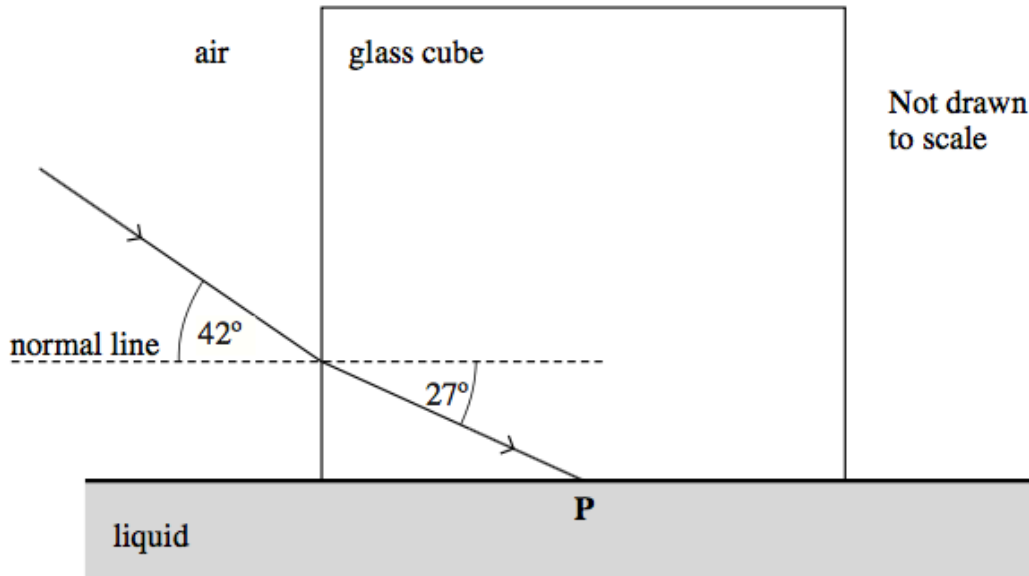


1)

A glass cube is held in contact with a liquid and a light ray is directed at a vertical face of the cube. The angle of incidence at the vertical face is then decreased to 42° as shown in **Figure 8**. At this point the angle of refraction is 27° and the ray is totally internally reflected at **P** for the first time.

Figure 8



(a) Complete **Figure 8** to show the path of the ray beyond **P** until it returns to air. (3 marks)

(b) Show that the refractive index of the glass is about 1.5.

(2 marks)

(c) Calculate the critical angle for the glass-liquid boundary.

answer = degrees
(1 mark)

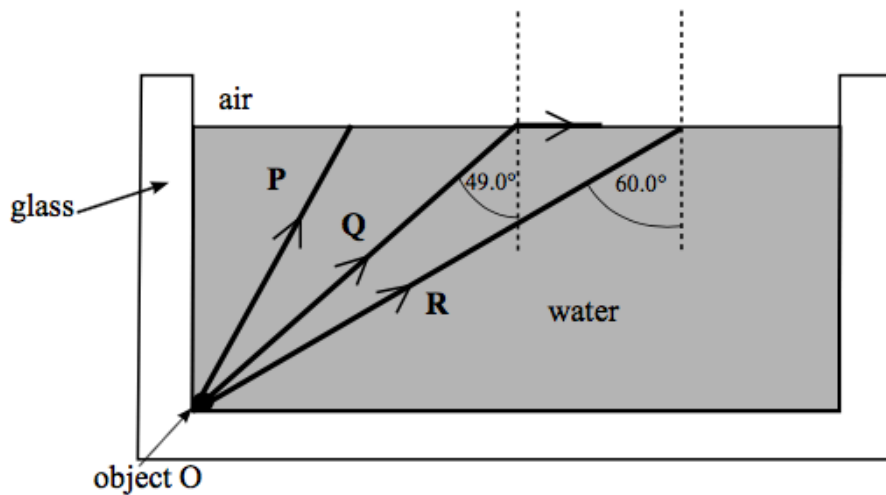
(d) Calculate the refractive index of the liquid.

answer =
(2 marks)

2)

Figure 6 shows a rectangular glass fish tank containing water. Three light rays, **P**, **Q** and **R** from the same point on a small object **O** at the bottom of the tank are shown.

