Past-paper walk-through

Images Formed by Lenses ▪ 13.4

eXercise

Questions in this set

- 2017 Q3

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 3

2017 ▪ Q3

[Diagram: An optical bench setup shown in 3D perspective. From left to right along a ruled track: a vertical screen with a ruled scale at the left end, a convex lens (drawn as an ellipse/ring) mounted upright in the middle, and a light box with a plate on its hidden side at the right end. A callout points from the light box to a small square labeled “Plate on Hidden Side of Box” showing an arrow and a bar-with-circle cutout shape. Labels: “Screen”, “Convex Lens”, “Light Box with Plate”.]

Some students are asked to determine the focal length of a convex lens. They have the equipment shown above, which includes a waterproof light box with a plate on one side, a lens, and a screen. The box has a bright light inside, and the plate on the side has shapes cut out of it through which the light shines to create a bright object. This particular plate has a cutout that is a vertical arrow and a horizontal bar with a circle at one end. In the view shown above, the circle is near the right edge of the plate.

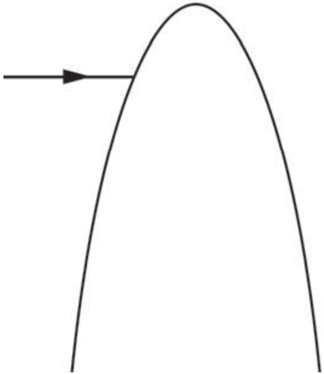
Question 3

With the screen and light box on opposite sides of the lens, the box is aligned so that the plate is 20 cm from the center of the lens, and an image of the arrow and bar is formed on the screen. The students find that the image is clear on the screen when the screen is 30 cm from the center of the lens.

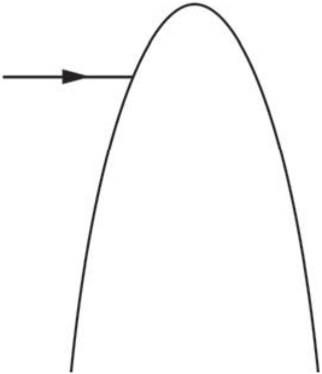
(a) On the figure below, sketch how the image on the screen appears to the students.
[Figure: A blank rectangular screen outline with a ruled scale down its right edge (tick marks), for the student to sketch the observed image.]

Question 3

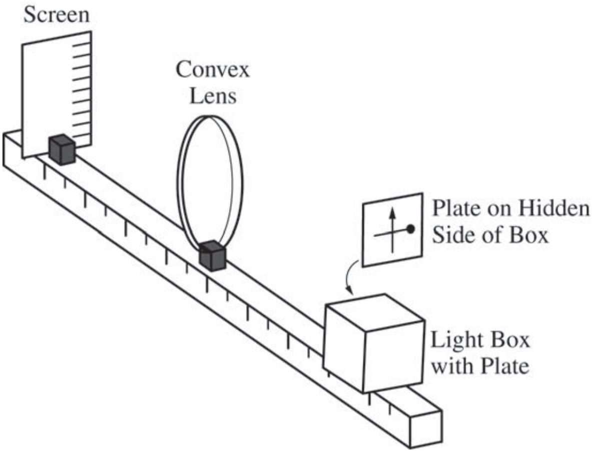
Cross Section of
Lens in Air



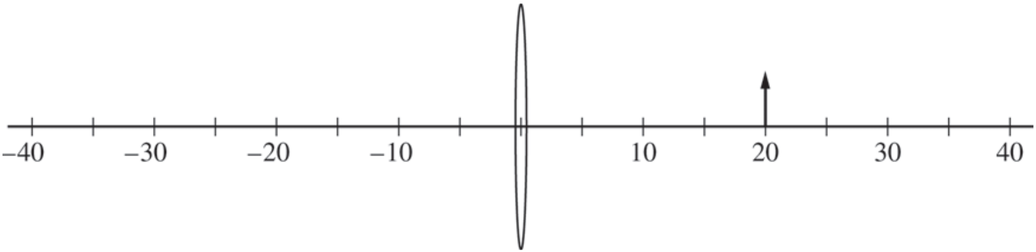
Cross Section of
Lens in Water



Question 3


Screen
Convex Lens
Plate on Hidden Side of Box
Light Box with Plate

Question 3



Question 3

2017 ▪ Q3

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(b)(i) Calculate the focal length of the lens.

(b)(ii) Calculate the magnitude of the magnification of the image.

