Write your name, centre number and candidate number in the boxes below.

| Surname | Other names |
|---|---|
| | |

Centre number | | | | | |

Candidate number | | | | |

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# Refraction and total internal reflection

Time allowed: 1 hour 10 minutes

**Subject code** **0625**

# Physics

## Questions from Paper 3 and Paper 4

**You must have:** a ruler marked in centimetres and millimetres, a protractor, compasses, a pen, an HB pencil and an eraser.

Total marks

**/ 70**

### Instructions

- Answer every question in the space provided on this paper.
- Write in black or dark blue ink. Pencil may be used for diagrams and graphs.
- Fill in your name, centre number and candidate number above.
- Show your working: a correct method can earn marks even if the answer is wrong.

### Information

- This paper has 10 questions worth 70 marks in total.
- The marks for each question or part are shown in brackets, for example [3].

### Advice

- Read every question through once before you write anything.
- Use the marks in brackets to judge how long to spend on each part.
- If you finish early, go back and check your working.

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Print at 100% (Actual size) so diagrams keep their real measurements.

1 **(a)** A ray of red light passes through a rectangular glass block, as shown in Fig. 6.1.

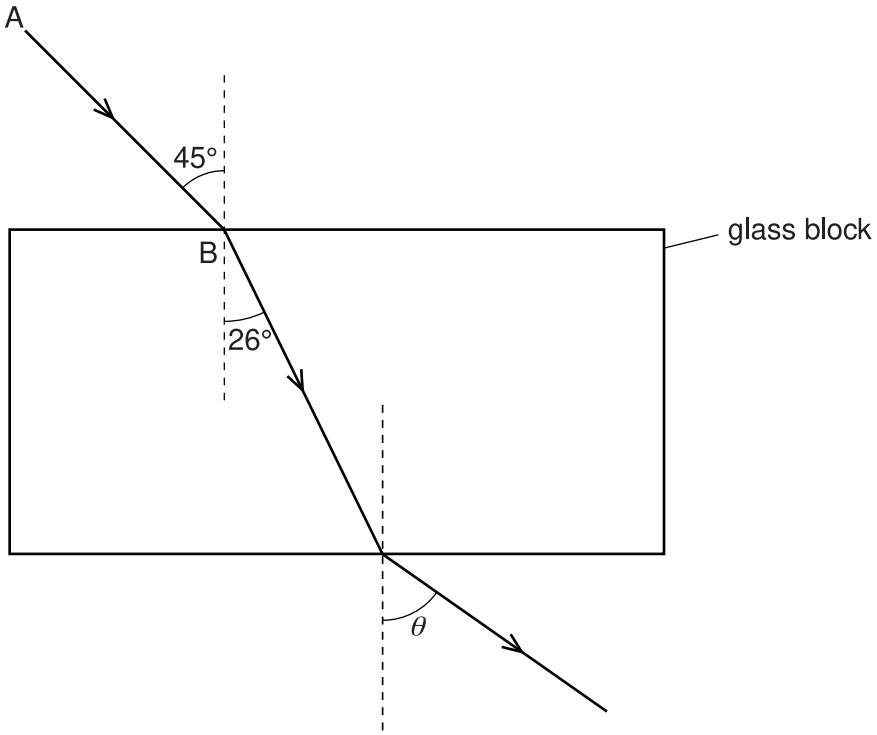



**Fig. 6.1**

**(i)** What name describes what happens to the ray of light at B?

.....

**(ii)** On Fig. 6.1, the emergent ray is not drawn at the correct angle $\theta$ to the normal.

State the correct value of the angle $\theta$.

$\theta$ = .....
[2]

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**(b)** A ray of blue light is directed into a glass prism, as shown in Fig. 6.2.

