature of light? (ii) How does the appearance of a bright spot in the centre of the shadow of the very small ball challenge this model?

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Model Answer

(i) The sharp shadow cast by the larger ball tells us that light travels in straight lines (rectilinear propagation). A small source of light casting a sharp shadow of an opaque object indicates that light does not bend around the object and follows a straight-line path (ray model of light).

(ii) When the ball is very small (comparable to the wavelength of light), light bends around it — a phenomenon called **diffraction**. The bright spot at the centre of the shadow cannot be explained by the straight-line (ray) model. This shows that light behaves as a **wave**, challenging the ray model of light.

Source: Chapter 9, Introduction

Explanation

- Part (i) tests rectilinear propagation — the key phrase is "sharp shadow → straight-line travel."
- Part (ii) tests diffraction — examiners expect the word *diffraction*, a mention of wave nature, and why the ray model fails.
- Don't over-explain; 2 crisp sentences per sub-part is enough for 3 marks (1+2 split likely).
- The passage explicitly states both ideas, so quote/paraphrase it closely.

Q2. medium | thorough-understanding | § Introduction **[1]**

In which of the following situations does the straight-line (ray) model of light fail to give an accurate description?

(A) Light passing through a large window and casting a sharp-edged shadow on the floor.
(B) Light reflecting off a plane mirror to form an image.
(C) Light bending around the edge of a very thin razor blade.
(D) Light travelling through a glass slab and emerging on the other side.

A Light passing through a large window and casting a sharp-edged shadow on the floor.
B Light reflecting off a plane mirror to form an image.
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Model Answer

(C) Light bending around the edge of a very thin razor blade.

When an opaque object becomes very small, light bends around it (diffraction), and the straight-line ray model fails.

Explanation

The passage explicitly states: *"If an opaque object on the path of light becomes very small, light has a tendency to bend around it... an effect known as diffraction of light. Then the straight-line treatment of optics using rays fails."* Options A, B, and D all involve phenomena (shadows, reflection, refraction through a slab) that are correctly explained by the ray model.

Q3. medium | thorough-understanding | § 9.1 REFLECTION OF LIGHT **[3]**

A candle placed in front of a plane mirror produces a virtual, erect image of the same size as the object. If the same candle is now placed between the pole and the principal focus of a concave mirror, compare the image formed with that in the plane mirror. State any TWO properties of the image that differ and explain the optical reason behind each difference.

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Model Answer

Plane mirror: Virtual, erect, same size as object.

Concave mirror (object between P and F): Virtual, erect, but **enlarged** (magnified).

Two properties that differ:

1. **Size of image:** The concave mirror forms an *enlarged* image, whereas the plane mirror forms an image of the *same size*. This is because the concave mirror's curved reflecting surface converges reflected rays such that they appear to diverge from a point behind the mirror farther apart, producing magnification greater than 1.

1. **Position of image:** In a plane mirror, the image is as far behind the mirror as the object is in front. In a concave mirror (object between P and F), the image forms *behind the mirror at a greater distance* than the object distance, due to the focusing action of the curved surface.

Source: Chapter 9, Table 9.1; Section 9.1

Explanation

- The key fact from Table 9.1: object between P and F → image is behind the mirror, virtual, erect, and **enlarged**. This is the critical difference from a plane mirror (same size, image distance = object distance).
- Examiners expect you to name the two differing properties clearly and give the optical reason for each. Don't just list properties — explain *why* (curved surface → convergence → magnification >1).
- "Virtual and erect" is **common** to both, so don't list those as differences.

Q4. medium | thorough-understanding | § 9.1 REFLECTION OF LIGHT **[1]**

A student claims: 'The laws of reflection only apply to flat mirrors; curved mirrors follow different rules.' Is this claim correct? Justify your answer.

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Model Answer

The claim is **incorrect**. The laws of reflection apply to **all types of reflecting surfaces**, including spherical (curved) mirrors, not just flat mirrors.

Explanation

The textbook explicitly states: *"These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces."* Examiners expect students to directly contradict the false claim and state the correct fact. One clear sentence is sufficient for 1 mark.

Q5. deep thorough-understanding § 9.1 REFLECTION OF LIGHT **[3]**

You hold the inner (concave) surface of a shining spoon close to your face and observe your reflection. As you slowly move the spoon farther away from your face, the image undergoes a noticeable change at one particular distance and then changes again beyond it. (i) Describe the nature, size, and orientation of the image at each stage of this sequence. (ii) Explain why the image changes at that particular distance.

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Model Answer

(i) Image at each stage (concave/inner surface of spoon):

- **Very close (between P and F):** Image is virtual, erect, and enlarged — face appears magnified.
- **At focal point F:** No image is formed; reflected rays are parallel.
- **Beyond F (object between F and C, at C, or beyond C):** Image is real, inverted, and the size varies — enlarged (between F and C), same size (at C), or diminished (beyond C).

(ii) Reason for the change:

The critical change occurs when the face crosses the **focal point (F)** of the concave mirror. Inside F, the reflected rays diverge and appear to come from behind the mirror (virtual image). Beyond F, reflected rays actually converge in front of the mirror to form a real, inverted image. The focal point is thus the boundary where image nature flips from virtual & erect to real & inverted.

Source: Chapter 9, Section 9.2.1, Table 9.1

Explanation

- Examiners expect all three stages to be addressed with **nature, size, and orientation** for each — use Table 9.1 as your reference.
- The key phrase is: **focal point is the boundary** between virtual-erect and real-inverted images — this directly answers part (ii).
- Avoid writing long paragraphs; bullet-point stages are cleaner and score better for this type of question.

Q6. medium | thorough-understanding | § 9.2 SPHERICAL MIRRORS **[3]**

A concave mirror is placed facing the Sun, and a piece of paper is held at its focus. After some time, the paper catches fire. Using the properties of reflection of parallel rays by a concave mirror and the concept of the principal focus, explain why this happens.

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Model Answer

The Sun is very far away, so rays of sunlight reaching the concave mirror are essentially parallel to its principal axis. According to the properties of reflection by a concave mirror, all rays parallel to the principal axis, after reflection, converge at the principal focus (F).

When the paper is held at the focus, all the reflected rays meet at that single point. This concentrates a large amount of solar energy onto a very small area of the paper, raising its temperature to its ignition point. Hence, the paper catches fire.

Source: Chapter 9, Section 9.2.2 – Representation of Images by Spherical Mirrors; Table 9.1

Explanation

- **Key ray property to state:** Rays parallel to the principal axis converge at focus F after reflection — this is the core point (1 mark).
- **Link to focus:** Paper held at F receives all reflected rays at one point (1 mark).
- **Consequence:** Concentrated energy → high temperature → paper ignites (1 mark).
- Don't forget to mention that sunlight rays are *parallel* because the Sun is at infinity — this justifies using the parallel-ray property.
- Table 9.1 confirms: object at infinity → image at focus F, real, point-sized — exactly the situation here.

Q7. medium | thorough-understanding | § 9.2 SPHERICAL MIRRORS **[3]**

A concave mirror has a radius of curvature of 40 cm. An object 5 cm tall is placed 20 cm in front of it. Using the mirror formula, find the position and size of the image. State its nature (real/virtual) and orientation (erect/inverted).

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Model Answer

Given: R = 40 cm, so f = R/2 = **−20 cm** (concave mirror); object height h = 5 cm; u = **−20 cm**

Mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

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

$$\frac{1}{v} = -\frac{1}{20} + \frac{1}{20} = 0 \implies v = \infty$$

Since the object is placed exactly at the focus (u = f = −20 cm), the reflected rays are parallel and **no image is formed at a finite distance** (image at infinity).

Magnification: $m = -\frac{v}{u}$ → undefined (image at infinity).

Nature: Real and inverted (for any finite screen, image cannot be obtained).

Source: Light – Reflection and Refraction, Table 9.1; Mirror Formula section

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Explanation

- For a concave mirror, both f and u are **negative** by sign convention (distances measured opposite to incident light).
- R = 40 cm → f = −20 cm. Since u = −20 cm = f, the object is **at the focus**, so the image forms at infinity — this is a standard result from Table 9.1.
- Examiners award marks for: correct f, correct substitution, correct conclusion (image at infinity), and nature statement. Don't leave out the sign convention step.

Q8. medium | thorough-understanding | § 9.2 SPHERICAL MIRRORS **[2]**

Drivers prefer a convex mirror over a plane mirror as a rear-view mirror even though a plane mirror gives undistorted sizes. Give TWO distinct optical reasons, based on the properties of image formation by a convex mirror, that justify this preference.

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Model Answer

1. **Wider field of view:** A convex mirror is curved outwards, so it has a wider field of view than a plane mirror of the same size. The driver can see a much larger area of traffic behind the vehicle.
1. **Always erect and fully visible image:** A convex mirror always forms a virtual, erect, and diminished image for any position of the object. This allows the driver to see a greater area without the image being inverted or cut off.

Source: Chapter 9, Uses of Convex Mirrors

Explanation

Examiners expect exactly **two distinct optical reasons**: (i) wider field of view due to outward curvature, and (ii) always erect (never inverted) image regardless of object distance. Both points are explicitly stated in the "Uses of convex mirrors" paragraph. Avoid simply saying "smaller image" as a reason — link it to the *consequence* (larger area visible). Each reason earns 1 mark.

Q9. medium | thorough-understanding | § 9.2 SPHERICAL MIRRORS **[3]**

Using the New Cartesian Sign Convention, an object is placed 20 cm in front of a concave mirror of focal length 15 cm. Calculate the image distance and magnification. State whether the image is real or virtual, and erect or inverted.

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Model Answer

Given: u = −20 cm, f = −15 cm (concave mirror)

Using mirror formula:

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

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-15} - \frac{1}{-20} = -\frac{1}{15} + \frac{1}{20} = \frac{-4+3}{60} = \frac{-1}{60}$$

$$\boxed{v = -60 \text{ cm}}$$

The image is formed **60 cm in front of the mirror**.

Magnification:

$$m = -\frac{v}{u} = -\frac{(-60)}{(-20)} = -3$$

The image is **real** (negative m) and **inverted** (negative sign), and magnified 3 times.

Source: Chapter 9, Section 9.2.4 — Mirror Formula and Magnification

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Explanation

- Always assign signs first: object in front → u is negative; concave mirror → f is negative.
- A negative v confirms the image is in front of the mirror → **real**.
- A negative magnification always means **real and inverted** for mirrors.
- The examiner awards marks for: correct formula use (1), correct v (1), correct m with nature of image (1).

Q10. deep | thorough-understanding | § 9.2 SPHERICAL MIRRORS **[3]**

A spherical mirror produces a magnification of –3 for an object placed 10 cm from the pole. What type of mirror is it? Where is the image formed, and what does the negative sign of magnification tell you about the image?

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Model Answer

Type of mirror: It is a **concave mirror**.

Finding image distance: Using $m = -\frac{v}{u}$, with $m = -3$ and $u = -10$ cm:

$$-3 = -\frac{v}{-10} \Rightarrow -3 = \frac{v}{10} \Rightarrow v = -30 \text{ cm}$$

The image is formed **30 cm in front of the mirror** (on the same side as the object).

Negative sign of magnification: A negative magnification indicates that the image is **real and inverted**.

Source: Chapter 9, Section 9.2.4 — Mirror Formula and Magnification

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Explanation

- **Why concave?** Only a concave mirror can form a real, magnified image ($|m| > 1$ with negative sign). A convex mirror always gives m between 0 and +1.
- **Key formula to remember:** $m = -v/u$. Always apply sign convention: object in front → u is negative.
- **Examiner expects:** identification of mirror type (1 mark), image position with calculation (1 mark), meaning of negative sign (1 mark). Don't skip the calculation step.

Q11. deep | thorough-understanding | § 9.2 SPHERICAL MIRRORS **[3]**

A student claims that a concave mirror can produce an image that is simultaneously virtual, erect and diminished — just like a convex mirror always does. Is the student correct? Justify your answer by analysing all possible object positions for a concave mirror and the nature of images formed in each case.

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Model Answer

The student is **incorrect**.

From Table 9.1, a concave mirror produces the following images:

Object Position	Image Nature
At infinity	Real, inverted, highly diminished
Beyond C	Real, inverted, diminished
At C	Real, inverted, same size
Between C and F	Real, inverted, enlarged
At F	No image formed
Between P and F	**Virtual, erect, enlarged**

In every case, the concave mirror either forms a real inverted image, or (when the object is between P and F) a virtual erect image that is **enlarged** — never diminished. A concave mirror **cannot** produce a virtual, erect, and diminished image for any object position. This combination is exclusive to convex mirrors.