Figure 6



(a) (i) Light ray **Q** is refracted along the water-air surface. The angle of incidence of light ray **Q** at the water surface is 49.0° . Calculate the refractive index of the water. Give your answer to an appropriate number of significant figures.

Answer.....
(1 mark)

(a) (ii) Draw on **Figure 6** the path of light ray **P** from the water-air surface.

(3 marks)

(b) In **Figure 6**, the angle of incidence of light ray **R** at the water-air surface is 60.0° .

(b) (i) Explain why this light ray is totally internally reflected at the water surface.

.....
.....

(2 marks)

(b) (ii) Draw the path of light ray **R** from the water surface and explain whether or not **R** enters the glass at the right-hand side of the tank.

the refractive index of the glass = 1.50

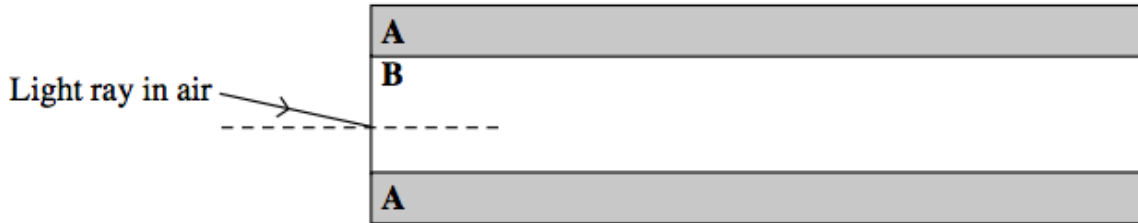
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(4 marks)

3)

Figure 3 shows a cross-section through a step index optical fibre.

Figure 3



(a) (i) Name the parts **A** and **B** of the fibre.

(1 mark)

A	
B	

(a) (ii) On **Figure 3**, draw the path of the ray of light through the fibre. Assume the light ray undergoes *total internal reflection* at the boundary between **A** and **B**.

(2 marks)

(b) Calculate the critical angle for the boundary between **A** and **B**. Give your answer to an appropriate number of significant figures.

The refractive index of part **A** = 1.46
 The refractive index of part **B** = 1.48

answer = degrees
 (2 marks)

- (c) State and explain **one** reason why part **B** of the optical fibre is made as narrow as possible.

.....

.....

.....

.....

(2 marks)

- (d) State **one** application of optical fibres and explain how this has benefited society.

Application

.....

.....

Benefit

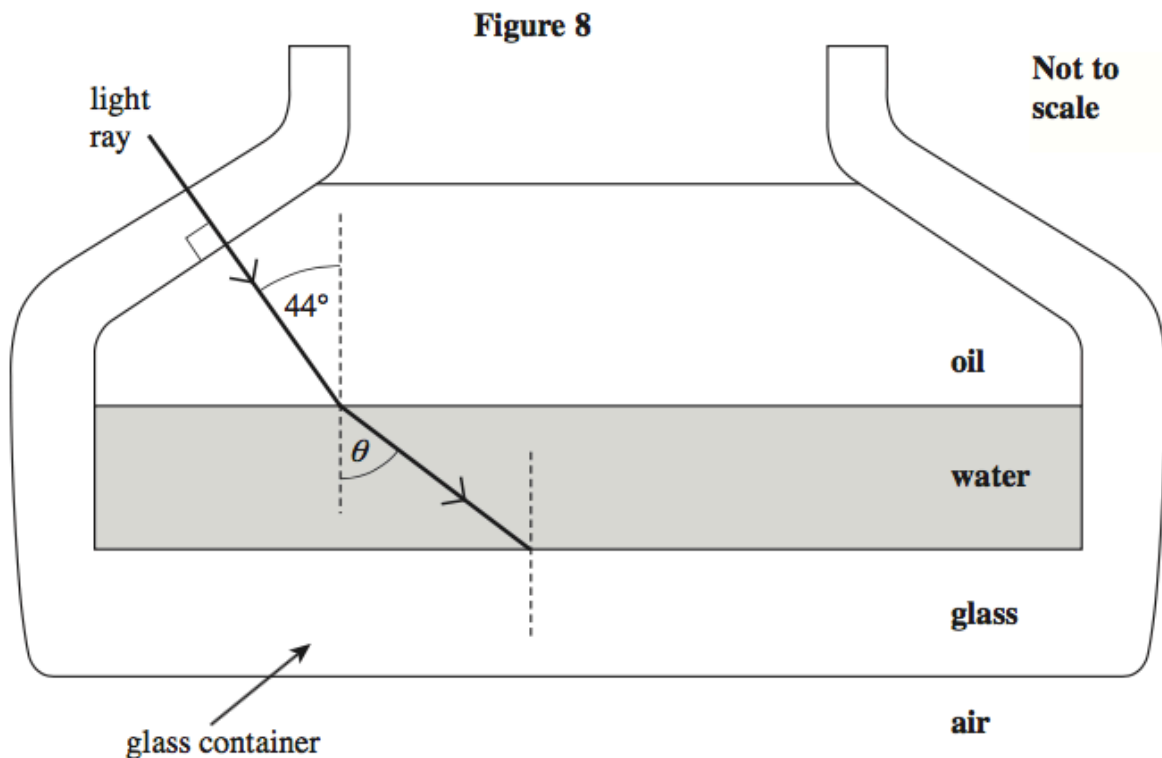
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(2 marks)

