ICSE CLASS 10 · PHYSICS

Chapter 5 : REFRACTION THROUGH A LENS

STEP-BY-STEP SOLUTIONS & MARKING SCHEME (40 MARKS)

Maximum Marks: 40 · Section A (20) compulsory · Section B: any two of three questions (2 × 10 = 20) · Lens formula: 1/v − 1/u = 1/f · m = v/u · P = 1/f (in m)

Marks for each step are shown in square brackets on the right. Rays completed in the solution diagrams are drawn in red.

SECTION A (20 Marks)

Question 1 — Multiple choice [8 marks, 1 mark each]

No.	Answer	Reason
(i)	**(c)** passes undeviated	A ray directed towards the optical centre of a thin lens passes straight through without any deviation or displacement.
(ii)	**(b)** $2F_1$	At $2F_1$ the image is formed at $2F_2$: real, inverted and of the same size (m = −1).
(iii)	**(a)** −4 D	P = 1 ÷ f (in metres) = 1 ÷ (−0.25) = −4 D (negative for a concave lens).
(iv)	**(b)** real, inverted and diminished	m is negative for a real, inverted image; |m| = 0.5 < 1 means diminished.
(v)	**(c)** Both (A) and (R) are true, and (R) is the correct explanation for (A).	Both are true: the sun is at infinity, the rays converge at the focus to give a real, highly diminished (bright) image, which burns paper; (R) explains (A).
(vi)	**(d)** 15 cm	u = −30, v = +30: 1 ÷ f = 1 ÷ v − 1 ÷ u = 1 ÷ 30 + 1 ÷ 30 = 2 ÷ 30 → f = 15 cm.
(vii)	**(c)** increases	The refractive index of the lens material relative to water is smaller than relative to air, so the lens bends light less and f increases.
(viii)	**(b)** +2 D	$P = P_1 + P_2$ = +3 D + (−1 D) = +2 D.

Question 2 [6 marks]

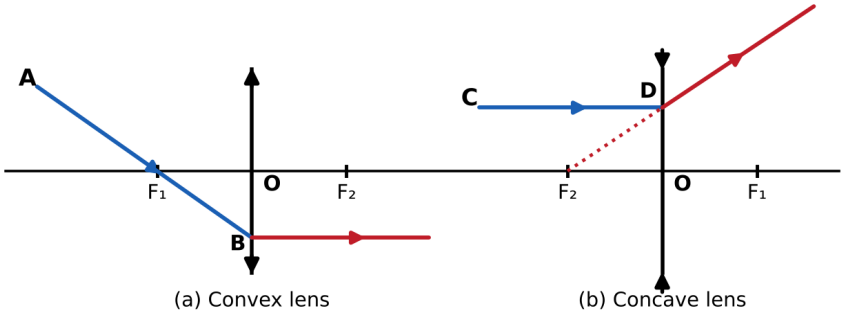
(a) (i) **Optical centre**: the point on the principal axis of a lens such that a ray of light directed towards it passes through the lens undeviated (emerging parallel to its original direction; for a thin lens it is undisplaced as well). [1] **[2]**

(ii) **Focal length**: the distance of the focus (second focus F_2) from the optical centre of the lens. [1]

(b) (i) A ray passing through the first focus F_1 of a convex lens emerges **parallel to the principal axis** (red ray in Fig. 1(a)). [1] **[3]**

(ii) A ray parallel to the principal axis of a concave lens diverges after refraction as if it came from the second focus; the refracted ray bends away from the axis and its backward extension (dotted) passes through F_2. [1]

(iii) The ray appears to diverge from the **second focus F_2** of the concave lens (a virtual focus). [1]



(a) Convex lens (b) Concave lens

Solution to Q2(b)

(c) (i) Convex lens: **positive**; (ii) concave lens: **negative**. [½ + ½] **[1]**

Question 3 [6 marks]

(a) Given: O = 6 cm, u = −30 cm, f = +12 cm. **[3]**

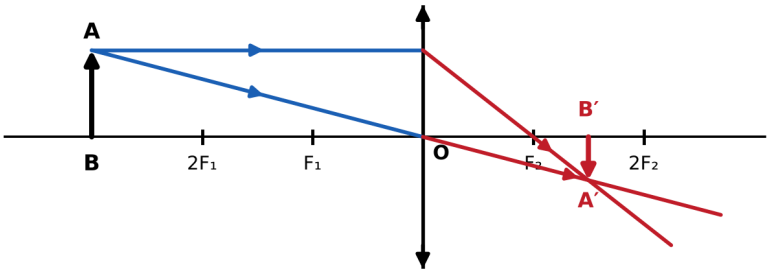
(i) $1 \div v = 1 \div f + 1 \div u = 1 \div 12 - 1 \div 30 = (5 - 2) \div 60 = 3 \div 60 \rightarrow$ **v = +20 cm** (20 cm behind the lens). [1]

