HIGHER

IG.P1 Lenses: Ray Diagrams and Magnification

EDEXCEL 4PH1 · Calculator allowed · about 70 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Define what is meant by a converging lens, in terms of its effect on a parallel beam of light.

(Total for Question 1 is 2 marks)

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2 Define the principal focus of a converging lens.

(Total for Question 2 is 1 mark)

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3 Define the focal length of a lens.

(Total for Question 3 is 1 mark)

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4 A ray diagram for a converging lens is usually constructed using three standard rays drawn from a point on top of the object. Describe each of these three rays.

Figure (to be drawn): A converging lens (drawn as a vertical double-headed-arrow symbol) on a horizontal principal axis, with the principal focus F marked on each side at the focal length. An object (an upright arrow) stands to the left, beyond F. Three rays are drawn from the top of the object to the top of the image: one travelling parallel to the axis then refracting through F on the far side; one passing straight through the centre of the lens; one passing through F on the near side before the lens, then refracting to run parallel to the axis after the lens. The rays cross to form an inverted image arrow on the right.

(Total for Question 4 is 3 marks)

5 For each object position given below, state the nature (real or virtual), orientation (upright or inverted) and size (magnified, diminished, or the same size) of the image formed by a converging lens.

(a) The object is beyond 2F (further from the lens than twice the focal length). **(2)**

(b) The object is exactly at 2F. **(2)**

(c) The object is between F and 2F. **(2)**

(d) The object is between the lens and F (closer to the lens than the focal length). **(2)**

(Total for Question 5 is 8 marks)

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6 State what is observed when an object is placed exactly at the principal focus of a converging lens, and explain why.

(Total for Question 6 is 2 marks)

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7 An object 2 cm tall produces an image 8 cm tall through a converging lens. Calculate the magnification of the lens in this instance.

(Total for Question 7 is 3 marks)

8 An object of height 3 cm is placed in front of a lens that produces a magnification of 5. Calculate the height of the image formed.

(Total for Question 8 is 2 marks)

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9 For a certain converging lens set-up, the object distance is u = 12 cm and the image distance is v = 36 cm. Calculate the magnification, using magnification = v / u, and state whether the image is magnified or diminished compared with the object.

(Total for Question 9 is 3 marks)

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10 A converging lens forms an image at v = 10 cm from an object placed at u = 4 cm from the lens. Calculate the magnification of the lens in this instance.

(Total for Question 10 is 2 marks)

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11 A stamp collector uses a magnifying glass, which is a converging lens of focal length 5 cm, to examine a stamp. The stamp is held 3 cm from the lens.

(a) State whether the object distance (3 cm) is less than, equal to, or greater than the focal length (5 cm). **(1)**

(b) Hence state the nature, orientation and size of the image formed. **(2)**

(c) The image seen through the magnifying glass appears to be 4.5 cm tall, and the stamp itself is 1.5 cm tall. Calculate the magnification. **(2)**

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(Total for Question 11 is 5 marks)

12 State two everyday uses of a converging lens.

(Total for Question 12 is 2 marks)

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13 State the type of image (in terms of nature, orientation and size) that is ALWAYS formed by a diverging (concave) lens, regardless of the object's position, and explain why this is the case.

Figure (to be drawn): A diverging lens (drawn as an inward-pointing double-headed-arrow symbol) on a horizontal principal axis. An upright object arrow stands to the left. A ray parallel to the axis strikes the lens and refracts outward (away from the axis); tracing this refracted ray backwards (shown as a dashed line) meets the near-side principal focus. A second ray through the centre of the lens continues straight. The two rays diverge on the right but their backward extensions (dashed) cross on the same side as the object, forming a small upright virtual image there.

(Total for Question 13 is 3 marks)

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14 State one everyday use of a diverging lens, and briefly explain why a diverging lens is suitable for it.

(Total for Question 14 is 2 marks)

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15 A camera uses a converging lens to form a real image of a person on its sensor. The person is 1.8 m tall and stands 3.6 m from the lens. The image formed on the sensor is 2 cm tall.