Source: Chapter 9, Section 9.2.1, Table 9.1

Explanation

Examiners expect you to go through **all six object positions** from Table 9.1 systematically. The key point to highlight is that the only virtual + erect image a concave mirror forms (object between P and F) is always **enlarged**, not diminished. Stating this clearly, ideally with the table, earns full marks. Never confuse concave mirror behaviour with convex mirror behaviour — convex mirrors always give virtual, erect, diminished images regardless of object position.

Q12. medium | thorough-understanding | § 9.2.1 Image Formation by Spherical Mirrors **[3]**

A concave mirror produces a virtual, erect and enlarged image of an object. What does this tell you about the position of the object relative to the mirror's focal point? Explain why the image cannot be captured on a screen in this case.

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Model Answer

When a concave mirror produces a virtual, erect, and enlarged image, the object is placed **between the pole (P) and the principal focus (F)** of the mirror — i.e., **between F and the mirror, closer than the focal length**.

In this position, the reflected rays diverge after reflection and do not actually meet in front of the mirror. They only *appear* to meet behind the mirror (virtual image). Since no reflected light rays actually converge at the image point, the image **cannot be caught on a screen —** a screen can only capture real images formed by actually intersecting rays.

Source: Chapter 9, Table 9.1 — Image formation by a concave mirror

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Explanation

- **Key fact from Table 9.1**: Object between P and F → image is behind the mirror, virtual, erect, enlarged.
- Examiners expect you to name the position clearly ("between P and F" or "between the pole and the focus").
- The reason the image can't be on a screen is the core concept: **virtual images are formed by diverging (not converging) reflected rays**; only real images (formed by converging rays) appear on a screen.
- Don't just say "it's virtual" — explain *why* virtual images can't be screened (rays don't actually meet).

Q13. medium | thorough-understanding | § 9.2.1 Image Formation by Spherical Mirrors **[3]**

An object is moved steadily from a very large distance towards the pole of a concave mirror. How does the position of the real image change as the object moves from beyond C to exactly at F? Describe the trend clearly.

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Model Answer

As the object moves from beyond C towards F, the real image shifts continuously **away from the mirror** (i.e., beyond C, further and further from it), and becomes progressively **larger (more enlarged)**.

Specifically:

- **Object beyond C** → Image forms between F and C; diminished, real, inverted.
- **Object at C** → Image forms at C; same size, real, inverted.
- **Object between C and F** → Image forms beyond C; enlarged, real, inverted.
- **Object at F** → Image shifts to infinity; no image is formed on a screen.

Thus, as the object moves from beyond C to F, the image moves from between F and C to infinity, and its size increases from diminished to infinitely large.

Source: Chapter 9, Section 9.2.1, Table 9.1

Explanation

- The examiner expects you to clearly describe the **trend** (image moves farther away, becomes larger) as well as the **specific positions** from Table 9.1.
- Mention all four stages: beyond C, at C, between C and F, and at F — this covers the full range asked.
- Key phrase to remember: image moves from **between F and C** → **to C** → **beyond C** → **infinity** as the object moves from far beyond C toward F.
- The nature remains **real and inverted** throughout (except at F, where no image is formed).

Q14. medium | thorough-understanding | § 9.2.1 Image Formation by Spherical Mirrors **[2]**

At which single position of the object in front of a concave mirror does the image form at the same location as the object? Justify your answer.

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Model Answer

When the object is placed **at the centre of curvature (C)** of a concave mirror, the image forms at the same position — also at C.

Justification: A ray passing through C strikes the mirror along the normal and reflects back along the same path. The reflected rays meet exactly at C, forming a real, inverted image of the same size as the object at C itself.

Source: Chapter 9, Section 9.2.2 — Image formation by Concave Mirror

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Explanation

- The key fact is **object at C** → **image at C** (same position).
- The justification comes from ray property (iii): a ray through the centre of curvature reflects back along the same path because it hits the mirror perpendicularly (along the normal).
- Examiners expect **both** the position AND a reason — that's why it's 2 marks (1 for position, 1 for justification).
- Mention the image nature (real, inverted, same size) for completeness, though it is not strictly required by the question.

Q15. deep | thorough-understanding | § 9.2.1 Image Formation by Spherical Mirrors **[3]**

A concave mirror is used in a solar furnace. (a) State the property of image formation by a concave mirror that makes it suitable for this application. (b) What must be true about the position of the Sun relative to the mirror for this property to be utilized? Explain.

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Model Answer

(a) A concave mirror converges parallel rays of light to meet at its principal focus, producing a very high concentration of heat energy at that point. This property of focusing parallel light rays makes it suitable for a solar furnace.

(b) The Sun must be at (or effectively at) **infinity** from the mirror. Since the Sun is extremely far away, the rays coming from it are nearly parallel. When these parallel rays fall on the concave mirror, they all converge at the principal focus F, generating intense heat sufficient to act as a furnace.

Source: Chapter 9, Section 9.2.2 — Uses of concave mirrors

Explanation

- **(a)** targets the optical property: concave mirror converges parallel rays at focus. Examiners expect the word "converge" or "concentrate" and mention of the principal focus.
- **(b)** targets Table 9.1: object at infinity → image at focus F. The key logic is Sun ≈ infinity ⇒ rays are parallel ⇒ all focus at F. Always link the position of the Sun (at infinity) to the resulting parallel rays.
- This question maps directly to Exercise Q8(c) in the textbook, so knowing "large concave mirrors concentrate sunlight to produce heat" is essential.

Q16. medium | thorough-understanding | § 9.2.2 Representation of Images Formed by Spherical Mirrors Using Ray Diagrams **[2]**

When constructing a ray diagram for a spherical mirror, why is it sufficient to use only two rays from an object point, even though an infinite number of rays originate from that point?

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Model Answer

Although infinite rays originate from each point on an object, it is more convenient to use only two rays for clarity of the ray diagram. The two rays are chosen such that their directions after reflection from the mirror are easily known. The intersection of these two reflected rays gives the position of the image.

Source: Chapter 9, Section 9.2.2 — Representation of Images Formed by Spherical Mirrors Using Ray Diagrams

Explanation

Examiners look for two key ideas: (1) convenience/clarity as the reason for using two rays, and (2) the principle that the intersection of two reflected rays is sufficient to locate the image point. Avoid listing the specific rays unless asked — the question is about *why* two rays are enough, not *which* rays to use.

Q17. medium | thorough-understanding | § 9.2.2 Representation of Images Formed by Spherical Mirrors Using Ray Diagrams **[3]**

A ray of light travelling parallel to the principal axis strikes a convex mirror. Describe the path of the reflected ray and explain, with reference to the law of reflection and the geometry of a spherical mirror, why its behaviour differs from what happens when the same ray strikes a concave mirror.

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Model Answer

When a ray travels parallel to the principal axis and strikes a **convex mirror**, it reflects such that the reflected ray appears to **diverge from the principal focus F**, which lies **behind** the mirror. An observer in front sees the reflected ray coming from F. The convex mirror thus acts as a **diverging mirror**.

By the law of reflection, the normal at any point on a spherical mirror passes through its centre of curvature C. For a convex mirror, C lies **behind** the reflecting surface, so the normal points outward. Applying the angle of incidence = angle of reflection to this geometry causes the reflected ray to spread away from the axis.

For a **concave mirror**, C lies **in front** of the surface; the geometry of the normal directs the reflected ray to actually **converge at F** in front of the mirror, making it a converging mirror.

Source: Chapter 9, Section 9.2 – Spherical Mirrors

Explanation

- Examiners want: (1) path of reflected ray for convex mirror (diverges, appears to come from F behind mirror), (2) reference to law of reflection (∠i = ∠r, normal through C), (3) contrast with concave mirror (converges at F in front).
- Key distinction: the **position of C** (behind for convex, in front for concave) determines whether the normal tilts the reflected ray inward or outward.
- Don't write "virtual focus" in isolation — say "appears to come from F behind the mirror" to show you understand it's virtual.
- Avoid over-explaining; 3 marks = ~3 clear points.

Q18. medium | thorough-understanding | § 9.2.2 Representation of Images Formed by Spherical Mirrors Using Ray Diagrams **[3]**

An object is placed between the pole P and the principal focus F of a concave mirror. Using ray diagram rules, explain why the image formed cannot be caught on a screen.

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Model Answer

When an object is placed between the pole (P) and the principal focus (F) of a concave mirror, the two reflected rays — one parallel to the principal axis and one passing through/directed toward the centre of curvature — diverge after reflection. These diverging rays **do not meet** in front of the mirror; they only appear to meet **behind the mirror** when extended backwards.

Since the reflected rays are diverging, no real point of intersection exists in front of the mirror. The image formed is **virtual, erect, and enlarged**, located behind the mirror. A screen can only catch a real image (where rays actually meet); because this image is virtual, it **cannot be caught on a screen**.

Source: Chapter 9, Section 9.2.1 & 9.2.2; Table 9.1

Explanation

- The key idea examiners want: **diverging reflected rays → virtual image → cannot be caught on screen**.
- Mention the ray diagram rules briefly (how the two standard rays behave) to justify *why* rays diverge.
- Table 9.1 confirms: object between P and F → image is **virtual and erect, behind the mirror**.
- A real image forms where rays *actually* converge; a virtual image forms where rays only *appear* to converge (behind the mirror), so no screen can catch it.
- Always use the terms **virtual**, **behind the mirror**, and **diverging rays** — these are the scoring keywords.

Q19. straightforward | thorough-understanding | § 9.2.2 Representation of Images Formed by Spherical Mirrors Using Ray Diagrams **[1]**

Which of the following correctly describes what happens to a ray passing through the centre of curvature C of a concave mirror after reflection?

(A) It passes through the principal focus F.

(B) It emerges parallel to the principal axis.

(C) It reflects back along the same path.

(D) It reflects at an angle equal to twice the angle of incidence.

A It passes through the principal focus F.
B It emerges parallel to the principal axis.
C It reflects back along the same path.
D It reflects at an angle equal to twice the angle of incidence.

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Model Answer

(C) It reflects back along the same path.

A ray passing through the centre of curvature C of a concave mirror falls normally on the mirror surface, so it reflects back along the same path.

Source: Chapter 9, Section 9.2.2

Explanation

A ray through C is along the radius (normal) of the spherical mirror, so the angle of incidence = 0°, and it retraces its path. This is one of the four standard rays used in ray diagrams for spherical mirrors. Examiners expect you to recall this rule directly.

Q20. medium | thorough-understanding | § 9.2.2 Representation of Images Formed by Spherical Mirrors Using Ray Diagrams **[3]**

A student draws a ray from the tip of an object directed towards the centre of curvature of a convex mirror. The ray does not actually reach C because C lies behind the mirror. How should the student correctly draw this reflected ray, and what principle justifies it?

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Model Answer

For a convex mirror, the centre of curvature (C) lies **behind** the mirror (virtual). A ray directed towards C, upon striking the mirror, is reflected **back along the same path** (i.e., the reflected ray retraces the incident ray and appears to diverge away from C when extended behind the mirror).

How to draw it: Draw the incident ray from the object tip aimed at C (behind the mirror). At the point where it hits the mirror surface, draw the reflected ray going straight back along the same direction as the incident ray, retracing the path.

Principle: The incident ray falls on the mirror **along the normal** to the reflecting surface (since every radius passes through the centre of curvature). The normal to a spherical mirror at any point passes through C. Therefore, the angle of incidence = 0°, so the angle of reflection = 0°, and the ray reflects back along the same path. This is consistent with the **laws of reflection**.

Source: Chapter 9, Section 9.2.2 — Rule (iii) for ray directed towards centre of curvature of a convex mirror

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Explanation

Examiners expect two things: **(1)** a clear description of how to draw the reflected ray (back along the same path / retracing) and **(2)** the justification — the ray travels along the normal because C is the centre of the sphere, so angle of incidence = 0° = angle of reflection. Quoting the textbook rule directly ("reflected back along the same path because the incident rays fall on the mirror along the normal") earns full marks. Don't just say "it follows laws of reflection" — explain *why* (the normal passes through C).

Q21. medium | thorough-understanding | § 9.2.2 Representation of Images Formed by Spherical Mirrors Using Ray Diagrams **[2]**

A ray strikes the pole of a concave mirror making an angle θ with the principal axis. Using the law of reflection and the fact that the principal axis is the normal at the pole, determine the angle the reflected ray makes with the principal axis. Would your answer change if the mirror were convex? Justify your reasoning.

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Model Answer

At the pole, the principal axis acts as the normal to the mirror. By the law of reflection, angle of incidence = angle of reflection. Since the incident ray makes angle θ with the principal axis (the normal), the reflected ray also makes angle **θ** with the principal axis.