(ii) $m = v \div u = 20 \div (-30) =$ **−2/3 (≈ −0.67)**. [1]

(iii) $I = m \times O = (-2/3) \times 6 =$ **−4 cm**: the image is 4 cm tall, **real and inverted** (diminished). [1]

(b) (i) Ray 1 from A parallel to the principal axis passes through F_2 after refraction; ray 2 from A through the optical centre O goes undeviated. The rays meet at A′; the perpendicular A′B′ is the image. [2] **[3]**

(ii) The image lies **between F_2 and $2F_2$** on the other side of the lens; it is **real, inverted and diminished**. [1]



Solution to Q3(b)

SECTION B (20 Marks) — any two questions

Question 4 [10 marks]

(a) Given: f = −15 cm (concave), u = −30 cm. **[3]**

(i) 1 ÷ v = 1 ÷ f + 1 ÷ u = −1 ÷ 15 − 1 ÷ 30 = −3 ÷ 30 → **v = −10 cm** (10 cm in front of the lens). [1]

(ii) m = v ÷ u = (−10) ÷ (−30) = **+1/3**. [1]

(iii) The image is **virtual, erect and diminished** (m positive and less than 1). [1]

(b) (i) **Power** is the reciprocal of the focal length (in metres), P = 1 ÷ f; it measures how strongly the lens deviates light. S.I. unit: **dioptre (D)**. [1] **[3]**

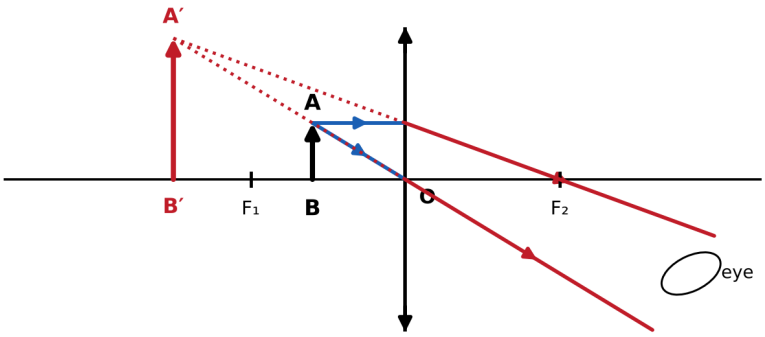
(ii) Convex lens: P_1 = 1 ÷ 0.25 = **+4 D**; concave lens: P_2 = 1 ÷ (−0.50) = **−2 D**. [1]

Combination: P = P_1 + P_2 = +4 − 2 = **+2 D**; f = 1 ÷ 2 = 0.5 m = **50 cm** (converging). [1]

(c) (i) Ray 1 from A parallel to the axis refracts through F_2; ray 2 from A through O is undeviated. The refracted rays diverge, so they are produced backwards (dotted) to meet at A′; A′B′ is the image. [2] **[4]**

(ii) The image is **virtual, erect and magnified**, formed on the same side as the object, behind it (farther from the lens than the object). [1]

(iii) A **magnifying glass (simple microscope)**; the eye is kept close to the lens on the side opposite the object. [1]



Solution to Q4(c)

Question 5 [10 marks]

(a) Any three (1 mark each): **[3]**

• Convex lens: image may be real or virtual (virtual only if the object is between O and F_1). Concave lens: image is always virtual.

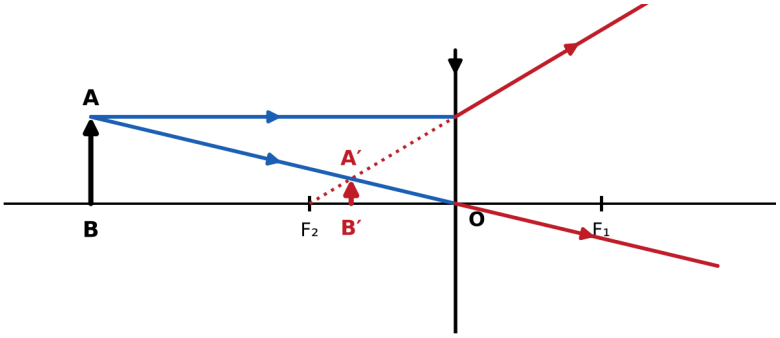
• Convex lens: image may be inverted or erect. Concave lens: image is always erect.