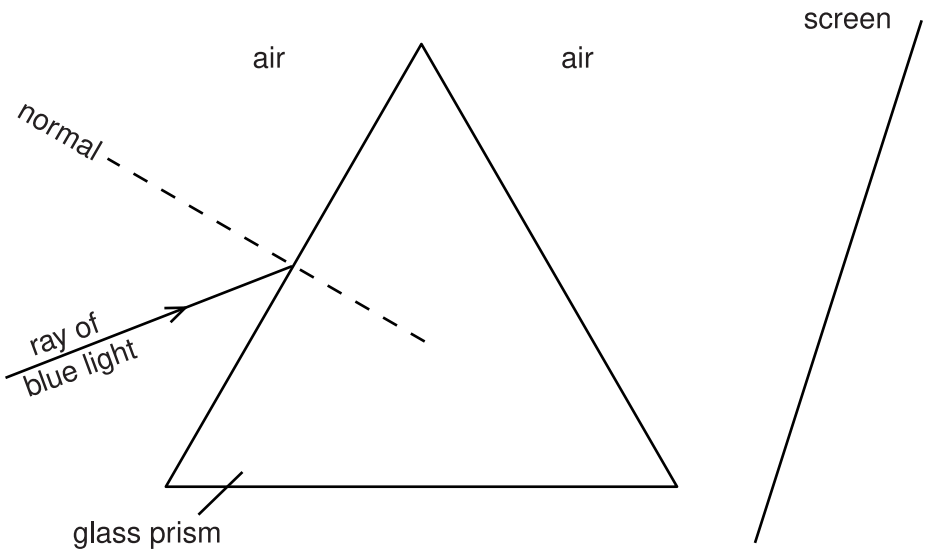



**Fig. 6.2**

**(i)** Using your ruler, draw a possible path for the blue light, until it reaches the screen.

**(ii)** The ray of blue light is replaced by a ray of red light.

On Fig. 6.2, mark an X to show where the red light might hit the screen.

[3]

[Total: 5]

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**1** **(a)** **(i)** refraction
accept refracted ray, ignore bends B1

**(ii)** 45 (°) condone no/incorrect unit B1

**(b)** **(i)** refracted down at first surface B1
refracted down at 2nd surface B1

**(ii)** X marked above point where candidate's blue light hits screen B1

**[Total: 5]**

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2 **(a)** In Fig. 7.1, a ray of light is shown passing into water from air. The angle of the refracted ray to the normal is 40°.

On Fig. 7.1, mark clearly the angle of incidence *i*. [1]

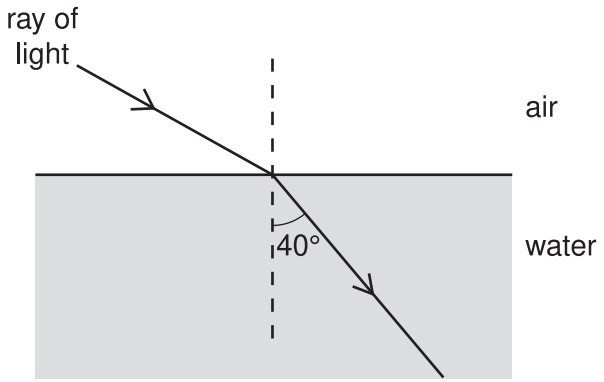



**Fig. 7.1**

**(b)** In Fig. 7.2, a ray of light is shown in water and reaching the surface with the air at an angle of 40° to the normal.

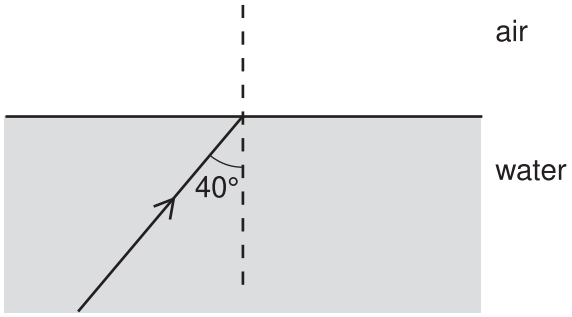



**Fig. 7.2**

**(i)** On Fig. 7.2, draw accurately the path of the ray in the air. [2]

**(ii)** The angle in the water in Fig. 7.2 is increased from 40° to 70°, and the ray no longer emerges into the air.

State what happens to the ray at the surface and explain why this happens.