(a) Convert the person's height to centimetres, and calculate the magnification of the camera lens in this instance. **(2)**

(b) Explain why this magnification is much less than 1, referring to the position of the person relative to the lens. **(2)**

(Total for Question 15 is 4 marks)

Mark scheme · IG.P1 Lenses: Ray Diagrams and Magnification

Question 1

- **B1** refracts (bends) parallel rays of light towards each other / brings them together
- **B1** so that they meet (converge) at a single point
- **Answer: A lens that refracts parallel rays of light so that they meet at a single point**

Question 2

- **B1** the point at which rays travelling parallel to the principal axis converge (meet) after passing through (refracting at) the lens
- **Answer: The point where parallel rays converge after refracting through the lens**

Question 3

- **B1** the distance from the centre of the lens to the principal focus
- **Answer: The distance from the centre of the lens to the principal focus**

Question 4

- **B1** Ray 1: a ray travelling parallel to the principal axis, which refracts at the lens and then passes through the principal focus on the far side
- **B1** Ray 2: a ray passing through the centre of the lens, which continues in a straight line without bending
- **B1** Ray 3: a ray passing through the principal focus on the near (object) side before reaching the lens, which refracts to travel parallel to the principal axis after the lens
- **Answer: Parallel ray through the far focus; ray straight through the centre; ray through the near focus then parallel**

Question 5

- (a) **B1** real and inverted
- (a) **B1** diminished (smaller than the object)
- **(a) Answer: Real, inverted, diminished**
- (b) **B1** real and inverted
- (b) **B1** the same size as the object
- **(b) Answer: Real, inverted, same size**
- (c) **B1** real and inverted
- (c) **B1** magnified (larger than the object)
- **(c) Answer: Real, inverted, magnified**
- (d) **B1** virtual and upright
- (d) **B1** magnified (larger than the object)
- **(d) Answer: Virtual, upright, magnified**

Question 6

- **B1** no image is formed (or: the image is formed 'at infinity')
- **B1** correct reason: the refracted rays emerge parallel to each other (and to the axis), so they never converge to form an image
- **Answer: No image forms; the refracted rays emerge parallel and never meet**

Question 7

- **M1** uses magnification = image height / object height
- **A1** magnification = 4 cao (8 / 2)
- **B1** states that magnification has no units (it is a ratio of two lengths)
- **Answer: Magnification = 4 (no units)**

Question 8

- **M1** rearranges magnification = image height / object height to image height = magnification x object height
- **A1** image height = 15 cm cao (5 x 3)
- **Answer: Image height = 15 cm**

Question 9

- **M1** magnification = v / u = 36 / 12 set up
- **A1** magnification = 3 cao
- **B1** magnified, since magnification is greater than 1, ft their value
- **Answer: Magnification = 3; the image is magnified**

Question 10

- **M1** magnification = v / u = 10 / 4 set up
- **A1** magnification = 2.5 cao
- **Answer: Magnification = 2.5**

Question 11

- (a) **B1** less than (the object is inside the focal length)
- **(a) Answer: Less than (3 cm < 5 cm)**
- (b) **B1** virtual and upright
- (b) **B1** magnified, ft from part (a)
- **(b) Answer: Virtual, upright, magnified**
- (c) **M1** magnification = image height / object height = 4.5 / 1.5 set up
- (c) **A1** magnification = 3 cao
- **(c) Answer: Magnification = 3**

Question 12

- **B1** any one valid use, e.g. magnifying glass
- **B1** any second valid use, different from the first, e.g. camera lens, projector lens, telescope objective lens, spectacle lens for long-sightedness, or the lens in the human eye
- **Answer: e.g. magnifying glass and camera lens (accept any two valid distinct uses)**

Question 13

- **B1** virtual
- **B1** upright and diminished (smaller than the object), formed between the lens and its principal focus
- **B1** correct reason: a diverging lens spreads out (diverges) rays that were parallel, so the refracted rays never actually meet on the far side; they only appear to come from a point on the near side when traced backwards
- **Answer: Always virtual, upright, diminished**

Question 14

- **B1** a valid use, e.g. spectacle lenses to correct short-sightedness (myopia)
- **B1** valid brief reason, e.g. in a short-sighted eye the eye focuses light too strongly (in front of the retina); a diverging lens spreads the light out slightly before it reaches the eye, reducing the eye's excess focusing power so the image forms correctly on the retina
- **Answer: e.g. correcting short-sightedness, because it diverges light before it enters an eye that focuses too strongly**

Question 15

- (a) **M1** converts 1.8 m to 180 cm, and forms magnification = image height / object height = 2 / 180
- (a) **A1** magnification = 1/90 oe (awrt 0.0111), cao
- **(a) Answer: Magnification = 1/90 (approximately 0.0111)**
- (b) **B1** the person is much further from the lens than 2F (camera lenses have a short focal length compared with typical subject distances)
- (b) **B1** so, as in Question 5(a), the image formed is real, inverted and greatly diminished, consistent with a magnification far below 1
- **(b) Answer: The person is far beyond 2F, so the image is real, inverted and greatly diminished**