No, the answer would **not** change for a convex mirror. The principal axis is the normal at the pole for both concave and convex mirrors, so the law of reflection applies identically at the pole regardless of the type of mirror.

Source: Chapter 9, Section 9.1 (Laws of Reflection) and Section 9.2 (Spherical Mirrors — principal axis is normal at the pole)

Explanation

- The key fact is from the passage: *"principal axis is normal to the mirror at its pole."* This means the angle with the principal axis = angle of incidence, so reflected angle = θ.
- Examiners expect you to explicitly state **why** (normal at pole = principal axis) and confirm the answer is the same for both mirror types with a brief reason.
- Do not confuse angle with principal axis with angle with the normal — here they are the same at the pole only.

Q22. medium | thorough-understanding | § 9.2.2 Representation of Images Formed by Spherical Mirrors Using Ray Diagrams **[2]**

In a ray diagram for a concave mirror, two reflected rays appear to diverge (they do not meet in front of the mirror). What does this tell you about the nature of the image, and how would you locate it on the diagram?

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Model Answer

When two reflected rays from a concave mirror diverge (do not actually meet in front of the mirror), the image formed is **virtual and erect**. This happens when the object is placed between the pole (P) and the principal focus (F).

To locate the image, extend the diverging reflected rays **behind the mirror** using dotted lines. The point where these extended lines meet is the position of the virtual image.

Source: Chapter 9, Section 9.2.2 & Table 9.1

Explanation

- The key concept is: real images are formed by **actual intersection** of reflected rays (in front of mirror); virtual images are formed by **apparent intersection** of extended rays (behind mirror).
- CBSE examiners expect you to state: (1) nature of image = virtual and erect, and (2) method of locating it = extend rays behind mirror with dotted lines.
- Refer to Table 9.1: object between P and F → image is behind mirror, enlarged, virtual and erect.

Q23. deep | thorough-understanding | § 9.2.2 Representation of Images Formed by Spherical Mirrors Using Ray Diagrams **[3]**

A concave mirror is used as a shaving mirror. A person positions their face close to the mirror and observes a magnified image. Using ray diagram rules for a concave mirror, identify the position of the face relative to the focal point F, and explain — with reference to the behaviour of the reflected rays — the nature and position of the image formed.

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Model Answer

The face must be placed **between the pole (P) and the principal focus (F)** of the concave mirror, i.e., the object distance is less than the focal length.

Ray diagram behaviour: A ray parallel to the principal axis reflects through F, and a ray directed towards C reflects back along the same path. When the object is between P and F, these two reflected rays **diverge** after reflection. They do not actually meet in front of the mirror; instead, they appear to meet **behind the mirror** when extended.

Nature and position of image: The image formed is **virtual, erect, and magnified**, located **behind the mirror**. This is why a concave mirror is used as a shaving mirror — it produces an enlarged image of the face.

Source: Chapter 9, Section 9.2.2 (Image formation by Concave Mirror) & Uses of concave mirrors

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Explanation

- The key fact examiners expect: object must be **between P and F** (not beyond F).
- Mention that reflected rays **diverge** → image is virtual (cannot be caught on screen).
- Three image properties must all appear: **virtual, erect, magnified** — missing any one costs a mark.
- Linking back to the shaving mirror use ties the answer to the question context and shows understanding.

Q24. deep | thorough-understanding | § 9.2.2 Representation of Images Formed by Spherical Mirrors Using Ray Diagrams **[2]**

When locating the image of an object placed beyond C in a concave mirror, a student uses only two specific rays and finds their point of convergence. A classmate argues that using a third ray from the same object point would give a different image point, making the diagram inconsistent. How would you refute this argument? What fundamental principle of optics underpins your response?

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Model Answer

The classmate's argument is incorrect. According to the laws of reflection, all rays originating from the same object point, after reflection from the mirror, **converge at the same image point**. The textbook states that "the intersection of at least two reflected rays gives the position of the image." Any third ray will pass through the **same point of convergence** — it will not give a different image point.

The fundamental principle underlying this is the **law of reflection** (angle of incidence = angle of reflection), which ensures all reflected rays from one object point meet consistently at one image point.

Source: Chapter 9, Section 9.2.2 — Representation of Images Formed by Spherical Mirrors Using Ray Diagrams

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Explanation

- Examiners expect you to directly refute the classmate using the textbook's statement that **any two reflected rays** give the image position, and a third ray will confirm — not contradict — that same point.
- The key phrase to include: "intersection of at least two reflected rays."
- Name the principle explicitly: **law of reflection**. This earns the second mark.
- Do not over-explain; two focused points cover both marks cleanly.

Q25. medium | thorough-understanding | § 9.2.3 Sign Convention for Reflection by Spherical Mirrors **[3]**

A student sets up an experiment with a concave mirror. She measures the object distance as 20 cm and the image distance as 30 cm, and writes both values as positive in the mirror formula. Her teacher marks this as incorrect. Explain what the student did wrong and write the correct signs for both distances, justifying your answer using the New Cartesian Sign Convention.

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Model Answer

Error made by the student: She wrote both object distance (u) and image distance (v) as positive, which violates the New Cartesian Sign Convention.

Correct signs and justification:

- **Object distance (u) = −20 cm** (negative): The object is always placed to the left of the mirror. Since distances measured to the left of the pole are negative, u must be −20 cm.
- **Image distance (v) = −30 cm** (negative): For a concave mirror, a real image is formed in front of the mirror, i.e., to the left of the pole. Distances measured to the left are negative, so v = −30 cm.

Both distances should be negative. Writing them as positive gives an incorrect result when applying the mirror formula $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$.

Source: Chapter 9, Section 9.2.3 & 9.2.4

Explanation

What examiners look for:

1. Clearly stating *what* the student did wrong (both values positive — 1 mark).
2. Correct sign for u with reason (1 mark).
3. Correct sign for v with reason — a real image forms in front of the mirror, hence negative (1 mark).

Key rule to remember: In New Cartesian Sign Convention, the object is always to the left → u is always negative for mirrors. A real image also forms in front (left side) of a concave mirror → v is negative. Only a virtual image (behind the mirror, right side) gives positive v.

Q26. deep | thorough-understanding | § 9.2.3 Sign Convention for Reflection by Spherical Mirrors **[3]**

A concave mirror has a focal length of –10 cm. Using the mirror formula, find the object distance if the image is formed at –30 cm. What does the negative sign of the image distance tell you about the nature of the image? Justify your answer using the New Cartesian Sign Convention.

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Model Answer

Given: f = –10 cm, v = –30 cm, u = ?

Using the mirror formula:

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

$$\frac{1}{u}=\frac{1}{f}-\frac{1}{v}=\frac{1}{-10}-\frac{1}{-30}=-\frac{1}{10}+\frac{1}{30}=\frac{-3+1}{30}=\frac{-2}{30}$$

$$u=-15\text{ cm}$$

The object is placed **15 cm** in front of the mirror.

Nature of image: The negative sign of image distance (v = –30 cm) indicates the image is formed **in front of the mirror** (on the same side as the object). According to New Cartesian Sign Convention, distances measured to the left of the pole are negative. Hence, the image is **real and inverted**.

Source: Chapter 9, Section 9.2.3 and 9.2.4

Explanation

- Examiners expect the full substitution step shown clearly — don't skip arithmetic.
- Two things are rewarded: (1) correct numerical value of u with sign, and (2) correct interpretation of negative v using sign convention terminology ("in front of mirror → real and inverted").
- Always state the sign convention rule explicitly: distances to the left of pole are negative → image in front = real.
- A common mistake is forgetting to use negative signs for f and v when substituting — always apply New Cartesian Sign Convention before calculating.

Q27. medium | thorough-understanding | § 9.2.4 Mirror Formula and Magnification **[2]**

While solving a problem using the mirror formula for a concave mirror, a student obtains a positive value for the image distance v. (i) What does the sign of v indicate about the position of the image relative to the mirror? (ii) State the nature (real/virtual, erect/inverted) of this image. (iii) Under what condition of object placement does a concave mirror produce such an image?

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Model Answer

(i) A positive value of image distance v indicates that the image is formed **behind the mirror** (to the right of the pole), i.e., on the same side as the observer.

(ii) The image is **virtual and erect**.

(iii) This occurs when the object is placed **between the pole (P) and the principal focus (F)** of the concave mirror.

Source: Light – Reflection and Refraction, Table 9.1 & Sign Convention (Section 9.2.3)

Explanation

- According to New Cartesian Sign Convention, distances measured to the **right** of the pole are **positive**; behind a concave mirror is the right side, so positive v = virtual image behind mirror.
- Table 9.1 directly states: object between P and F → image is behind the mirror, virtual and erect.
- Examiners expect all three parts answered precisely; missing the "erect/inverted" or "real/virtual" loses marks.

Q28. medium | thorough-understanding | § 9.2.4 Mirror Formula and Magnification **[3]**

An object is placed 20 cm in front of a concave mirror of focal length 20 cm. Using the mirror formula, determine where the image is formed and explain what this result means physically.

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Model Answer

Given: Object distance, $u = -20$ cm; Focal length, $f = -20$ cm (concave mirror)

Mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-20} - \frac{1}{-20} = -\frac{1}{20} + \frac{1}{20} = 0$$

$$v = \infty$$

Result: The image is formed at infinity.

Physical meaning: When the object is placed at the principal focus (F) of a concave mirror, the reflected rays become parallel and never meet. Therefore, no image is formed at any finite distance — the image is said to be formed at infinity.

Source: Chapter 9, Section 9.2.1 (Table 9.1)

Explanation

- Use the sign convention: distances measured in the direction of incident light are positive; opposite are negative. Both u and f are negative for a concave mirror.
- The key result $1/v = 0 \Rightarrow v = \infty$ directly matches Table 9.1: "At F → image at infinity."
- Examiners expect: correct formula substitution, the calculation shown step-by-step, and a clear physical interpretation — all three earn the 3 marks.

Q29. medium | thorough-understanding | § 9.2.4 Mirror Formula and Magnification **[3]**

The magnification produced by a spherical mirror is –3. What does the negative sign tell you, and what does the magnitude 3 tell you? In what region in front of the mirror must the object be placed to produce this image?

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Model Answer

Negative sign: A negative magnification indicates that the image is **real and inverted** (formed in front of the mirror).

Magnitude 3: The image is **3 times enlarged** compared to the object (height of image = 3 × height of object).

Position of object: For a concave mirror to produce a real, inverted, and enlarged image ($|m| > 1$), the object must be placed **between the centre of curvature (C) and the focus (F)** of the concave mirror.

Source: Chapter 9, Section 9.2.4 Mirror Formula and Magnification

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Explanation

- The sign of magnification tells nature + orientation: negative → real + inverted; positive → virtual + erect.
- The magnitude tells the size ratio: $|m| = 3$ means image is three times the object size.
- Examiners expect all three parts answered: sign meaning, magnitude meaning, and object position. Missing the object-position part loses a mark.
- Remember: only a **concave mirror** can give $m = -3$ (real, enlarged image), achieved when the object is between F and C.

Q30. deep | thorough-understanding | § 9.2.4 Mirror Formula and Magnification **[3]**

The magnification for a spherical mirror is given by m = –v/u, while for a lens it is m = v/u. A student argues that both formulae should give the same sign for magnification when the image is real and inverted. Evaluate the student's claim: using the sign convention, show what sign m takes in each case when a real, inverted image is formed, and explain why the formulae are actually consistent with each other despite the apparent difference in form.

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Model Answer

The student's claim is **correct** — both formulae give a **negative** value of m for a real, inverted image. Here's why:

For a spherical mirror: Object distance u is negative (object on left). A real image forms in front of the mirror, so v is also negative. Using $m = -v/u$:

$$m = -\frac{(-v)}{(-u)} = -\frac{v}{u} \Rightarrow \text{negative}$$

For a lens: u is negative (object on left), v is positive (real image on opposite side). Using $m = v/u$:

$$m = \frac{(+v)}{(-u)} \Rightarrow \text{negative}$$

Both give m < 0 for a real, inverted image. The difference in formula form (–v/u vs v/u) compensates for the fact that in a mirror, both u and v are negative, while in a lens, u is negative but v is positive.

Source: Chapter 9, Sections 9.2.4 and 9.3.7

Explanation

Examiners look for: (1) correct sign assignment using New Cartesian Convention, (2) numerical substitution showing sign of m for each case, (3) a clear concluding statement that both are consistent. The key insight is that the "extra negative" in the mirror formula exists precisely because real images in mirrors have negative v (unlike lenses), so the two formulas are deliberately written to yield the same physical result.