.....

.....

.....

..... [2]

[Total: 5]

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**2** **(a)** *i* correctly shown B1

**(b)** **(i)** ray shown in air at angle > 40° C1
angle same as in Fig. 7.1, by eye A1

**(ii)** ray reflected (MO if says along surface) M1
critical angle exceeded A1

**[Total: 5]**

**3** **(a)** **(i)** Describe what is observed during *total internal reflection*.

.....

..... [1]

**(ii)** State **two** conditions required for light to be totally internally reflected.

1. .....

.....

2. .....

.....
[2]

**(b)** Describe and explain the action of optical fibres in communication technology. You may draw a diagram in your answer.

.....

.....

.....

..... [3]

[Total: 6]

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| | | |
|---|---|---|
| 3(a)(i) | wave / light / energy / ray is completely / entirely reflected (at the boundary between two mediums) **or** no refraction **or** no wave / light / energy / ray passes into second medium / across boundary **or** only reflection occurs | **B1** |
| 3(a)(ii) | light (must pass) from medium where it travels slower **or** to medium where it is faster **or** from medium with larger refractive index **or** to medium with smaller refractive index | **B1** |
| | angle of incidence (must be) greater than the critical angle / $\sin^{-1}(1 \div n)$ | **B1** |
| 3(b) | light / infrared travels in fibre | **B1** |
| | total internal reflection at inner surface **or** within (graded-index) fibre | **B1** |
| | light carries information / signal / data / message or signal / light encoded | **B1** |

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**4** Fig. 7.1 shows red light travelling from air into a prism made of diamond. The path of the red light is incomplete.

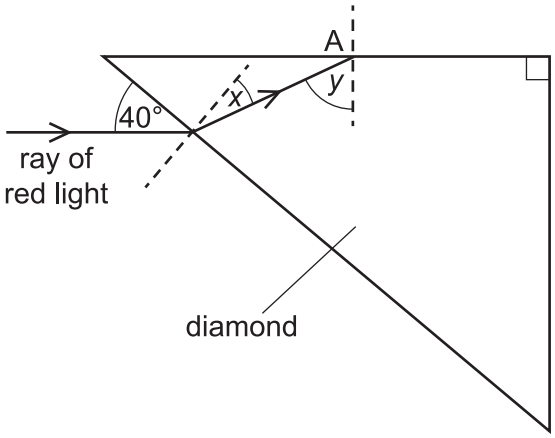



**Fig. 7.1** (not to scale)

**(a)** The refractive index of diamond is 2.42.

Calculate angle *x*.

angle *x* = ..... [2]

**(b)** Explain the term *total internal reflection*.

.....

.....

.....

.....

..... [3]

**(c)** The angle *y* is greater than the critical angle of diamond.

On Fig. 7.1, draw the path of the red light through and out of the prism after point A. [2]

[Total: 7]

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| | | |
|---|---|---|
| **4**(a) | sin *i* / sin *r* = n in any form | **C1** |
| | *r* = 18° | **A1** |
| **4**(b) | light travelling from optically dense medium to optically less dense medium | **B1** |
| | all light reflected OR no light refracted | **B1** |
| | angle of incidence is greater than the critical angle | **B1** |
| **4**(c) | ray reflected at face AB with *i* = *r* by eye | **B1** |
| | ray refracted at face BC and bent away from the normal | **B1** |

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5 **(a)** State what is meant by total internal reflection.

.....

..... [2]

**(b)** Fig. 7.1 shows a ray of light from a light source in a tank containing a liquid.

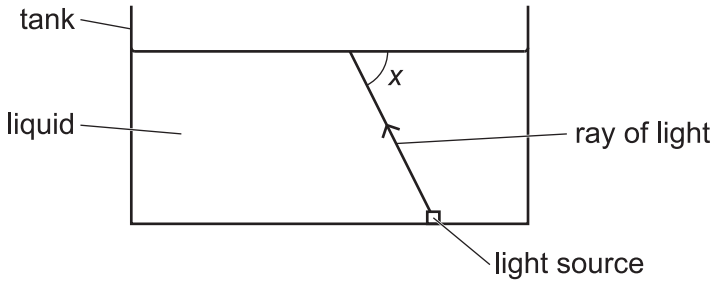



**Fig. 7.1**

The ray of light strikes the surface of the liquid at an angle $x$.