4)

Figure 8 shows a layer of oil that is floating on water in a glass container. A ray of light in the oil is incident at an angle of 44° on the water surface and refracts.



The refractive indices of the materials are as follows.

refractive index of oil	= 1.47
refractive index of water	= 1.33
refractive index of the glass	= 1.47

- (a) Show that the angle of refraction θ in **Figure 8** is about 50° .

(2 marks)

- (b) The oil and the glass have the same refractive index. On **Figure 8**, draw the path of the light ray after it strikes the boundary between the water and the glass and enters the glass. Show the value of the angle of refraction in the glass.

(2 marks)

- (c) Explain why the total internal reflection will not occur when the ray travels from water to glass.

.....
.....
.....

(1 mark)

- (d) Calculate the critical angle for the boundary between the glass and air.

answer =degrees
(2 marks)

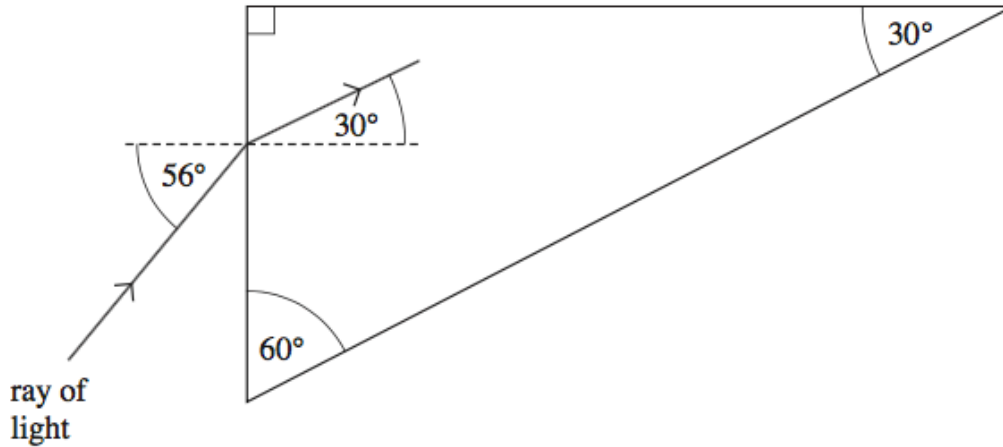
- (e) On **Figure 8**, complete the path of the ray after it strikes the boundary between the glass and air.

(2 marks)

5)

Figure 6 shows a glass prism. Light is directed into the prism at an angle of 56° . The path of the ray of light is shown as it enters the prism.

Figure 6



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

answer =
(2 marks)

(a) (ii) Calculate the critical angle for the glass-air boundary.