Q31. deep | thorough-understanding | § 9.2.4 Mirror Formula and Magnification **[3]**

A convex mirror always produces a magnification between 0 and +1 for any real object. Using the mirror formula and the sign convention, justify why the magnification for a convex mirror can never be negative or greater than 1.

◆ Light – Reflection and Refraction

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Model Answer

For a convex mirror, the focal length **f** is positive and the object distance **u** is negative (object is real, placed in front of the mirror).

From the mirror formula: $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$

Since **f > 0** and **u < 0**, both terms $\frac{1}{f}$ and $-\frac{1}{u}$ are positive, so **v > 0** (image is behind the mirror, virtual).

Magnification: $m = -\frac{v}{u}$

Since **v > 0** and **u < 0**, $m = -\frac{(+)}{(-)} = +ve$ → **m is never negative**.

Also, for a convex mirror the image always forms between the pole and focus, so $|v| < |f|$ and $|v| < |u|$, meaning $|v| < |u|$, thus $m = \frac{v}{|u|} < 1$.

Therefore, **0 < m < 1** always for a convex mirror.

Source: Light – Reflection and Refraction, Chapter 9

Explanation

- Examiners expect you to **apply sign convention explicitly**: state signs of u, f, and deduce sign of v.
- Then use $m = -v/u$ and show why it is positive (erect image) and less than 1 (diminished image).
- The key insight: image distance |v| is always less than object distance |u| for a convex mirror, so the ratio stays between 0 and 1.
- Avoid vague statements — back every claim with the formula and signs.

Q32. medium thorough-understanding § 9.3 REFRACTION OF LIGHT **[3]**

A ray of light travels from glass (refractive index ≈ 1.5) into water (refractive index ≈ 1.33). (i) State whether the ray bends towards or away from the normal at the interface. (ii) Using the relationship between the speed of light and optical density, explain why it bends in that direction.

◆ **Light – Reflection and Refraction**

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Model Answer

(i) The ray bends **away from the normal** at the interface.

(ii) Glass (n = 1.5) is optically denser than water (n = 1.33). A higher refractive index means light travels slower in that medium. So when the ray passes from glass (slower speed) into water (higher speed), it speeds up. A ray travelling from a denser medium to a rarer medium speeds up and bends away from the normal.

Source: Chapter 9, Section 9.3.2 – The Refractive Index

Explanation

- **Key rule to remember:** Denser → Rarer = bends away from normal; Rarer → Denser = bends towards normal.
- Compare refractive indices to decide which medium is denser: higher n = optically denser = slower light.
- Glass (1.5) > Water (1.33), so glass is denser. Ray goes denser→rarer, hence bends away from normal.
- Examiners expect you to explicitly link refractive index → optical density → speed → direction of bending. All three steps must appear for full marks.

Q33. medium | thorough-understanding | § 9.3 REFRACTION OF LIGHT **[3]**

When a light ray passes through a rectangular glass slab at an angle, the emergent ray is parallel to the incident ray but shifted sideways. What causes this lateral shift, and why does the shift vanish when the ray hits the slab perpendicularly?

◆ Light – Reflection and Refraction

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Model Answer

Cause of lateral shift:

When a ray strikes the glass slab obliquely at surface AB (air to glass), it bends **towards** the normal (denser medium). At the opposite surface CD (glass to air), it bends **away** from the normal by an equal and opposite amount. Since the two refracting surfaces AB and CD are parallel, the bending at each surface is equal and opposite, so the emergent ray is parallel to the incident ray but displaced sideways — this sideways displacement is called **lateral shift**.

Why shift vanishes for normal incidence:

When a ray hits the slab perpendicularly (angle of incidence = 0°), it passes straight through both surfaces without any bending at either interface. Since there is no change in direction at AB or CD, no lateral displacement occurs and the shift becomes zero.

Source: Chapter 9, Section 9.3.1 — Refraction through a Rectangular Glass Slab

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Explanation

- Examiners expect two distinct parts: (1) cause of lateral shift and (2) normal incidence case.
- Key phrase to use: "equal and opposite bending at parallel surfaces."
- The textbook explicitly states: *"The extent of bending... at the opposite parallel faces AB and CD... is equal and opposite. This is why the ray emerges parallel to the incident ray. However, the light ray is shifted sideward slightly."*
- For normal incidence, angle of incidence = 0°, so angle of refraction = 0° — no bending, no shift. The textbook hints at this: *"What happens when a light ray is incident normally to the interface?"*
- Avoid writing about refractive index formula unless asked — it wastes word count here.

Q34. medium thorough-understanding § 9.3 REFRACTION OF LIGHT **[3]**

The speed of light in medium A is 2.0×10^8 m s^{-1} and in medium B is 2.5×10^8 m s^{-1}. A ray travels from medium A into medium B. (i) Which medium is optically denser? (ii) Calculate the refractive index of medium A with respect to medium B. (iii) State the direction in which the ray bends at the interface.

◆ **Light – Reflection and Refraction**

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Model Answer

(i) Optically denser medium:

Medium A is optically denser because the speed of light in it (2.0×10^8 m/s) is lower. A medium in which light travels slower has a higher refractive index and is optically denser.

(ii) Refractive index of medium A with respect to medium B:

$$n_{AB} = \frac{\text{Speed of light in medium B}}{\text{Speed of light in medium A}} = \frac{v_B}{v_A} = \frac{2.5 \times 10^8}{2.0 \times 10^8} = 1.25$$

(iii) Direction of bending:

The ray travels from medium B (rarer) into medium A (denser). Therefore, it **bends towards the normal** at the interface.

Source: Chapter 9, Section 9.3.2 – The Refractive Index

Explanation

- **Optically denser = lower speed of light = higher refractive index.** Always link these three together.
- For n_{AB} (A with respect to B), use the formula: speed in B ÷ speed in A (i.e., speed of the *second* medium in the numerator when naming is "first w.r.t. second" — follow Eq. 9.6 pattern carefully).
- Bending direction rule: rarer → denser = bends **towards** normal; denser → rarer = bends **away** from normal. Examiners expect this stated explicitly.

Q35. deep · thorough-understanding · § 9.3 REFRACTION OF LIGHT **[2]**

Kerosene floats on water, showing that its mass density is less than that of water. Yet a light ray bends more when entering kerosene from air than when entering water from air. How do you account for this apparent contradiction?

◆ **Light – Reflection and Refraction**

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Model Answer

Mass density and optical density are two different properties. The refractive index of a medium depends on its **optical density** (i.e., the speed of light in it), not its mass density. Kerosene has a refractive index of 1.44, which is higher than that of water (1.33). This means light travels slower in kerosene than in water, so it bends more when entering kerosene from air. There is no contradiction — a medium of lower mass density can still be optically denser.

Source: Chapter 9, Section 9.3.2 (The Refractive Index)

Explanation

- Examiners expect you to clearly distinguish **mass density** from **optical density / refractive index**.
- Key fact to cite: kerosene $n = 1.44$ > water $n = 1.33$ (from Table 9.3).
- The core idea: bending of light depends on the **speed of light** in the medium (optical density), NOT on how heavy the substance is.
- This is explicitly noted in the textbook: *"an optically denser medium may not possess greater mass density."*

Q36. deep | thorough-understanding | § 9.3 REFRACTION OF LIGHT **[5]**

A coin lying at the bottom of a water tank appears to be closer to the surface than it actually is. (i) Using the concept of refraction of light, explain why the coin appears raised. Draw a ray diagram to support your answer. (ii) The actual depth of the water is 40 cm and the refractive index of water is 1.33. Calculate the apparent depth of the coin. (iii) If water is replaced by a liquid of refractive index 1.5 (same actual depth), how does the apparent depth change? What does this tell you about the relationship between refractive index and apparent depth?

◆ Light – Reflection and Refraction

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Model Answer

(i) Explanation with Ray Diagram:

When light rays from the coin travel from water (denser medium) to air (rarer medium), they bend **away from the normal** at the water-air interface. Our eyes trace these refracted rays back in straight lines, and they appear to meet at a point higher than the actual position of the coin. Thus, the coin appears raised/closer to the surface.

Ray Diagram:

```
Air | / ← Refracted ray (bends away from normal)
--------|/------- water surface
Water |\
| \ ← Actual ray from coin
| [COIN] (actual position)
(apparent position shown higher up)
```

(ii) Calculation of Apparent Depth:

$$\text{Refractive index} = \frac{\text{Real depth}}{\text{Apparent depth}}$$

$$\text{Apparent depth} = \frac{\text{Real depth}}{n} = \frac{40}{1.33} \approx 30.08 \text{ cm}$$

Apparent depth ≈ 30.1 cm

(iii) Effect of higher refractive index (n = 1.5):

$$\text{Apparent depth} = \frac{40}{1.5} \approx 26.67 \text{ cm}$$

The apparent depth **decreases** further (from 30.1 cm to 26.7 cm).

Conclusion: Higher the refractive index of the medium, lesser the apparent depth — i.e., apparent depth is **inversely proportional** to refractive index.

Source: Chapter 9, Section 9.3 – Refraction of Light; Section 9.3.2 – The Refractive Index

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Explanation

- **Part (i):** Examiners expect the key phrase "bends away from normal" (denser to rarer) and the idea that the eye traces rays backward. A simple diagram showing the coin, two diverging refracted rays, and the apparent (virtual) position earns full credit.
- **Part (ii):** The formula **n = Real depth / Apparent depth** is standard and must be recalled. Show substitution clearly.

- **Part (iii):** Always compare the two values numerically, then state the inverse relationship explicitly — examiners look for both the calculation and the conclusion.

Q37. medium | thorough-understanding | § 9.3.1 Refraction through a Rectangular Glass Slab **[3]**

A ray of light enters one face of a rectangular glass slab obliquely and exits through the opposite parallel face. What happens to the direction of the emergent ray compared to the incident ray? Explain, with reference to refraction at each surface, why this outcome occurs.

◆ **Light – Reflection and Refraction**

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Model Answer

The emergent ray is **parallel to the incident ray** but slightly shifted sideways (laterally displaced).

At surface AB (air → glass): Light travels from a rarer to a denser medium, so it bends **towards the normal**.

At surface CD (glass → air): Light travels from a denser to a rarer medium, so it bends **away from the normal** by an equal amount.

Since both parallel surfaces cause equal and opposite bending, the two effects cancel out, and the emergent ray emerges parallel to the incident ray, though laterally displaced.

Source: Chapter 9, Section 9.3.1 — Refraction through a Rectangular Glass Slab

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Explanation

- The key conclusion (parallel + lateral shift) is worth 1 mark; explaining refraction at each of the two surfaces is worth the remaining 2 marks.
- Always name the two surfaces/interfaces and state the direction of bending (towards/away from normal) with the reason (rarer→denser / denser→rarer).
- The phrase "equal and opposite bending" is the textbook explanation — use it directly.
- Do not forget to mention lateral displacement; many students miss it.

Q38. medium | thorough-understanding | § 9.3.1 Refraction through a Rectangular Glass Slab **[2]**

A light ray strikes the flat surface of a rectangular glass slab at exactly 90° (i.e., along the normal). Will it be refracted as it enters the glass? Justify your answer using the laws of refraction.

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Model Answer

No, the light ray will **not be refracted**.

When a ray strikes the surface along the normal, the angle of incidence (i) = 0°. By Snell's law:

$$\frac{\sin i}{\sin r} = \text{constant} \Rightarrow \frac{\sin 0^\circ}{\sin r} = \text{constant} \Rightarrow \sin r = 0 \Rightarrow r = 0^\circ$$

Since the angle of refraction is also 0°, the ray passes straight through without bending.

Source: Chapter 9, Section 9.3.1 & Snell's Law (9.3.2)

Explanation

- Examiners expect you to **state the conclusion** (no refraction) and **justify using Snell's law** with the substitution i = 0°.
- Simply saying "it goes straight" without the law earns partial credit only.
- Note the textbook itself asks students to find out what happens at normal incidence — this is the expected answer to that implicit question.

Q39. deep | thorough-understanding | § 9.3.1 Refraction through a Rectangular Glass Slab **[2]**

A ray of light emerges from a rectangular glass slab parallel to the incident ray but shifted sideways. (i) What is the name given to this shift? (ii) State any two factors on which the magnitude of this shift depends, and explain how each factor affects it.

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Model Answer

(i) The sideward shift of the emergent ray is called **lateral displacement** (or lateral shift).

(ii) Two factors:

- **Angle of incidence:** Greater the angle of incidence, greater is the lateral displacement.
- **Thickness of the glass slab:** Greater the thickness, greater is the lateral displacement.