**(i)** The refractive index of the liquid is 1.5.

Calculate the largest value of $x$ for which total internal reflection can occur.

$x$ = ..... [3]

**(ii)** The speed of light in air is $3.0 \times 10^8$ m/s.

Calculate the speed of light in the liquid.

speed = ..... [2]

[Total: 7]

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| | | |
|---|---|---|
| 5(a) | any **two** from:<br>• all light is reflected<br>• no light is refracted<br>• (occurs) when light travels in a more dense medium towards a (boundary with a) less dense medium | **B2** |
| 5(b)(i) | ($x$ =) 48° | **A3** |
| | $n = 1 / \sin c$ **OR** $c = \sin^{-1}(1/n)$ **OR** $\sin c = 1 / 1.5$ **OR** $c = \sin^{-1}(1/1.5)$ | C1 |
| | $c = 42$(°) | C1 |
| 5(b)(ii) | (speed =) $2.0 \times 10^8$ m / s | **A2** |
| | $n = \frac{\text{speed of light in vacuum}}{\text{speed of light in liquid}}$ **OR** $n = \frac{\text{(approx.) speed of light in air}}{\text{speed of light in liquid}}$<br>**OR** $n = c / v$ **OR** ($v$ =) $c / n$<br>**OR** $1.5 = \frac{3\times10^8}{\text{speed of light in liquid}}$ | C1 |

**6** Fig. 8.1 shows a section through the swimming pool in a hotel.

To make the pool more attractive at night, there are submerged lamps in the pool. Fig. 8.1 shows three rays coming from one of these lamps.

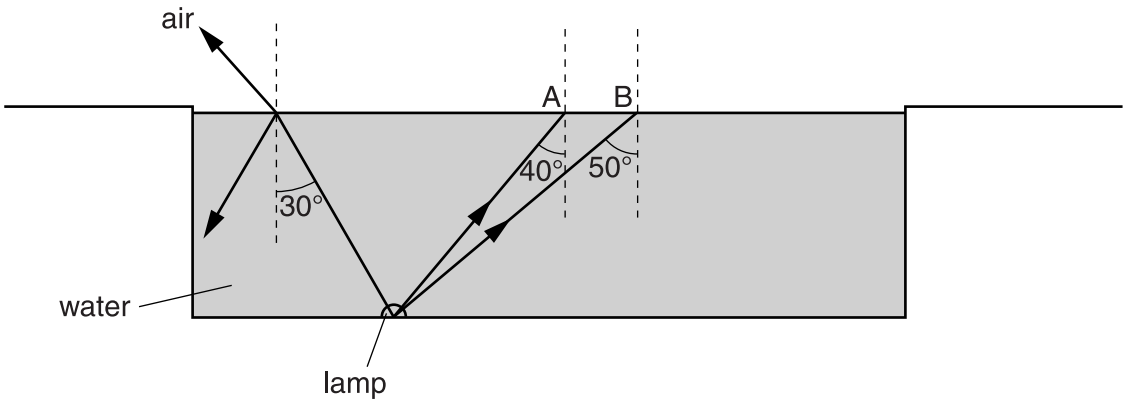



**Fig. 8.1**

The critical angle for the water/air boundary is 48 °.

**(a)** State what is meant by the *critical angle* for a ray of light.

.....

.....