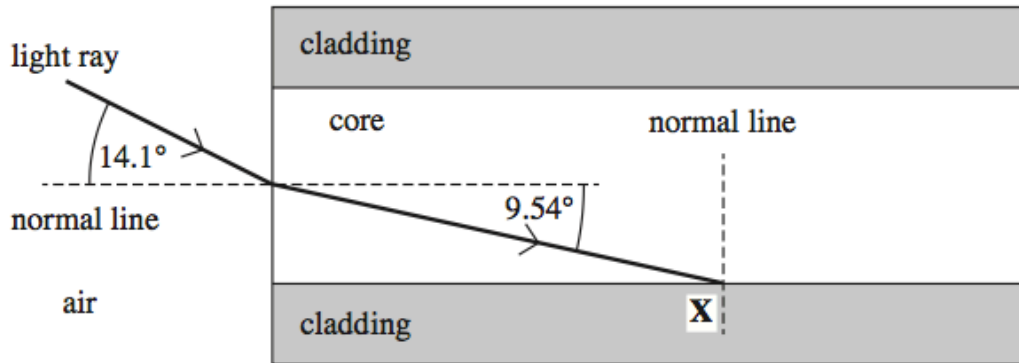
answer = degrees
(2 marks)

(b) On **Figure 6**, continue the path of the ray of light until it emerges from the prism.
(2 marks)

6)

Figure 4 shows a section of a typical glass step-index optical fibre used for communications.

Figure 4



(a) Show that the refractive index of the core is 1.47.

(1 mark)

(b) The refracted ray meets the core-cladding boundary at an angle exactly equal to the critical angle.

(b) (i) Complete **Figure 4** to show what happens to the ray after it strikes the boundary at **X**.

(2 marks)

(b) (ii) Calculate the critical angle.

critical angle =degrees
(1 mark)

(b) (iii) Calculate the refractive index of the cladding.

refractive index =
(2 marks)

(c) Give **two** reasons why optical fibres used for communications have a cladding.

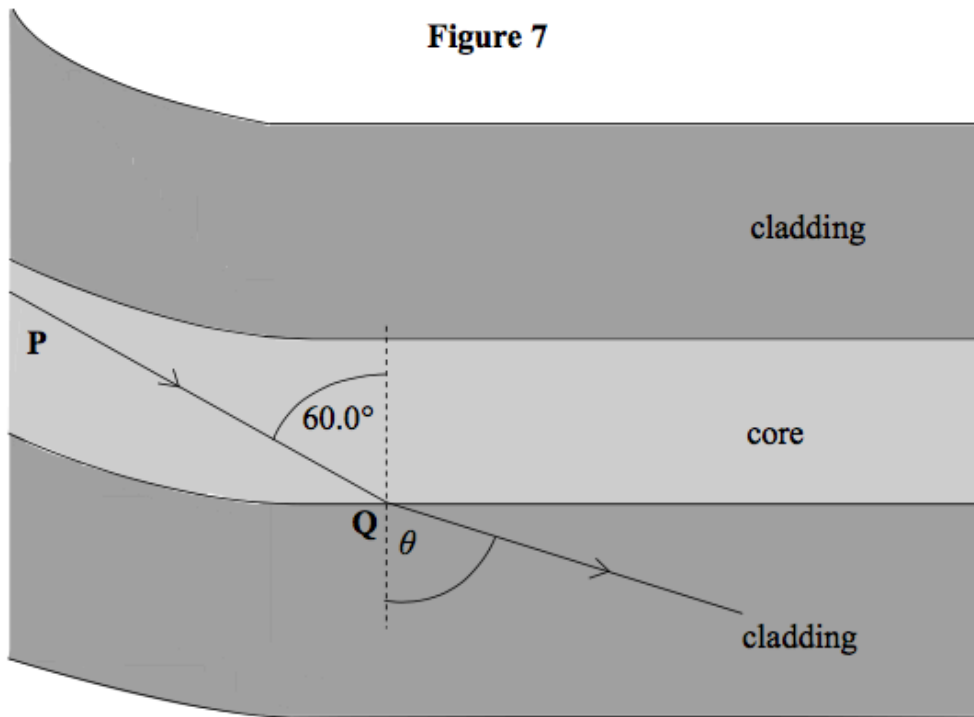
reason 1
.....

reason 2
.....