Source: Chapter 9, Section 9.3.1 – Refraction through a Rectangular Glass Slab

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Explanation

The question is 2 marks, so keep it concise. Examiners expect the correct term "lateral displacement" for part (i) (1 mark), and any two valid factors with a brief explanation of effect for part (ii) (1 mark). Other acceptable factors include the refractive index of the glass (higher refractive index → greater lateral displacement). Do not confuse lateral displacement with the emergent ray being parallel — these are two separate observations.

Q40. deep · thorough-understanding · § 9.3.1 Refraction through a Rectangular Glass Slab **[5]**

A student places a rectangular glass slab over a straight line drawn on paper, with one edge of the slab at an angle to the line. Viewing from the side, the line appears bent at the edges of the slab. However, when the slab is placed with its edge exactly perpendicular to the line and the student looks from directly above, the line appears raised but not bent sideways. Why is there a difference between these two observations?

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Model Answer

Observation 1 — Slab at an angle (line appears bent):

When one edge of the glass slab is inclined to the drawn line, light from the line travels *obliquely* from air into glass (denser medium) and bends **towards the normal** (angle of refraction < angle of incidence). At the opposite face it passes from glass back into air and bends **away from the normal**. According to Snell's law, $\frac{\sin i}{\sin r} = \text{constant}$. Because the ray strikes the surface at an oblique angle, the lateral (sideward) shift is visible, making the line appear **bent/displaced sideways** at the edges of the slab.

Observation 2 — Slab perpendicular to the line (line appears raised, not bent):

When the slab edge is exactly perpendicular to the line, light travels *normally* (straight down) through the slab. A ray incident normally ($i = 0°$) passes without any change in direction, so there is **no bending or lateral shift**. However, the slab is denser than air, so light slows down inside it. The portion of the line beneath the slab appears **raised** (shifted upward) due to the difference in optical density — exactly like printed letters appearing raised when a thick glass slab is placed over them.

Conclusion:

The key difference is the **angle of incidence**: oblique incidence causes lateral displacement (bent appearance); normal incidence causes only apparent depth shift (raised appearance) with no bending.

Source: Chapter 9, Section 9.3 Refraction of Light; Activity 9.9; Section 9.3.1 Refraction through a Rectangular Glass Slab

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Explanation

What examiners look for (5 marks):

- 1 mark: Identifying that Case 1 involves oblique incidence → refraction at both faces → lateral shift/bending.
- 1 mark: Correctly applying Snell's law / bending towards/away from normal.
- 1 mark: Identifying that Case 2 involves normal (perpendicular) incidence → $i = 0$ → no bending.
- 1 mark: Explaining why the line still *appears raised* (apparent depth / denser medium effect).
- 1 mark: Clear concluding contrast between the two cases.

Key points to remember:

- A ray at 0° incidence passes straight through — no lateral displacement, no bending.
- Apparent raising of objects seen through a slab is due to the *denser medium* slowing light, not due to oblique refraction.
- The textbook (Activity 9.9) explicitly contrasts these two placements — always link your answer to that activity.

Q41. medium | thorough-understanding | § 9.3.2 The Refractive Index **[3]**

Light travels from water (refractive index 1.33) into carbon disulphide (refractive index 1.63). In which direction does the refracted ray bend at the interface — towards the normal or away from it? Justify your answer in terms of the speeds of light in the two media.

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Model Answer

The refracted ray bends **towards the normal**.

Justification: Carbon disulphide has a higher refractive index (1.63) than water (1.33). Since refractive index is inversely related to the speed of light in a medium, light travels **slower** in carbon disulphide than in water. When light travels from a rarer medium (water) to an optically denser medium (carbon disulphide), it slows down and bends towards the normal at the interface.

Source: Chapter 9, Section 9.3.2 — The Refractive Index

Explanation

What examiners look for (3 marks):

- 1 mark: Correct direction — *towards the normal*
- 1 mark: Identifying water as rarer (lower n) and carbon disulphide as denser (higher n), and linking higher n to lower speed
- 1 mark: Stating the rule — rarer → denser = slows down = bends towards normal

Key rule to remember: Higher refractive index = lower speed of light = optically denser medium. Light going from rarer to denser always bends towards the normal. Never confuse optical density with mass density.

Q42. straightforward | thorough-understanding | § 9.3.2 The Refractive Index **[1]**

The absolute refractive index of diamond is 2.42. What is the speed of light inside diamond? (Speed of light in air = 3×10^8 m s^{-1})

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Model Answer

Using $n_m = \frac{c}{v}$, speed of light in diamond $= \frac{3 \times 10^8}{2.42} \approx 1.24 \times 10^8 \text{ m s}^{-1}$.
Source: Chapter 9, Section 9.3.2 The Refractive Index

Explanation

The examiner expects the formula $n = c/v$ rearranged to $v = c/n$, substitution of values, and the final answer with correct unit. Writing the formula first earns the method mark; the correct numerical answer earns the answer mark (in a 2-mark version). For 1 mark, the final answer with unit is essential.

Q43. medium | thorough-understanding | § 9.3.2 The Refractive Index **[3]**

Kerosene has a higher refractive index than water, yet kerosene is less dense than water. What does this tell you about the relationship between optical density and mass density? Explain why these two properties are independent of each other.

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Model Answer

Optical density and mass density are **independent** properties — they measure different things and do not necessarily vary together.

- **Optical density** depends on how much a medium slows down light (i.e., its refractive index: $n = c/v$). A higher refractive index means the medium is optically denser.
- **Mass density** depends on how much matter is packed per unit volume.

Kerosene (n = 1.44) has a higher refractive index than water (n = 1.33), so it is optically denser than water. Yet kerosene's mass density is less than that of water (it floats on water). This clearly shows that optical density is determined by the interaction of light with the molecular structure of the medium, **not** by how closely the molecules are packed. Hence, an optically denser medium may not possess greater mass density.

Source: Chapter 9, Section 9.3.2 (The Refractive Index), Table 9.3 note

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Explanation

- Examiners expect you to define both terms clearly, then use the kerosene–water example (directly from the textbook note in Table 9.3) to show they are independent.
- Key phrase to include: *"an optically denser medium may not possess greater mass density"* — this is the exact language from the NCERT note and scores a mark directly.
- Don't confuse "rarer/denser medium" (optical) with physical/mass density — this distinction is what the question tests.

Q44. straightforward | thorough-understanding | § 9.3.2 The Refractive Index **[1]**

[mcq] Light travels at speed v_w in water and at speed v_g in glass, where v_g < v_w. Which expression correctly gives the refractive index of glass with respect to water?

(A) v_g / v_w
(B) v_w / v_g
(C) (v_w + v_g) / 2
(D) v_g × v_w

- A v_g / v_w
- B v_w / v_g
- C (v_w + v_g) / 2
- D v_g × v_w

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Model Answer

(B) v_w / v_g

The refractive index of medium 2 w.r.t. medium 1 = speed in medium 1 ÷ speed in medium 2. So, $n_{gw} = \frac{v_w}{v_g}$.

Source: Chapter 9, Section 9.3.2

Explanation

The key formula from the textbook (Eq. 9.5) is: $n_{21} = \frac{v_1}{v_2}$ — speed in the **first** medium divided by speed in the **second** medium. Here, glass is medium 2 and water is medium 1, so the answer is v_w/v_g. Since $v_g < v_w$, this value is greater than 1, which makes sense as glass is optically denser than water. Avoid the common error of inverting the ratio.

Q45. medium | thorough-understanding | § 9.3.2 The Refractive Index **[2]**

[short_answer] The refractive indices of air, ice, and ruby are approximately 1.0003, 1.31, and 1.71 respectively. Rank these three media in increasing order of the speed of light passing through them. Explain your reasoning using the relationship between refractive index and speed of light.

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Model Answer

The relationship is: $n_m = \frac{c}{v}$, so a higher refractive index means a lower speed of light.

Increasing order of speed of light:

Ruby (n = 1.71) < Ice (n = 1.31) < Air (n = 1.0003)

Since refractive index is inversely proportional to speed, light travels slowest in ruby (highest n) and fastest in air (lowest n).

Source: Chapter 9, Section 9.3.2 – The Refractive Index

Explanation

- The key formula is $n_m = c/v$, meaning speed $v = c/n_m$. Higher refractive index → lower speed.
- Examiners expect you to state the inverse relationship clearly, then apply it to rank the three media correctly.
- Always write the ranking explicitly — don't leave it implied.

Q46. deep thorough-understanding § 9.3.2 The Refractive Index **[5]**

[long_answer] A glass sample is found to allow light to travel through it at a speed of 2.0×10^8 m s^{-1}. (Speed of light in air = 3×10^8 m s^{-1}.)
(i) Calculate the refractive index of this glass sample.
(ii) Crown glass has a refractive index of 1.52. Is this glass sample optically denser or rarer than crown glass? Justify your answer.
(iii) If a ray of light passes from air into each of these two glass types at the same angle of incidence, in which glass will the refracted ray make a smaller angle with the normal? Explain why.

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Model Answer

(i) Calculation of Refractive Index:

$$n = \frac{\text{Speed of light in air}}{\text{Speed of light in glass}} = \frac{c}{v} = \frac{3 \times 10^8}{2.0 \times 10^8} = \mathbf{1.5}$$

(ii) Optically denser or rarer than crown glass?

The refractive index of this glass sample = 1.5, while crown glass has refractive index = 1.52.
Since 1.5 < 1.52, **this glass sample is optically rarer than crown glass.**
The medium with the larger refractive index is optically denser; since crown glass has a higher refractive index, it is the denser medium.

(iii) In which glass does the refracted ray make a smaller angle with the normal?

The refracted ray makes a **smaller angle with the normal in crown glass** (n = 1.52).
When light passes from air (rarer) into glass (denser), it bends towards the normal. A higher refractive index means greater bending towards the normal, i.e., a smaller angle of refraction. Since crown glass has a higher refractive index (1.52 > 1.5), it bends light more, giving a smaller angle with the normal.

Source: Chapter 9, Section 9.3.2 — The Refractive Index

Explanation

- **Part (i):** Directly apply formula $n = c/v$. Show substitution and result clearly — 1 mark for formula, 1 for correct answer.
- **Part (ii):** The key rule is: *higher refractive index = optically denser*. Since 1.5 < 1.52, this sample is rarer. State this rule explicitly — examiners award marks for the justification.
- **Part (iii):** At the same angle of incidence, the denser medium bends light more towards the normal → smaller angle of refraction. Crown glass is denser, so the angle is smaller there. Always link the conclusion to the concept of bending towards the normal.

Q47. medium | thorough-understanding | § 9.3.3 Refraction by Spherical Lenses **[3]**

A convex lens is called a 'converging lens' while a concave lens is called a 'diverging lens'. What physical feature of each lens shape causes this difference in behaviour when parallel rays of light pass through them?

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Model Answer

A **convex lens** is thicker in the middle than at the edges. When parallel rays pass through it, the thicker central portion refracts the rays inward, causing them to converge at a point called the principal focus — hence it is a **converging lens**.

A **concave lens** is thicker at the edges than in the middle. When parallel rays pass through it, the thicker edges refract the rays outward, causing them to diverge — appearing to spread out from a principal focus on the same side as the incident light — hence it is a **diverging lens**.

Source: Chapter 9, Section 9.3.3 — Refraction by Spherical Lenses

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Explanation

- The key physical feature examiners look for is the **shape/thickness profile** of each lens — thicker at middle (convex) vs. thicker at edges (concave).
- Link the shape directly to the behaviour: thick middle → converges; thick edges → diverges.
- Mention "principal focus" to show understanding of refraction outcome.
- Do not just say "curved surfaces" — be specific about *where* the lens is thicker, as that is what drives the answer.

Q48. medium | thorough-understanding | § 9.3.3 Refraction by Spherical Lenses **[3]**

A lens has two principal foci, F_1 and F_2, one on each side. Explain why a lens must have two principal foci rather than just one. A student argues that both foci are always equidistant from the optical centre — under what condition is this true, and what does this tell us about the medium surrounding the lens?

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Model Answer

A lens has **two** principal foci because light can enter from **either side**. F_1 is the focus for light entering from the right, and F_2 is the focus for light entering from the left. Since refraction works in both directions, one focus alone would be insufficient to describe the lens's behaviour for all cases.

Both foci are equidistant from the optical centre **only when the medium on both sides of the lens is the same** (e.g., the lens is surrounded by air or water on both sides). This tells us that the medium has a **uniform refractive index** on both sides, so the speed of light — and hence the degree of refraction — is identical on each side.

Source: Chapter 9, Sections 9.3.4 and 9.3.5

Explanation

- Examiners expect you to state **why two foci exist** (reversibility/two directions of light) and the **condition for equal focal lengths** (same medium on both sides).
- Linking equal focal distances to **same refractive index / same medium** on both sides scores the third mark.
- The source passages show F_1 and F_2 marked on either side of the lens in all ray diagrams and tables, confirming light travels both ways through a lens.

