6.4 Lenses and visible light

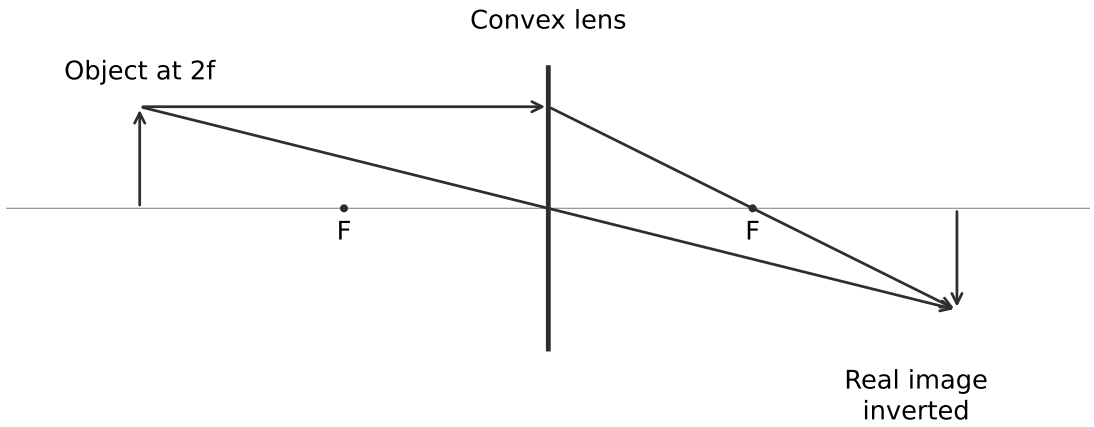
Name: _____ Class: _____ Date: _____ **Total: 26 marks**

KEY WORDS convex • concave

Objective

Draw convex and concave lens ray diagrams, compute magnification, and explain colour, filters and reflection types. Physics only. Original questions for spec statements 4.6.2.5–4.6.2.6.

1 Key knowledge and worked examples



Two rays locate the image.

Lens	Parallel rays	Image
convex	converge at the **principal focus** (focal length = lens-to-focus)	real or virtual
concave	spread as if from the focus	**virtual for a real object**

Ray rules: parallel-to-axis ray refracts through the focus (or appears to come from it); a ray through the lens centre passes straight on.

$$\text{magnification} = \frac{\text{image height}}{\text{object height}} \quad \text{(a ratio: no units)}$$

Both heights in mm, or both in cm.

Colour (physics only):

- Spectral colours correspond to wavelength ranges; mixtures can also give perceived colours (red longest → violet shortest).
- **Filters** absorb some wavelengths, transmit others.
- An **opaque** object's colour = the wavelengths it **reflects most strongly**; others are absorbed. Under white light, strong reflection across the visible spectrum gives white; almost complete absorption gives black.
- Smooth surface: specular; rough: diffuse – a matt red surface scatters.

Worked example. A 5.0 mm object forms a 20 mm image.

$$m = \frac{\text{image height}}{\text{object height}} = \frac{20}{5.0} = 4.0 \text{ (no units)}$$

Worked example. Magnification 0.25 for an object 8.0 cm high.

$$\text{image height} = m \times \text{object height} = 0.25 \times 8.0 = 2.0 \text{ cm}$$

2 Practice

2.1 An object 2.0 cm high forms an image 6.0 cm high. Calculate the magnification. [2]

2.2 State the difference between the images a convex and a concave lens can form. [2]

2.3 In an ideal model where a red object reflects only red wavelengths, why does it look red in white light, and what does it become in blue light? [2]

3 Exam-style questions

3.1 A student investigates a convex lens.

(a) Draw a ray diagram for an object at twice the focal length. Label the image real and inverted. [3]

(b) The object moves inside the focal length. Describe the new image. [2]

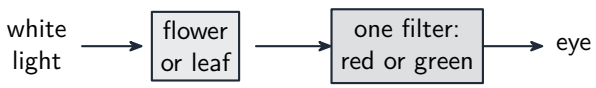
(c) The image height is 14 mm and magnification is 2.8. Calculate the object height. [2]

3.2 A gardener views a red flower and green leaves in white light, with ideal green and red filters between the objects and the eye. Model the flower as reflecting only red and the leaves only green.

(a) Explain what the flower looks like through each filter. [3]

(b) The leaves look black through the red filter. Explain why. [2]

(c) A shiny leaf differs from a matt leaf in reflection type. Name both types and state which spreads light. [2]



3.3 For this question, use the supplied relation $m_{\text{total}} = m_1 m_2$. A lens system gives magnification 40; the first lens alone gives 5.0.

(a) Calculate the second lens's magnification. [2]

(b) An object 0.20 mm wide is viewed. Calculate the final image width in mm. [2]

(c) State why magnification has no unit, and one advantage of the unitless ratio. [2]

Solutions

2.1 $m = h_i/h_o = 6.0/2.0 = \mathbf{3.0}$ (C1; no unit stated A1).

2.2 Convex: image can be real or virtual; concave: always virtual.

2.3 It reflects red wavelengths most strongly and absorbs the rest; in blue light no red is present to reflect, so it absorbs the blue and appears black.

3.1 (a) Two correct rays (parallel through focus; straight through centre); image located where rays cross, on the far side, upside down; labelled real and inverted. (b) Virtual, upright and magnified on the same side as the object. (c) object height = image height/m = $14/2.8 = \mathbf{5.0}$ mm (C1, A1).

3.2 (a) Through the red filter: red – the filter transmits red and the flower reflects it. Through the green filter: black – the green filter absorbs red, so no light from the flower passes the filter to the eye. (b) Leaves reflect green and absorb red; the red filter absorbs that reflected green before it reaches the eye, so the leaf appears black. (c) Specular and diffuse; diffuse reflection spreads the light.

3.3 (a) Total $m = 40 = 5.0 \times m_2$ so $m_2 = \mathbf{8.0}$ (C1, A1). (b) $h_i = mh_o = 40 \times 0.20 = \mathbf{8.0}$ mm (C1, A1). (c) It is a ratio of two lengths in the same unit, which cancels; advantage: the value is the same in mm or cm, provided both lengths use the same unit; mixing mm and cm still causes errors.