

1

An electromagnetic wave enters a fibre-optic cable from air. On entering the cable, the wave slows down to three-fifths of its original speed.

What is the refractive index of the core of the fibre-optic cable?

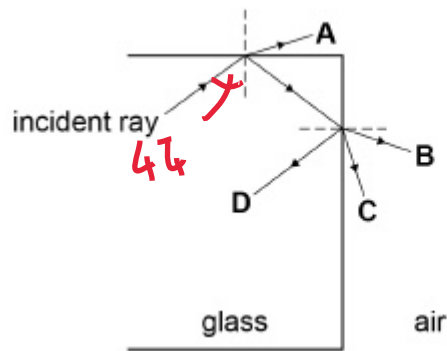
- A 0.67
- B 1.33
- C 1.50
- D 1.67**

$$n = \frac{c}{c_s} = \frac{1}{\frac{3}{5}} = 1.67$$

(Total 1 mark)

2

A ray of light is incident on a glass-air boundary of a rectangular block as shown.



critical angle  $\sin \theta_c = \frac{n_2}{n_1}$   
 $= 41.8$  so  
 TIR at first normal.

not to scale

The refractive index of this glass is 1.5

The refractive index of air is 1.0

The angle of incidence of the light at the first glass-air boundary is  $44^\circ$

What is the path of the ray of light?

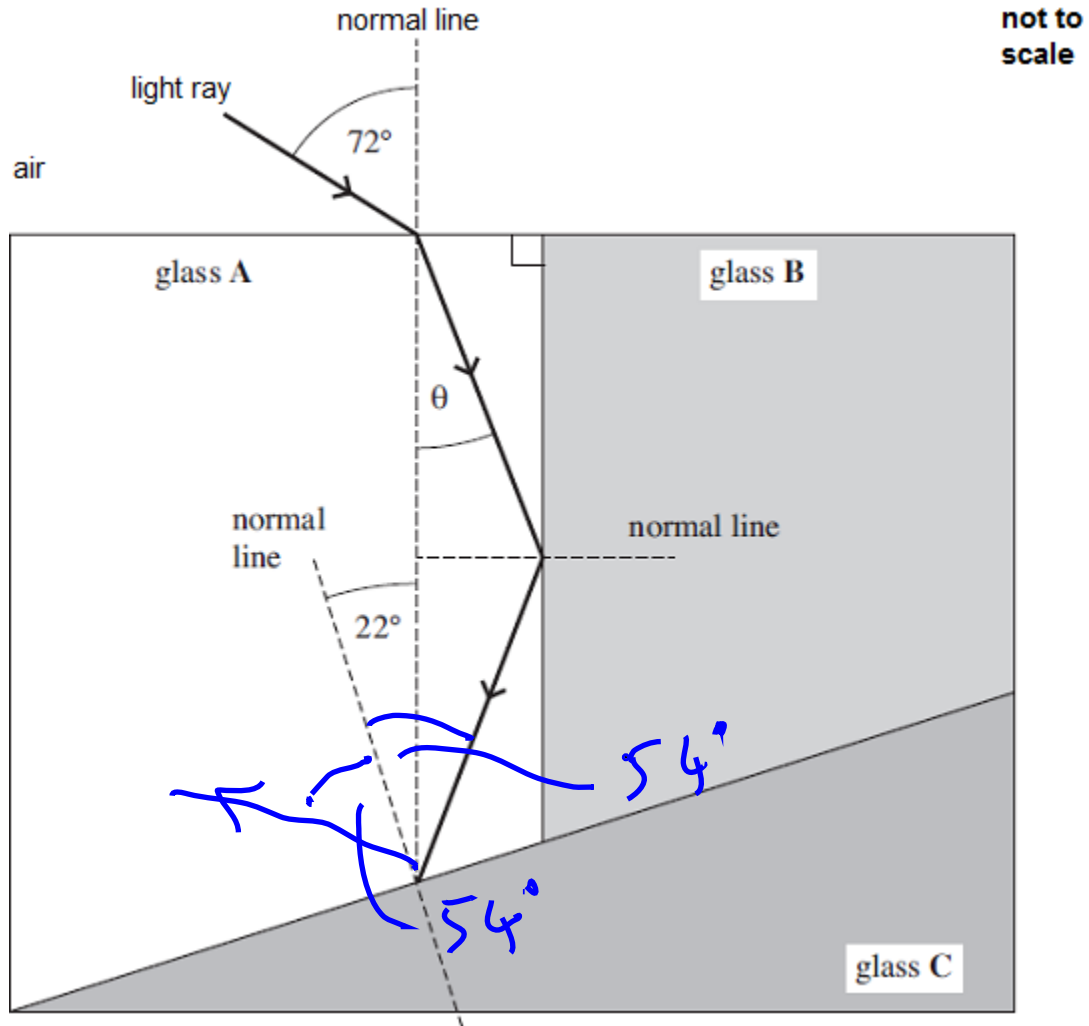
- A
- B
- C
- D**

At 2<sup>nd</sup> normal  
 angle of incidence  
 $= 90 - 44$   
 $= 46$  so  
 also TIR

(Total 1 mark)

3

The diagram below shows three transparent glass blocks **A**, **B** and **C** joined together. Each glass block has a different refractive index.