Q49. medium | thorough-understanding | § 9.3.3 Refraction by Spherical Lenses **[2]**

You are given two convex lenses: Lens P has a short focal length and Lens Q has a long focal length. Both are held in sunlight. For which lens will the sharp image of the Sun form closer to the lens, and why?

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Model Answer

Lens P (short focal length) will form the sharp image of the Sun closer to the lens.

A convex lens forms the image of a distant object (like the Sun, which is at infinity) at its principal focus F_2. The shorter the focal length, the closer this focus is to the lens. Since Lens P has a shorter focal length than Lens Q, its image forms nearer to the lens.

Source: Chapter 9, Table 9.4 — Image at focus F_2 when object is at infinity.

Explanation

- The key concept is: **object at infinity → image at focus**. This comes directly from Table 9.4.
- Examiners award 1 mark for identifying **Lens P** and 1 mark for the reason (shorter focal length = focus closer to lens).
- Don't just say "focal length is less" — link it to *where the image forms* (at the focus).

Q50. deep | thorough-understanding | § 9.3.3 Refraction by Spherical Lenses **[3]**

A transparent object can function as a lens only if at least one of its surfaces is spherical. A flat glass slab, however, also refracts light. Why can a flat glass slab not be used as a lens to converge or diverge light rays?

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Model Answer

A flat glass slab has two parallel flat surfaces. When light enters the first surface, it refracts and bends. However, at the second parallel surface, it refracts again by an equal and opposite amount. As a result, the emergent ray comes out **parallel** to the incident ray — only laterally shifted. Since the rays are never made to converge or diverge, the slab cannot act as a lens. A lens works because its curved (spherical) surfaces refract rays by different amounts at different points, bringing them to a focus or spreading them out.

Source: Chapter 9, Section 9.3.1 (Refraction through a Rectangular Glass Slab) and Section 9.3.3 (Refraction by Spherical Lenses)

Explanation

- The key physics is that **parallel surfaces cancel each other's bending effect**, so there is no net convergence or divergence — only lateral displacement.
- Examiners want you to explicitly state: (1) two refractions are equal and opposite, (2) emergent ray is parallel to incident ray, (3) therefore no focusing/diverging action.
- Contrast this with a lens: its **curved surfaces** bend rays by varying amounts at different heights, creating a principal focus.
- Do not just say "it has flat surfaces" — explain *why* flat surfaces prevent convergence/divergence.

Q51. deep | thorough-understanding | § 9.3.3 Refraction by Spherical Lenses **[5]**

A concave lens and a concave mirror both diverge a parallel beam of light, yet a concave mirror can form a real image of a distant object while a concave lens cannot. (a) Describe what each does to a parallel beam incident on it, clearly distinguishing between the two. (b) Explain the fundamental physical reason why a concave mirror converges reflected rays to a real focus, whereas a concave lens diverges refracted rays to a virtual focus.

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Model Answer

(a) Action on a parallel beam:

- **Concave lens:** A parallel beam of light, after refraction through a concave lens, diverges (spreads out). The refracted rays appear to come from a point on the **same side** as the incident light — this is the virtual principal focus (F). The image of a distant object is virtual, erect and diminished.
- **Concave mirror:** A parallel beam striking a concave mirror is **reflected** and the reflected rays actually converge to a real point (real principal focus F) in **front** of the mirror. A distant object therefore forms a real, inverted image at F.

(b) Fundamental physical reason:

A concave lens works by **refraction** — light bends at two curved surfaces as it passes through the glass. Because the lens is thinner at the centre than at the edges, it bends parallel rays **outward**, producing only a virtual focus from which rays appear to diverge.

A concave mirror works by **reflection** — the law of reflection causes each parallel ray to bounce back toward the principal axis. The curved geometry ensures all reflected rays meet at a real point in front of the mirror. No light passes through; it is redirected, allowing actual convergence to a real focus.

Source: Chapter 9, Sections 9.3.3 and 9.3.5

Explanation

- Examiners look for: (a) correct description of **diverging refracted rays → virtual focus** for the lens vs **converging reflected rays → real focus** for the mirror; (b) the key contrast — **refraction vs reflection** and the geometrical reason (thinner at centre for lens; curved reflecting surface for mirror).
- Use the words *real focus* and *virtual focus* explicitly — they carry marks.
- Do not confuse "concave mirror diverges" (it doesn't — that is a convex mirror). The question's opening statement is a common misconception trap; your answer should make clear the mirror **converges**.
- Keep part (b) tied to the physics: refraction bends light outward in a concave lens; reflection at a concave surface bends light inward.

Q52. deep | thorough-understanding | § 9.3.3 Refraction by Spherical Lenses **[3]**

The principal focus of a convex lens is defined using rays parallel to the principal axis. What would you observe if, instead of parallel rays, you directed rays from a point source placed exactly at the principal focus F_1 through the convex lens? Justify your answer using the principle involved.

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Model Answer

When rays from a point source placed at the principal focus F_1 of a convex lens pass through the lens, they will emerge as a beam of parallel rays on the other side, parallel to the principal axis. No image is formed (image is at infinity).

Principle involved: According to the rules of ray diagrams, a ray of light passing through the principal focus of a convex lens, after refraction, emerges parallel to the principal axis. As the object is at F_1, all refracted rays become parallel and never converge, so the image is formed at infinity. This is also confirmed by Table 9.4: when object is at focus F_1, "image would not be formed" (i.e., it is at infinity).

Source: Chapter 9, Section 9.3.5 (Image Formation in Lenses Using Ray Diagrams) and Section 9.3.4 (Table 9.4)

Explanation

- The key ray rule to quote is: **a ray through the principal focus emerges parallel to the principal axis** after refraction through a convex lens.
- Since all rays from the point source at F_1 emerge parallel, they never meet → image at infinity → effectively no real image is formed.
- Examiners expect you to: (1) state the observation clearly, (2) name/apply the relevant ray rule, and (3) link it to the table or diagram. All three earn the 3 marks.
- This question tests **reversibility of the ray diagram rule**: just as parallel rays converge at F_2, a source at F_1 produces parallel rays on the other side.

Q53. medium thorough-understanding § 9.3.4 Image Formation by Lenses **[3]**

A student places a candle at various positions in front of a convex lens and tries to catch the image on a screen. At one particular position of the candle, no image can be formed on the screen, yet an image does exist. Where is the candle, and why can the image not be caught on a screen?

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Model Answer

The candle is placed **between the focus F_1 and the optical centre O** of the convex lens.

When the object is placed between F_1 and O, the refracted rays diverge on the other side of the lens — they do not actually meet, but appear to diverge from a point on the **same side as the object**. The image formed is **virtual, erect, and enlarged**.

Since the rays only appear to diverge (they never actually converge), a screen cannot catch this image. It can only be seen by looking through the lens directly.

Source: Chapter 9, Table 9.4 — Image Formation by Lenses

Explanation

- The key fact from Table 9.4: when object is between F_1 and O → image is virtual, erect, enlarged, on the same side as the object.
- **Why no screen?** A screen can only catch a **real** image (where rays actually meet). A virtual image is formed by the backward extension of diverging rays, so it cannot be projected.
- Examiners expect: correct position of candle + reason linked to virtual/diverging rays. Both parts are necessary for full marks.

Q54. medium | thorough-understanding | § 9.3.4 Image Formation by Lenses **[3]**

A concave lens is described as a 'diverging lens'. Explain, using the concept of ray behaviour, why a concave lens cannot form a real image of a real object regardless of where the object is placed.

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Model Answer

A concave lens is called a diverging lens because it spreads out (diverges) light rays after refraction. When a ray parallel to the principal axis strikes a concave lens, it refracts and **appears to diverge** from the principal focus on the **same side** as the object. These diverged refracted rays never actually meet on the other side of the lens; they only appear to meet when extended backwards.

Since refracted rays always diverge and never actually converge at any point, no real image (which requires actual intersection of rays) can be formed. Regardless of object position, the image formed is always **virtual, erect, and diminished**, as confirmed by Table 9.5.

Source: Chapter 9, Sections 9.3.3, 9.3.5, 9.3.4

Explanation

- Examiners look for three key ideas: (1) the diverging behaviour of rays, (2) the rays only *appear* to meet (not actually converge), and (3) the conclusion that a real image requires actual intersection of refracted rays — which a concave lens cannot produce.
- Quoting or referencing Table 9.5's conclusion ("always virtual, erect, diminished") adds direct textbook support and scores well.
- Don't just say "rays diverge" — explain *why* that prevents real image formation.

Q55. straightforward | thorough-understanding | § 9.3.4 Image Formation by Lenses **[1]**

A convex lens of focal length 20 cm is used as a simple magnifier. State the range of object distances for which this lens acts as a magnifier, and explain why the image formed in this case cannot be caught on a screen.

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Model Answer

The object must be placed between the focus F_1 and the optical centre O (i.e., within 20 cm from the lens). The image formed is virtual and erect, meaning light rays only appear to diverge from it and do not actually meet — hence it cannot be caught on a screen.

Explanation

For a convex lens to act as a magnifier, the object must be within the focal length so the image is virtual, enlarged, and erect (Table 9.4). A virtual image is formed by the apparent intersection of diverging rays, not real convergence of light, so no screen can capture it. Examiners expect both the range (between F and O) and the reason (virtual image).

Q56. deep | thorough-understanding | § 9.3.4 Image Formation by Lenses **[5]**

An object is moved steadily from a very large distance towards a convex lens along its principal axis. Describe how the position of the real image changes as the object moves from far beyond $2F_1$ to just outside F_1. What happens to the size of the image during this journey? Justify your answer using the image formation data for a convex lens.

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Model Answer

As an object moves from far beyond $2F_1$ towards F_1 along the principal axis of a convex lens, the real image shifts progressively farther from the lens, and its size continuously increases.

Position changes (from Table 9.4):

Object position	Image position
Far beyond $2F_1$	Just beyond F_2 (highly diminished)
Beyond $2F_1$	Between F_2 and $2F_2$
At $2F_1$	At $2F_2$
Between F_1 and $2F_1$	Beyond $2F_2$
At F_1	At infinity (no image formed)

Size changes: The image starts highly diminished (point-sized when object is at infinity), becomes diminished, then same size as the object (at $2F_1$), then enlarged, and finally the image would not be formed as the object reaches F_1.

Throughout this journey, all images are **real and inverted**. As the object moves closer to F_1, the image moves farther away and grows larger, because the refracted rays become more nearly parallel, requiring a greater distance to converge.

Source: Chapter 9, Section 9.3.4 — Image Formation by Lenses (Table 9.4)

Explanation

- Examiners expect you to trace the image **position** and **size** systematically through all five object positions from Table 9.4. Missing any position loses marks.
- Mentioning that images are **real and inverted** throughout (until F_1) is essential — it's a key characteristic the examiner checks.
- The brief justification (rays becoming nearly parallel near F_1 → image at infinity) shows understanding beyond rote memory, which earns full marks on a 5-mark question.
- A small table is acceptable and saves words while covering all positions clearly.

Q57. deep | thorough-understanding | § 9.3.4 Image Formation by Lenses **[3]**

A convex lens and a concave lens both have a magnitude of focal length 15 cm. An object is placed 30 cm to the left of each lens separately. For which lens is the image real, and for which is it virtual? Give a reason for each.

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Model Answer

Convex lens (f = +15 cm), object at u = –30 cm:

Using the lens formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\frac{1}{v} = \frac{1}{15} + \frac{1}{(-30)} = \frac{2-1}{30} = \frac{1}{30}$

So v = +30 cm (positive, on opposite side of lens) → **Image is real and inverted.**

Reason: The object is placed at 2F1 of the convex lens. A convex lens forms a real image when the object is placed beyond its focus.

Concave lens (f = –15 cm), object at u = –30 cm:

$\frac{1}{v} = \frac{1}{-15} + \frac{1}{-30} \cdots$

Wait — $\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{-15} + \frac{1}{-30} \cdots$

$\frac{1}{v} = -\frac{2}{30} - \frac{1}{30} = -\frac{3}{30} \cdots$

Correcting: $\frac{1}{v} = \frac{1}{-15} - \frac{1}{-30} = -\frac{2}{30} + \frac{1}{30} = -\frac{1}{30}$

So v = –10 cm (negative, same side as object) → **Image is virtual and erect.**

Reason: A concave lens always forms a virtual, erect and diminished image, regardless of the position of the object.