• Convex lens: image may be magnified, same size or diminished. Concave lens: image is always diminished.

• Convex lens forms the image on either side; a concave lens always forms it between the focus and the lens on the object side.

(b) (i) Ray 1 parallel to the axis diverges as if from F_2 (dotted back to F_2); ray 2 through O is undeviated. The back-extensions meet at A′, between F_2 and the lens; A′B′ is the image. [2] **[3]**

(ii) The image is **virtual, erect and diminished** (formed between F_2 and O on the object side). [1]

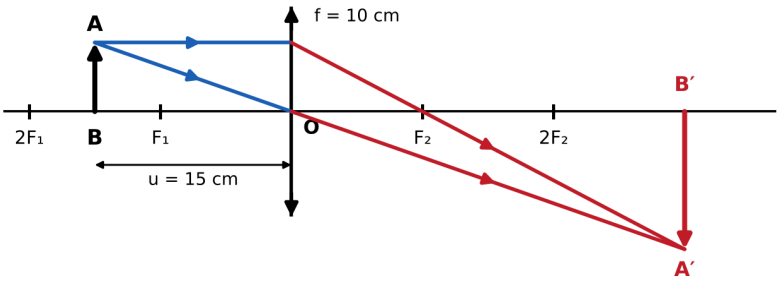


Solution to Q5(b)

(c) (i) Ray 1 parallel to the axis passes through F_2; ray 2 through O is undeviated; they meet beyond $2F_2$ (the object lies between F_1 and $2F_1$), giving a real inverted magnified image A′B′. [2] **[4]**

(ii) u = −15 cm, f = +10 cm: $1 \div v = 1 \div 10 - 1 \div 15 = (3 - 2) \div 30 = 1 \div 30 \rightarrow$ **v = +30 cm**. [1]

(iii) $m = v \div u = 30 \div (-15) =$ **−2**; $I = m \times O = -2 \times 4 =$ **−8 cm** (8 cm tall, inverted). [1]



Solution to Q5(c)

Question 6 [10 marks]

(a) (i) Image at infinity: object at the **first focus F_1**. [1] **[3]**

(ii) Real, inverted and same size: object at **$2F_1$** (image at $2F_2$, m = −1). [1]

(iii) Real, inverted and magnified: object **between F_1 and $2F_1$** (image beyond $2F_2$). [1]

(b) **Principle:** rays from a very distant object are nearly parallel to the principal axis, so a convex lens converges them to a point on its focal plane (at the focus). [1] **[3]**

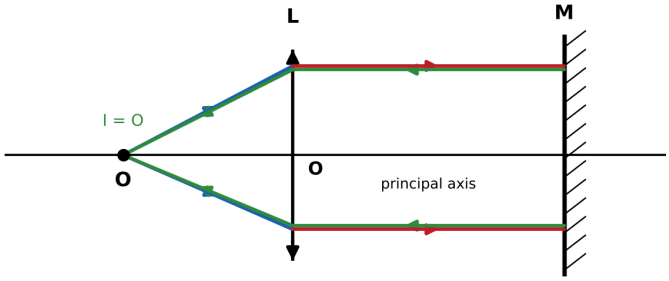
Method: hold the lens vertically near a white wall opposite a distant object (e.g. a tree or window) and move it to and fro until a sharp, small, inverted image falls on the wall. [1]

Measurement: measure the distance between the lens and the wall with a metre rule; this is the approximate focal length f. [1]

(c) (i) Rays from O fall on the lens and, since O lies at the first focus, emerge **parallel** to the axis; they hit the plane mirror normally, return along the same paths, and the lens converges them back to O (red = forward, green = returning). [2] **[4]**

(ii) The image is **of the same size as the object** (pin), and is **real and inverted**. [1]

(iii) To **O itself**: the parallel beam always strikes the mirror normally, so it is reflected back along its own path whatever the lens–mirror distance. [1]



Solution to Q6(c)

Marks summary	
Section A: Q1 (8) + Q2 (2 + 3 + 1 = 6) + Q3 (3 + 3 = 6)	**20**
Section B: any two of Q4 – Q6 (10 marks each)	**20**
Total	**40**