- (a) State the **two** conditions necessary for a light ray to undergo total internal reflection at the boundary between two transparent media.

condition 1 first material must be more optically dense.

condition 2 angle of incidence > critical angle

not just denser - must be optically

(2)

- (b) Calculate the speed of light in glass **A**.

refractive index of glass **A** = 1.80

$$c_s = \frac{3 \times 10^8}{1.8}$$

$$n = \frac{c}{c_s} \Rightarrow c_s = \frac{c}{n}$$

speed of light 1.7 × 10<sup>8</sup> ms<sup>-1</sup>

(2)

- (c) Show that angle  $\theta$  is about 30°.

$$\begin{aligned} n_1 \sin \theta_1 &= n_2 \sin \theta_2 \Rightarrow \sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2} \\ &= \frac{1 \sin 72}{1.8} \\ &= 31.9 \\ &= 32 \text{ (2sf)} \end{aligned}$$

(2)

- (d) The refractive index of glass **C** is 1.40.

Calculate the critical angle between glass **A** and glass **C**.

$$\sin \theta_c = \frac{n_2}{n_1} = \frac{1.4}{1.8}$$

critical angle 51 (2sf) degrees

(2)

- (e) (i) State and explain what happens to the light ray when it reaches the boundary between glass **A** and glass **C**.

The angle of incidence = 32 + 22 = 54  
so greater than  $\theta_c$  so get  
total internal reflection - no refraction

(2)

- (ii) On the diagram above continue the path of the light ray after it strikes the boundary between glass **A** and glass **C**.

(1)

(Total 11 marks)

## Mark schemes

1 D

[1]

2 D

[1]

3 (a)  $n_1 > n_2$  ✓

Allow correct reference to 'optical density'

(incident) angle > critical angle (allow  $\theta_c$  not 'c')

**OR** critical angle must be exceeded ✓

Allow  $n_A > n_B$

Do not allow: 'angle **passes** the critical angle'

2

(b)

$$\left( n_2 = \frac{c}{c_2} \right)$$

$$\left( c_A = \frac{c}{n_A} \right) \frac{3.00 \times 10^8}{1.80} \quad \checkmark$$

For second mark, don't allow  $1.6 \times 10^8$

Allow  $1.66 \times 10^8$  or  $1.70 \times 10^8$

Allow  $1.6. \times 10^8$

$$(\text{=} 1.667 \times 10^8) = 1.67 \times 10^8 \text{ (ms}^{-1}\text{)} \checkmark$$

2

(c)  $\sin 72 = 1.80 \sin \theta$  ✓

$$\left( \sin \theta = \frac{\sin 72}{1.80} = \frac{0.9510565}{1.8} = 0.52836 \right)$$

Correct answer on its own gets both marks

$$\theta = 31.895 = 31.9 \text{ correct answer } \geq 2\text{sf seen } \checkmark$$

Do not allow 31 for second mark

Allow 31.8 – 32

2

(d)  $1.80 \sin \theta_c = 1.40$  **OR**  $\sin \theta_c = \frac{1.40}{1.80}$   
 $\theta_c = 51.058 = 51.1^\circ$  ✓ (accept 51)

Correct answer on its own gets both marks

Don't accept 50 by itself

2

**OR** = 0.778 ✓

- (e) (i) 22 + their (c) ( $22 + 31.9 = 53.9$ ) ✓  
53.9 > (51.1) critical angle ✓

*If  $c + 22 < d$  then TIR expected*

*If  $c + 22 > d$  then REFRACTION expected*

**OR**

$c + 22 <$  their  $d$  ( $\theta_c$ ) ✓ ecf from (c) and (d)  
angle less than critical angle ✓

*Allow max 1 for 'TIR because angle > critical angle' only if their  $d > c + 22$*

2

- (ii) TIR angle correct ✓  
ecf from e(i) for refraction answer

*Tolerance: horizontal line from normal on the right / horizontal line from top of lower arrow.*

*If ei not answered then ecf (d). If ei and d not answered then ecf c*

1

[11]