Question 3

2017 ▪ Q3

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(c)(i) In the side view below, the arrow represents the bright object created by the plate. Draw a ray diagram on the figure below that is consistent with your calculations in parts (b)(i) and (ii). Show at least two rays, as well as the location and orientation of the image.

[Figure: A horizontal optical axis numbered from -40 to 40 in increments of 10, with a thin convex lens drawn vertically at the origin (position 0) and an upward-pointing arrow (the object) at position 20 on the axis, representing the object placed 20 cm from the lens.]

Question 3

(c)(ii) Explain how your diagram is consistent with your calculated focal length and magnification in parts (b)(i) and (ii).

Question 3

2017 ▪ Q3

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(d)(i) The entire apparatus is now submerged in water, whose index of refraction is greater than that of air but less than that of the lens.

The figures below show cross sections of the top portion of the convex lens in air and the convex lens in water. An incident ray is shown in both cases. On each figure, draw the ray as it passes through the lens and back into the air or water.

[Figure: Two side-by-side diagrams, each showing the cross section of the top (curved) portion of a convex (plano-convex-like, rounded-top) lens shape. The left diagram is labeled “Cross Section of Lens in Air” with a horizontal incident ray arrow approaching the curved surface from the left. The right diagram is labeled “Cross Section of Lens

Question 3

in Water" with an identical horizontal incident ray arrow approaching the curved surface from the left. Both lens outlines are otherwise identical and unshaded.]
(d)(ii) Describe how the focal length of the lens and the position and size of the image formed by the lens when it is in the water compare to when the lens is in air. Explain how the rays drawn in the figures in part (d)(i) support your answer.

Solution 3

(a)

Mark scheme

- Sketch the image on the screen. 2 points:
- 1 pt for the arrow drawn upside down (inverted) relative to the object.
- 1 pt for the bar/circle drawn left-to-right reversed relative to the object, or consistent with an (incorrect) upright arrow.

Solution 3

(b)(i) Mark scheme

- $\dfrac{1}{f} = \dfrac{1}{d_o} + \dfrac{1}{d_i} = \dfrac{1}{20\text{ cm}} + \dfrac{1}{30\text{ cm}}$
- $f = 12$ cm.
- 1 pt for correctly showing this calculation and a correct answer with units.

Solution 3

(b)(ii)

Mark scheme

- $M = d_i/d_o = 30\text{ cm}/20\text{ cm}$
- $M = 1.5.$
- 1 pt for correctly showing the magnification calculation (with or without sign) and a correct answer.

Solution 3

(c)(i)

Mark scheme

- Ray diagram consistent with the calculated focal length ($f = 12$ cm): draw at least two rays from the tip of the object (at position $+20$) through the lens, showing them converge on the far side to form an inverted image (around position -30, height $\approx 1.5\times$ the object, pointing downward). 1 pt for two reasonably correctly drawn rays consistent with the calculated focal length, including the inverted image.

Solution 3

(c)(ii)

Mark scheme

- Explain the ray diagram. 2 points:
- 1 pt for a correct explanation of how the drawn rays relate to the focal length.
- 1 pt for a correct explanation of how the image relates to the magnification.
- Example: The horizontal ray from the object bends to cross the axis at 12 cm from the middle of the lens, which is the focal length. The image arrow is about 1.5 times the height of the object, which is the magnification.

Solution 3

(d)(i) Mark scheme

- Draw the refracted ray at the top surface of the plano-convex lens, for the lens in air and again for the lens in water. 2 points:
- 1 pt for showing the downward refraction of the ray at the lens surface when in air (i.e., bending toward the normal entering the lens / away from the normal leaving the lens).
- 1 pt for showing the ray refracted by the lens in water at a greater angle to the normal than the corresponding angle for the lens in air — i.e., less bending (this point can be earned even if the first point was not; scoring is relative to whatever was drawn for the lens in air).

Solution 3

(d)(ii) Mark scheme

- Compare the focal length/image in water vs. air, using the rays drawn in (d)(i). 3 points:
- 1 pt for describing a greater focal length when the lens is in water (or a comparison consistent with the student's own part (d)(i)).
- 1 pt for describing a larger image distance and image size (or a comparison consistent with (d)(i)).
- 1 pt for describing how the rays drawn in (d)(i) support these descriptions.

Solution 3

- Example: The rays do not bend as much passing from water to glass as they do passing from air to glass (and vice versa). This means parallel rays entering the lens converge at a farther distance, so the focal length is longer. Rays from an object also converge farther from the lens, so the new image is farther away and larger.