Source: Chapter 9, Section 9.3.4 & 9.3.6

Explanation

- **Convex lens:** object at 30 cm = 2F, so image forms at 2F on the other side — real and inverted. Examiners want you to apply the lens formula and state the sign of v.
- **Concave lens:** always produces a virtual image (v is always negative). The lens formula confirms v = –10 cm. Quoting the textbook rule ("a concave lens always gives a virtual, erect, diminished image") scores the reason mark.
- Always use the **New Cartesian Sign Convention**: distances measured from optical centre; object distance u is negative; f of concave lens is negative.

Q58. medium | thorough-understanding | § 9.3.5 Image Formation in Lenses Using Ray Diagrams **[3]**

A ray of light travelling parallel to the principal axis strikes (i) a concave mirror and (ii) a convex lens. Describe the path of the reflected/refracted ray in each case and draw the corresponding ray diagrams. Using the concepts of reflection and refraction, explain why the behaviour of the ray differs in the two cases.

◆ **Light – Reflection and Refraction**

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Model Answer

(i) Concave Mirror: A ray parallel to the principal axis, after reflection, passes through the principal focus F of the concave mirror. (Law of reflection is obeyed.)

(ii) Convex Lens: A ray parallel to the principal axis, after refraction, passes through the principal focus F_2 on the other side of the convex lens. (Law of refraction is obeyed.)

Ray Diagrams:

\`\`\`

Concave Mirror: Convex Lens:
→→→→→\ →→→→→|→→→→↘
↘→F | F_2
\`\`\`

(Students should draw neat labelled diagrams showing the above paths.)

Reason for different behaviour: In a concave mirror, the ray bounces back (reflection) from the curved surface, converging to F in front of the mirror. In a convex lens, the ray passes through the glass (refraction) and bends towards the normal at each surface, converging to F_2 on the other side. One involves reflection; the other involves refraction.

Source: Chapter 9, Sections 9.2.2 and 9.3.5

Explanation

- Examiners expect you to clearly state what happens in **each case separately** and give the **reason** in terms of reflection vs. refraction.
- Draw simple, labelled diagrams — label the mirror/lens, principal axis, F, and the ray path. Diagrams carry marks.
- Key distinction: mirror obeys laws of **reflection** (ray stays on same side); lens obeys laws of **refraction** (ray crosses to other side).
- Avoid writing extra details about image formation — the question only asks about the ray's path and the reason for different behaviour.

Q59. medium | thorough-understanding | § 9.3.5 Image Formation in Lenses Using Ray Diagrams **[1]**

A ray of light is directed towards the principal focus F_1 on the left side of a convex lens but strikes the lens before actually reaching F_1. Draw the path of this ray after refraction through the lens and explain, using the principle of reversibility of light, why it travels in that direction.

◆ **Light – Reflection and Refraction**

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Model Answer

After refraction, the ray emerges **parallel to the principal axis**. By the principle of reversibility, a ray parallel to the principal axis passes through F_2 after refraction; reversing this, a ray directed towards F_1 must emerge parallel to the principal axis.

Source: Chapter 9, Section 9.3.5

Explanation

The key ray rule here is rule (ii): a ray through F_1 emerges parallel to the principal axis. Reversibility means if you reverse the emergent ray (parallel), it retraces to pass through F_1 — so any ray *directed toward* F_1 (even if it hits the lens first) must emerge parallel. Examiners expect you to name the direction ("parallel to principal axis") and explicitly mention the reversibility principle.

Q60. medium | thorough-understanding | § 9.3.6 Sign Convention for Spherical Lenses **[3]**

A lens forms a virtual, erect image of an object placed 8 cm in front of it. The image is located 4.8 cm from the lens on the same side as the object. (a) Using the lens formula, calculate the focal length of this lens and state what type of lens it is. (b) With the help of sign convention, explain why the focal length carries the sign you obtained.

◆ Light – Reflection and Refraction

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Model Answer

Given: u = −8 cm, v = −4.8 cm (image on same side as object, so negative)

Using lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-4.8} - \frac{1}{-8} = -\frac{1}{4.8} + \frac{1}{8}$$

$$\frac{1}{f} = \frac{-5+3}{24} = \frac{-2}{24} = \frac{-1}{12}$$

∴ **f = −12 cm**

(a) The focal length is **−12 cm**. Since f is negative, this is a **concave lens**. (This is consistent with the concave lens always forming a virtual, erect, diminished image on the same side as the object.)

(b) By sign convention, all distances are measured from the optical centre. The image is virtual and forms on the same side as the object, so v is negative. Applying the lens formula gives a negative f. According to sign convention, the focal length of a concave (diverging) lens is always negative.

Source: Chapter 9, Sections 9.3.6 and 9.3.7

Explanation

- **Signs are critical:** Object is always on the left → u is negative. Virtual image on the same side as the object → v is also negative. Plugging both negatives into the lens formula yields a negative f.
- **Lens type identification:** Negative focal length = concave lens. Examiners expect you to state this explicitly.
- **Part (b)** is conceptual: just link the sign of v (virtual image, same side) to the resulting negative f and the rule that concave lenses have negative focal lengths.
- Don't confuse v being negative here (virtual image) with the mirror convention — lens formula is $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, not the mirror formula.

Q61. deep | thorough-understanding | § 9.3.7 Lens Formula and Magnification **[3]**

The lens formula for a spherical lens is written as 1/v − 1/u = 1/f, while the mirror formula is written as 1/v + 1/u = 1/f. Why can the same formula not be used for both, even though both involve a curved optical surface forming an image?

◆ Light – Reflection and Refraction

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Model Answer

Mirrors and lenses work on different optical principles — mirrors work by **reflection**, while lenses work by **refraction**. Due to this fundamental difference, the sign conventions and the geometry of image formation differ.

In a mirror, the object and image are both on the **same side** (in front of the mirror), so distances are measured from the pole, and the formula is $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$.

In a lens, the object and image are on **opposite sides**, with all distances measured from the optical centre. This geometric difference changes the algebraic relationship, giving $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$.

Thus, despite both involving curved surfaces, the different physical processes and measurement conventions make a single formula unsuitable for both.

Source: Chapter 9, Sections 9.2.4 and 9.3.7

Explanation

- Examiners expect you to identify **reflection vs. refraction** as the root cause.
- Then explain the **geometric difference** — same side vs. opposite sides — which changes the sign relationship between u, v, and f.
- Avoid just quoting the two formulas without explaining *why* they differ; that won't fetch full marks.
- Key terms to use: pole, optical centre, sign convention, reflection, refraction.

Q62. medium | thorough-understanding | § 9.3.7 Lens Formula and Magnification **[2]**

A concave lens always produces a magnification that is positive and has a magnitude less than 1, regardless of where the object is placed. Justify both of these statements using the lens formula and the definition of magnification, and describe what they together tell us about the image formed.

◆ **Light – Reflection and Refraction**

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Model Answer

For a concave lens, f is negative and object distance u is always negative. From the lens formula:

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

both terms on the right are negative, so v is always negative (virtual image on same side as object).

Magnification $m = \frac{v}{u}$ = (negative)/(negative) = **positive** (erect image).

Since the concave lens diverges rays, |v| < |u| always, so $|m| < 1$ (image is diminished).

Together, a concave lens always forms a **virtual, erect, and diminished** image, regardless of object position.

Source: Chapter 9, Sections 9.3.6 (Sign Convention) and 9.3.5 (Image Formation)

Explanation

- Examiners expect you to use the sign convention: for concave lens $f < 0$, $u < 0$, which forces $v < 0$.
- Show $m = v/u$ explicitly to justify the positive sign.
- The key conclusion — virtual, erect, diminished — must be stated; it ties both statements together and is a common direct question.

Q63. medium | thorough-understanding | § 9.3.7 Lens Formula and Magnification **[3]**

An object 3 cm tall is placed 12 cm from a convex lens of focal length 8 cm. Find the height of the image and determine whether it is erect or inverted.

◆ Light – Reflection and Refraction

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Model Answer

Given: Object height (h) = 3 cm, u = −12 cm, f = +8 cm (convex lens)

Using Lens Formula:

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

$$\frac{1}{v} - \frac{1}{-12} = \frac{1}{8}$$

$$\frac{1}{v} = \frac{1}{8} - \frac{1}{12} = \frac{3-2}{24} = \frac{1}{24}$$

$$v = +24 \text{ cm}$$

Magnification:

$$m = \frac{v}{u} = \frac{24}{-12} = -2$$

Height of image:

$$h' = m \times h = -2 \times 3 = -6 \text{ cm}$$

The image is **6 cm tall** and **inverted** (negative sign indicates inversion). The image is real and magnified, formed beyond $2F_2$.

Source: Chapter 9, Section 9.3.5 & 9.3.6

Explanation

- Always apply sign convention: u is negative (object on left), f is positive for convex lens.
- A negative image height (h′) means the image is **inverted**; negative magnification confirms this.
- The object is between F and 2F (12 cm is between 8 cm and 16 cm), so from Table 9.4, the image must be real, inverted, and enlarged — consistent with our result.
- Examiners award marks for: correct formula use (1), correct v (1), correct h′ with erect/inverted conclusion (1).

Q64. deep | thorough-understanding | § 9.3.7 Lens Formula and Magnification **[3]**

When an object is placed exactly at the focus of a convex lens, what does the lens formula predict about the position of the image? Explain physically why this result makes sense, and identify one practical application that exploits exactly this condition.

◆ Light – Reflection and Refraction

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Model Answer

When the object is placed at the focus F_1 of a convex lens (u = –f), substituting in the lens formula:

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \implies \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{f} - \frac{1}{f} = 0$$

So v = ∞. The image is formed at infinity.

Physical reason: A ray passing through the focus refracts and emerges parallel to the principal axis (as stated in ray diagram rules). All such refracted rays are parallel and never converge, so the image forms at infinity.

Practical application: This principle is used in **torches/searchlights/vehicle headlights** — a bulb placed at the focus of a concave reflector (or lens) produces a powerful parallel beam of light.

Source: Chapter 9, Section 9.3.4 (Table 9.4) and Section 9.3.5

Explanation

- The lens formula substitution showing v = ∞ earns the formula/calculation mark.
- The physical reason (parallel refracted rays never meet) links to the ray diagram rule from Section 9.3.5(ii) — examiners expect this connection.
- For the application, the textbook explicitly mentions torches/searchlights/headlights in the concave mirror section; the same optical principle applies. Write **one** specific application — do not list many.
- Keep the formula step brief but shown; board examiners award a mark for it.

Q65. straightforward | thorough-understanding | § 9.3.8 Power of a Lens **[1]**

A lens has a power of –2.5 D. (a) Calculate its focal length. (b) What type of lens is it? (c) Where should an object be placed in front of this lens so that the image is formed at the focus?

◆ **Light – Reflection and Refraction**

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Model Answer

(a) $f = \frac{1}{P} = \frac{1}{-2.5} = -0.4\ \text{m}$

(b) It is a **concave (diverging) lens** (negative focal length).

(c) The object should be placed at **infinity** so that the image forms at the focus.

Source: Chapter 9, Section 9.3.7 (Power of lens) and Table 9.5

Explanation

- **Power formula**: $P = 1/f$ (f in metres). Negative power → negative focal length → concave lens.
- For a concave lens, when the object is at infinity, the image forms at focus F_1 (highly diminished, virtual and erect) — directly from Table 9.5.
- Examiners expect all three parts answered; missing any part loses the mark. Keep calculations brief and state the sign convention result clearly.

Q66. medium | thorough-understanding | § 9.3.8 Power of a Lens **[3]**

An optician tests a patient's eye and places two corrective lenses of power +1.5 D and +0.75 D in contact inside the trial frame. (a) What is the equivalent power of this combination? (b) What focal length single lens could replace the combination? (c) Why is it more practical for opticians to work with powers rather than focal lengths when combining lenses?

◆ **Light – Reflection and Refraction**

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Model Answer

(a) Equivalent power of the combination:

$$P = P_1 + P_2 = +1.5\ \text{D} + 0.75\ \text{D} = +2.25\ \text{D}$$

(b) Focal length of the equivalent single lens:

$$f = \frac{1}{P} = \frac{1}{2.25} \approx 0.44\ \text{m}$$

(c) When lenses are placed in contact, their net power is simply the **algebraic sum** of individual powers. This makes calculation quick and easy. Using focal lengths instead would require a more complex formula, making it inconvenient during eye-testing.

Source: Chapter 9, Section 9.3.8 Power of a Lens

Explanation

- **Part (a):** Use $P = P_1 + P_2$ — this is the key formula for lenses in contact.
- **Part (b):** $f = 1/P$; remember f must be in metres when P is in dioptres.
- **Part (c):** The examiner wants the word "algebraic sum" and the idea that addition is simpler than the focal-length equivalent. The textbook explicitly states this as the reason opticians prefer powers. Don't overthink it — one or two sentences suffice for a 1-mark sub-point.