.....[3]

**(b)** On Fig. 8.1, use your ruler to draw approximate paths for the rays after they reach the surface at A and B. [4]

[Total: 7]

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| | | | |
|---|---|---|---|
| 6 | **(a)** | (maximum) angle of incidence | B1 |
| | | for a ray to be just refracted / emerge **OR** resulting in an angle of refraction of $90^{o}$ | B1 |
| | | beyond this angle the ray is totally internally reflected<br>**OR** ray travelling from (optically) dense medium to less dense medium | B1 |
| | **(b)** | ray at A: one emergent ray and one reflected ray | B1 |
| | | refracted away from normal | B1 |
| | | ray at B: one reflected ray only | B1 |
| | | angle of reflection is 50° by eye | B1 |

**[Total: 7]**

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7 Fig. 5.1 shows four rays of red light, P, Q, R and S, coming from a spotlight in a swimming pool.

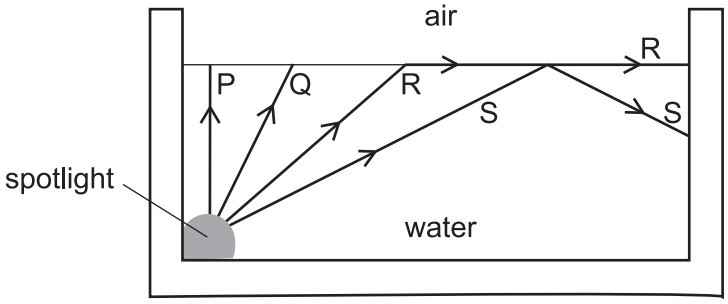



**Fig. 5.1**

**(a)** Define, in words, refractive index for a ray of light travelling from air to water.

..... [1]

**(b)** On Fig. 5.1, draw the path of rays P and Q at the water–air boundary. [2]

**(c)** The angle of incidence for ray R is 49°.

Calculate the refractive index of the water.

refractive index = ..... [2]

**(d)** Explain why ray S is totally internally reflected at the water surface.

.....

..... [2]

[Total: 7]

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| | | |
|---|---|---|
| 7(a) | (refractive index is) the ratio of the speed of light in two different mediums<br>**OR** (refractive index =) $\frac{\text{speed of light in air}}{\text{speed of light in water}}$<br>**OR** (refractive index =) $\frac{\text{sine of angle of incidence}}{\text{sine of angle of refraction}}$ | **B1** |
| 7(b) | P continues vertical | **B1** |
| | Q refracted away from normal in the correct direction | **B1** |
| 7(c) | 1.3 | **A2** |
| | ($n$ =) 1 ÷ sin 49 **OR** ($n$ =) 1 ÷ sin $c$ | C1 |
| 7(d) | any **two** from:<br>• (ray travelling from) dense to less dense medium **OR** water is more dense than air<br>• critical angle = 49°<br>• angle of incidence exceeds critical angle / 49° | **B2** |

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**8** Fig. 5.1 shows a ray of yellow light incident on a glass prism ABC.

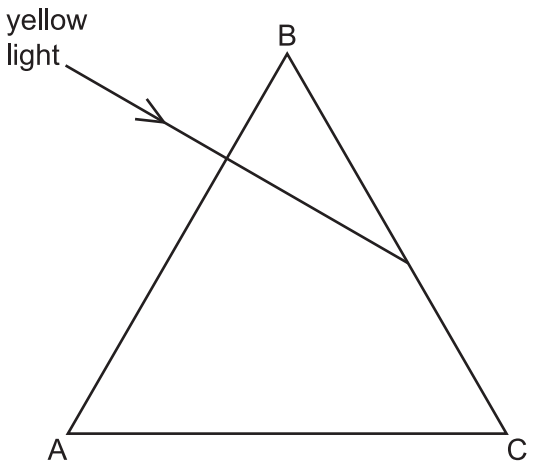



**Fig. 5.1**

**(a)** Explain why the ray does **not** change direction when it enters the prism at face AB.

.....

..... [1]

**(b)** The critical angle for the glass is 42°.

**(i)** Calculate the refractive index of the glass.

Show your working.

refractive index = ..... [2]

**(ii)** On Fig. 5.1, continue the path of the light through the prism and after it leaves the prism. [3]

**(c)** Internet data can be transferred using infrared waves in optical fibres.

State **two** advantages of using optical fibres to transmit data.

1 .....

2 ..... [2]

[Total: 8]

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| | | |
|---|---|---|
| **8**(a) | ray travels along the normal **OR** angle of incidence = 0(°) | **B1** |
| **8**(b)(i) | $n$ = 1 / sin $c$ **OR** ($n$ =) 1 / sin $c$ **OR** ($n$ =) 1 / sin 42 (°) | **M1** |
| | 1.5 | **A1** |
| **8**(b)(ii) | ray reflected at BC **AND** no refracted ray | **M1** |
| | ray hits AC with angle of incidence = 0 ° | **A1** |
| | correct refraction of candidate's ray into air at AC | **B1** |

| | | |
|---|---|---|
| **8**(c) | any **two** from:<br>• high rates (of data transmission) / fast (data transmission)<br>• carry large amounts (of data / information)<br>• secure<br>• little signal / data loss<br>• glass is transparent to (some) infrared | **B2** |

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**9** Fig. 7.1 shows a ray of light approaching face AB of a glass prism of refractive index 1.5.

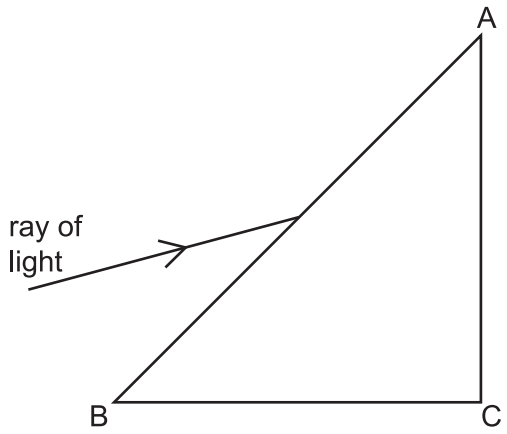



**Fig. 7.1**

**(a)** **(i)** On Fig. 7.1, accurately draw the path of the ray within the prism from face AB to face AC. You will need to make a measurement from Fig. 7.1 and carry out a calculation.

[4]

**(ii)** Determine the angle of incidence of this ray when it strikes face AC.

angle = ..... [1]

**(b)** Without further measurement or calculation, sketch on Fig. 7.1 the approximate path of the ray after passing through the face AC. [1]

**(c)** Fig. 7.2 shows a ray of light travelling within an optical fibre.

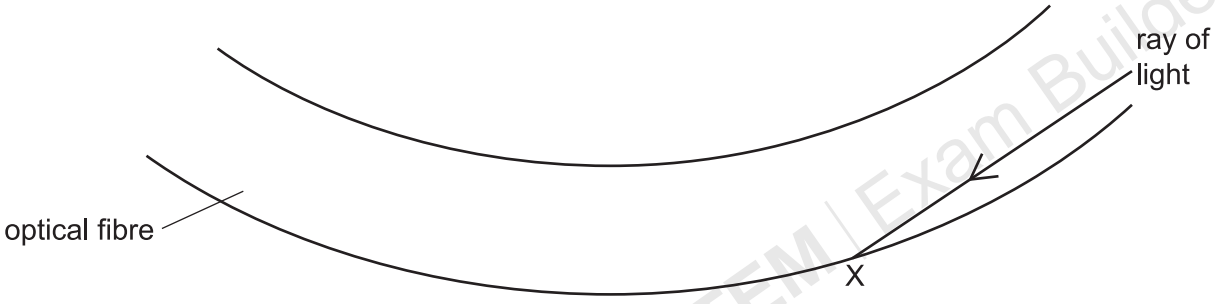



**Fig. 7.2**

**(i)** Complete the path of the ray of light to the left-hand end of the fibre. [2]

**(ii)** Name the process taking place at X. ..... [1]

[Total: 9]

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| | | |
|---|---|---|
| 9(a)(i) | $i$ = 60° used or seen | C1 |
| | sin $i$ / sin $r$ = $n$ in any form | C1 |
| | ray refracted toward normal and toward AC | C1 |
| | ray clearly refracted down in prism reaching AC with r = 35(°) | A1 |
| 9(a)(ii) | 10° | B1 |
| 9(b) | refracted away from normal | B1 |
| 9(c)(i) | (total internal) reflection at X<br>NOT refraction at X or anywhere else | B1 |
| | reaches end of fibre with only one additional reflection (off lower internal edge of fibre) | B1 |
| 9(c)(ii) | total internal reflection | B1 |

**10** **(a)** Fig. 4.1 shows a ray of light as it enters the side of a plastic block. The ray of light passes from air into the plastic.