Q67. medium | thorough-understanding | § 9.3.8 Power of a Lens **[3]**

Two convex lenses P and Q have focal lengths 10 cm and 40 cm respectively. (a) Calculate the power of each lens. (b) A parallel beam of light falls on each lens separately. For which lens will the refracted rays converge closer to the lens, and why? (c) If these two lenses are placed in contact, what is the power of the combination? What type of lens does this combination behave like?

◆ Light – Reflection and Refraction

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Model Answer

(a) Power of each lens:

$$P_P = \frac{1}{f_P} = \frac{1}{0.10 \text{ m}} = +10 \text{ D}$$

$$P_Q = \frac{1}{f_Q} = \frac{1}{0.40 \text{ m}} = +2.5 \text{ D}$$

(b) Lens **P** (focal length 10 cm) will converge the parallel beam closer to the lens. A convex lens of shorter focal length bends light rays through larger angles, focusing them nearer to the optical centre.

(c) Power of combination:

$$P = P_P + P_Q = 10 + 2.5 = +12.5 \text{ D}$$

Since the combined power is positive, the combination behaves like a **convex (converging) lens**.

Source: Chapter 9, Section 9.3.8 — Power of a Lens

Explanation

- Always convert focal length to **metres** before calculating power.
- Both lenses are convex → positive focal lengths → positive powers.
- Key concept: shorter focal length = higher power = stronger convergence (rays focus closer).
- For combined power, simply add individual powers algebraically; positive result → convex behaviour. Examiners expect you to state both the numerical value and the lens type.

Q68. deep | thorough-understanding | § 9.3.8 Power of a Lens **[3]**

A student claims: 'A concave lens of power −4 D and a convex lens of power +4 D placed in contact will act as a flat glass plate — light will pass through without any bending.' Evaluate this claim. Is the student correct? Justify your answer using the concept of power of a lens, and state what assumption must hold for this to be true.

◆ Light – Reflection and Refraction

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Model Answer

The student's claim is **correct**, provided both lenses are thin and placed in perfect contact.

Using the concept of power of a lens:

The net power of lenses placed in contact is the algebraic sum of individual powers:

$$P = P_1 + P_2 = (-4\ \mathrm{D}) + (+4\ \mathrm{D}) = 0\ \mathrm{D}$$

A power of 0 D means the focal length is infinite, so the combination neither converges nor diverges light. Light passes through without any bending, exactly like a flat glass plate.

Assumption that must hold: Both lenses must be **thin lenses** placed in **perfect contact**, so that the formula $P = P_1 + P_2$ applies.

Source: Light – Reflection and Refraction, Section 9.3.8 (Power of a Lens)

Explanation

- Examiners want: (1) correct use of $P = P_1 + P_2$, (2) the conclusion that P = 0 D → no bending, and (3) the thin-lens-in-contact assumption stated explicitly.
- Do not just say "they cancel out" — show the calculation.
- The word "flat glass plate" in the question is a conceptual description of infinite focal length; link it clearly to P = 0.

Q69. medium | thorough-understanding | § (whole-chapter synthesis) **[3]**

A concave mirror and a convex lens are often said to behave analogously. Under what conditions does a concave mirror produce a virtual image, and under what conditions does a convex lens produce a virtual image? Identify the single common geometric condition that triggers a virtual image in both devices and explain why that condition causes the reflected/refracted rays to diverge rather than converge.

◆ **Light – Reflection and Refraction**

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Model Answer

Concave mirror produces a virtual image when the object is placed **between the pole and the principal focus** (i.e., object distance < focal length).

Convex lens produces a virtual image when the object is placed **between the optical centre and the principal focus** (i.e., object distance < focal length).

Common geometric condition: In both cases, the object is placed **closer than the focal length** from the mirror/lens.

Reason: When the object is within the focal length, the reflected/refracted rays diverge after interaction and never actually meet on the same side as the outgoing rays. They only appear to meet when extended backwards, forming a virtual image behind the mirror or on the same side as the object (for the lens).

Source: Chapter 9, Image Formation by Spherical Mirrors and Lenses

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Explanation

- The examiner expects you to state the condition for each device separately, then identify the common principle.
- Key phrase: *object placed between the pole/optical centre and the principal focus* — use this exact language.
- The reason must mention that rays **diverge** and only **appear to meet** when extended — this distinguishes a virtual image from a real one.
- Do not confuse a convex lens (virtual image when object < f) with a concave lens (always virtual). The question is specifically about the convex lens analogy with a concave mirror.

Q70. medium | thorough-understanding | § (whole-chapter synthesis) **[3]**

A ray of light travelling in air strikes a concave mirror and separately strikes a glass slab, in both cases hitting the surface obliquely. Compare what happens to the direction of the ray at the surface in each case, and explain the different physical reason behind each change in direction.

◆ Light – Reflection and Refraction

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Model Answer

Concave Mirror (Reflection):
When a ray of light strikes a concave mirror obliquely, it bounces back (reflects) such that the angle of incidence equals the angle of reflection. The direction changes due to **reflection** — the ray does not pass through the surface; it simply bounces off the polished reflecting surface.

Glass Slab (Refraction):
When a ray strikes the glass slab obliquely, it bends towards the normal on entering (air to glass, denser medium) and away from the normal on exiting (glass to air, rarer medium). The direction changes due to **refraction** — caused by the change in speed of light as it travels from one transparent medium to another.

Key Difference: In a mirror, direction changes due to reflection (no penetration); in a glass slab, direction changes due to refraction (change in speed of light in different media).

Source: Chapter 9, Sections 9.1 (Reflection of Light) and 9.3.1 (Refraction through a Rectangular Glass Slab)

Explanation

- Examiners look for **two named phenomena** (reflection vs. refraction) and **two distinct physical reasons**.
- For the mirror: state the law — angle of incidence = angle of reflection.
- For the glass slab: state that bending is due to *change in speed* of light, and mention the direction of bending (towards/away from normal).
- Do not confuse "the ray bouncing back" (reflection) with "the ray bending and passing through" (refraction). This contrast is the core of the answer.

Q71. medium | thorough-understanding | § (whole-chapter synthesis) **[3]**

An object is placed at the centre of curvature C of a concave mirror of focal length f. A separate but identical object is placed at a distance 2f in front of a convex lens of the same focal length f. Predict and compare the position, size, and nature of the image in each case. Explain the underlying reason why the two results are similar in character.

◆ Light – Reflection and Refraction

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Model Answer

Concave Mirror (object at C, i.e., distance = 2f):
From Table 9.1, the image forms **at C itself** (distance = 2f in front of mirror). The image is **same size** as the object, and **real and inverted**.

Convex Lens (object at 2f):
From the lens ray diagrams (Fig. 9.16), the image forms **at 2f on the other side**. The image is **same size** as the object, and **real and inverted**.

Comparison: Both cases produce an image that is real, inverted, and of the same size as the object, formed at a distance 2f from the optical element.

Reason: In both cases the object is placed at the centre of curvature / twice the focal length (2f). This is the symmetric point for both a concave mirror and a convex lens, so refracted/reflected rays reconverge at the same distance 2f, producing a 1:1 image.

Source: Chapter 9, Section 9.2.1 (Table 9.1) and Section 9.3.5 (Fig. 9.16)

Explanation

- The table (Table 9.1) directly states: object at C → image at C, same size, real and inverted.
- For the convex lens, placing the object at 2f is the standard case (Exercise Q3 confirms same-size image at 2f).
- Examiners award marks for: correct position (2f / at C), correct size (same), correct nature (real, inverted), and the comparative/reasoning point.
- Keep the comparison explicit — don't just describe each case separately.

Q72. medium | thorough-understanding | § (whole-chapter synthesis) **[1]**

Assertion (A): A convex mirror is preferred as a rear-view mirror in vehicles even though it produces a diminished image, whereas a concave mirror of the same size would give a larger image of the same object.
Reason (R): A convex mirror has a wider field of view than a plane or concave mirror of the same aperture because its reflecting surface curves outward.

Choose the correct option:
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is NOT the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

A Both A and R are true and R is the correct explanation of A.
B Both A and R are true but R is NOT the correct explanation of A.
C A is true but R is false.
D A is false but R is true.

◆ **Light – Reflection and Refraction**

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Model Answer

(A) Both A and R are true and R is the correct explanation of A.

A convex mirror is used as a rear-view mirror *because* its outward-curving surface provides a wider field of view, allowing the driver to see more area behind the vehicle, despite forming a diminished image.

Explanation

The Assertion is true — convex mirrors are indeed preferred as rear-view mirrors even though they give smaller images. The Reason is also true and directly explains *why*: the outward curvature gives a wider field of view, which is the actual reason for its preference. Since R correctly and completely explains A, option **(A)** is correct. Students often confuse this with (B); remember — the wider field of view IS the reason for using a convex mirror, so R is the correct explanation.

Q73. deep thorough-understanding § (whole-chapter synthesis) **[3]**

Light travels from water (refractive index 1.33) into glass (refractive index 1.52). (a) In which medium does light travel faster, and how does the difference in speed determine the direction in which the ray bends at the interface? (b) If this piece of glass is shaped into a concave lens and a ray parallel to the principal axis enters it from air, describe the complete path of the ray after it exits the lens and explain where an observer on the transmission side would perceive the ray to have originated.

◆ **Light – Reflection and Refraction**

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Model Answer

(a) Light travels faster in water (n = 1.33) than in glass (n = 1.52), since a higher refractive index means lower speed. When light passes from water into glass (rarer to denser medium), it slows down and **bends towards the normal** at the interface.

(b) A ray parallel to the principal axis, after entering the concave lens from air, diverges (spreads out) after refraction. The diverging ray, when extended backwards on the transmission side, appears to meet at the principal focus **on the same side as the incident ray** (in front of the lens). An observer on the transmission side would perceive the ray as originating from this virtual, erect focus located between the optical centre and the lens.

Source: Chapter 9, Sections 9.3, 9.3.1, 9.3.2

Explanation

- **Part (a):** The key link is refractive index ↔ speed: higher n = slower speed. Water→glass is rarer→denser, so the ray bends *towards* the normal. Many students confuse the direction; always use the rarer-to-denser rule.
- **Part (b):** A concave lens always forms a virtual, erect, diminished image. A ray parallel to the principal axis diverges after passing through a concave lens, and its backward extension passes through the focal point on the *same side as the object* (incident side). This focal point is virtual — the observer perceives the ray as coming from there. Examiners expect you to mention: divergence of ray, virtual focus, and observer's perception of origin.

Q74. medium | thorough-understanding | § (whole-chapter synthesis) **[5]**

A 4 cm tall object is placed 30 cm in front of a concave mirror of focal length 10 cm. Using the mirror formula and magnification formula, find: (i) the image distance, (ii) the height of the image, and (iii) whether the same object placed 30 cm in front of a convex lens of focal length 10 cm would give an image on the same side or the opposite side of the device compared to the object. Justify your answer for part (iii) without calculation.

◆ Light – Reflection and Refraction

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Model Answer

(i) Image distance (Concave Mirror):

Given: h = +4 cm, u = −30 cm, f = −10 cm

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

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-10} - \frac{1}{-30} = -\frac{1}{10} + \frac{1}{30} = \frac{-3+1}{30} = \frac{-2}{30}$$

$$v = -15 \text{ cm}$$

The image is formed **15 cm in front of the mirror** (real and inverted).

(ii) Height of image:

$$m = -\frac{v}{u} = -\frac{(-15)}{(-30)} = -\frac{1}{2}$$

$$h' = m \times h = -\frac{1}{2} \times 4 = -2 \text{ cm}$$

The image is **2 cm tall, real and inverted**.

(iii) Convex lens (f = +10 cm, u = −30 cm):

The object is placed beyond 2F of the convex lens (since 2f = 20 cm < 30 cm). A convex lens forms a **real, inverted image on the opposite side** of the lens from the object. For a concave mirror, the real image forms on the **same side** as the object. Thus, the two devices give real images on **opposite sides** relative to the object's position.

Source: Chapter 9, Sections 9.2.4 and 9.3.7

Explanation

- Always apply New Cartesian Sign Convention: distances measured in the direction of incident light are positive; against it are negative. For a concave mirror, both u and f are negative.
- The mirror formula is $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$; the lens formula is $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ — note the difference in signs between the two formulas.
- For part (iii), no calculation is needed — the justification is conceptual: a convex lens always forms a real image on the **opposite** side to the object (when object is beyond F), whereas a concave mirror forms a real image on the **same** side as the object. Examiners expect this distinction clearly stated.
- Negative h′ confirms the image is inverted and real — mention this explicitly for full marks.

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