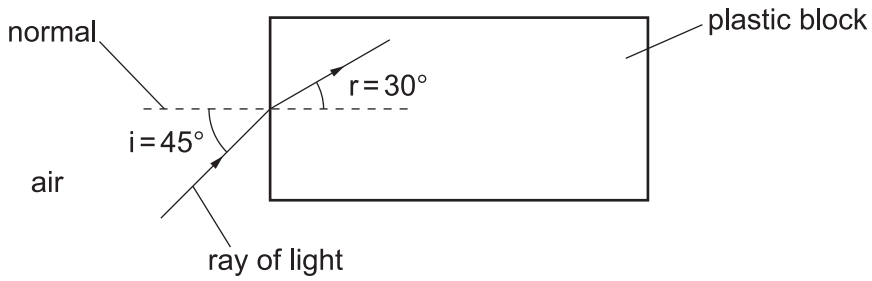



**Fig. 4.1**

**(i)** State how the speed, wavelength and frequency of the wave in the plastic block compare with their values in the air.

speed: .....

wavelength: .....

frequency: .....

[2]

**(ii)** Show that the refractive index of the plastic is 1.4.

Show your working.

[1]

**(iii)** Calculate the critical angle for the plastic.

critical angle = ..... [2]

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**(b)** Fig. 4.2 shows the same plastic as in **(a)** used to make an optical fibre. A ray of light is passing along the fibre.

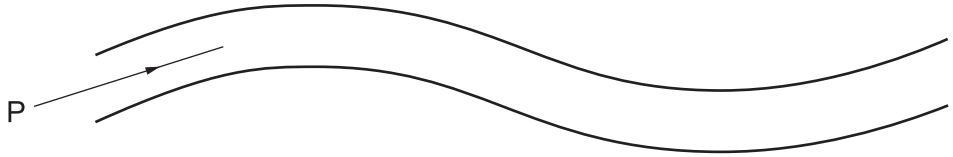



**Fig. 4.2**

**(i)** Carefully continue the ray of light P until it reaches the other end of the fibre. [2]

**(ii)** State **two** uses for optical fibres.

1 .....

2 .....
[2]

[Total: 9]

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| | | |
|---|---|---|
| 10(a)(i) | any **two** correct = 1 mark<br>all **three** correct = 2 marks<br>• speed decreases / gets less / slower<br>• wavelength decreases / gets smaller / shorter<br>• frequency unchanged / stays the same / no effect | **B2** |
| 10(a)(ii) | ($n$ =) sin 45 / sin 30 | **B1** |
| 10(a)(iii) | 46° ***OR*** 45° | **A1** |
| | $n$ = 1 / sin $c$ ***OR*** ($c$ =) $\sin^{-1}$ (1 / $n$) ***OR*** ($c$ =) $\sin^{-1}$ (1 / 1.4) ***OR*** sin $c$ = 1 / $n$ | **M1** |
| 10(b)(i) | total internal reflection ***AND*** $i = r$ for initial reflection | **B1** |
| | ray reaches end of fibre after a total of 2 or 3 reflections only | **B1** |
| 10(b)(ii) | any **two** from:<br>• internet transmission / (highspeed) broadband<br>• telephone networks<br>• cable TV<br>} ***OR*** telecommunications<br>• endoscope<br>• lasers in surgery<br>• microscopy<br>• military aircraft wiring<br>• imaging (cameras) in industry<br>• inspection of pipes or other hard to reach places | **B2** |

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