(2 marks)

7)

An optical fibre used for communications has a core of refractive index 1.55 which is surrounded by cladding of refractive index 1.45.



(a) **Figure 7** shows a light ray **P** inside the core of the fibre. The light ray strikes the core-cladding boundary at **Q** at an angle of incidence of 60.0°.

(a) (i) Calculate the critical angle of the core-cladding boundary.

answer.....degrees
(3 marks)

(a) (ii) State why the light ray enters the cladding at **Q**.

.....
.....

(1 mark)

(a) (iii) Calculate the angle of refraction, θ , at Q.

answer.....degrees
(3 marks)

(b) Explain why optical fibres used for communications need to have cladding.

.....

.....

.....

.....

.....

.....

(2 marks)

8)

(a) The speed of light is given by

$$c = f \lambda$$

State how each of these quantities will change, if at all, when light travels from air to glass.

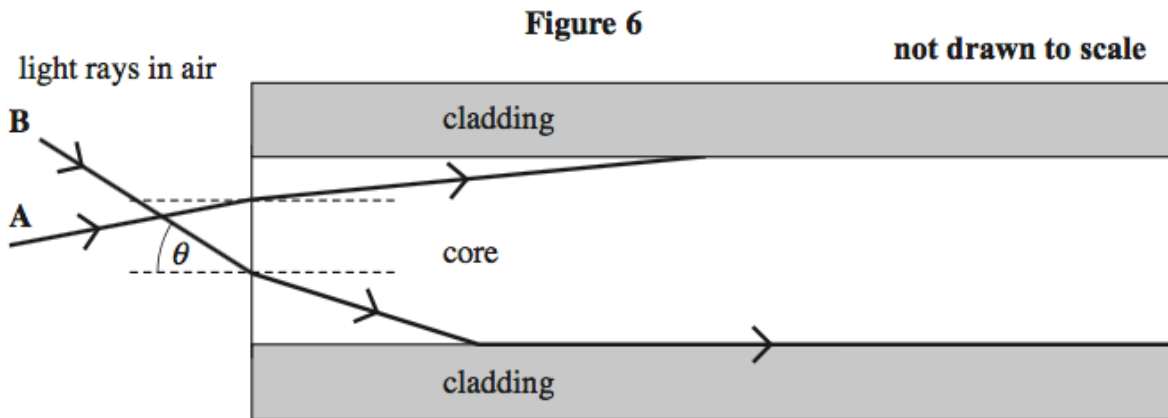
c

f

λ

(3 marks)

Figure 6 shows a side view of a step index optical fibre.



(b) Ray A enters the end of the fibre and then undergoes total internal reflection. On Figure 6 complete the path of this ray along the fibre.

(2 marks)

(c) (i) The speed of light in the core is $2.04 \times 10^8 \text{ ms}^{-1}$. Show that the refractive index of the core is 1.47.

(2 marks)

(c) (ii) Show that the critical angle at the boundary between the core and the cladding is about 80° .

refractive index of the cladding = 1.45

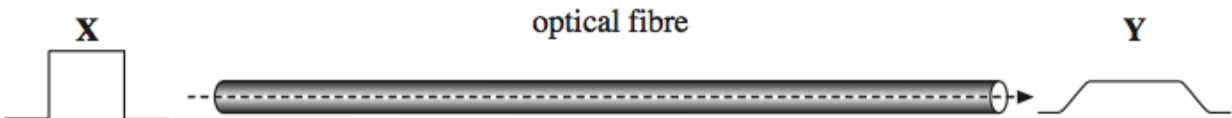
(2 marks)

- (d) Ray **B** enters the end of the fibre and refracts along the core-cladding boundary. Calculate the angle of incidence, θ , of this ray at the point of entry to the fibre.

answer = degrees
(3 marks)

- (e) **Figure 7** shows a pulse of monochromatic light (labelled **X**) that is transmitted a significant distance along the fibre. The shape of the pulse after travelling along the fibre is labelled **Y**. Explain why the pulse at **Y** has a lower amplitude and is longer than it is at **X**.

Figure 7



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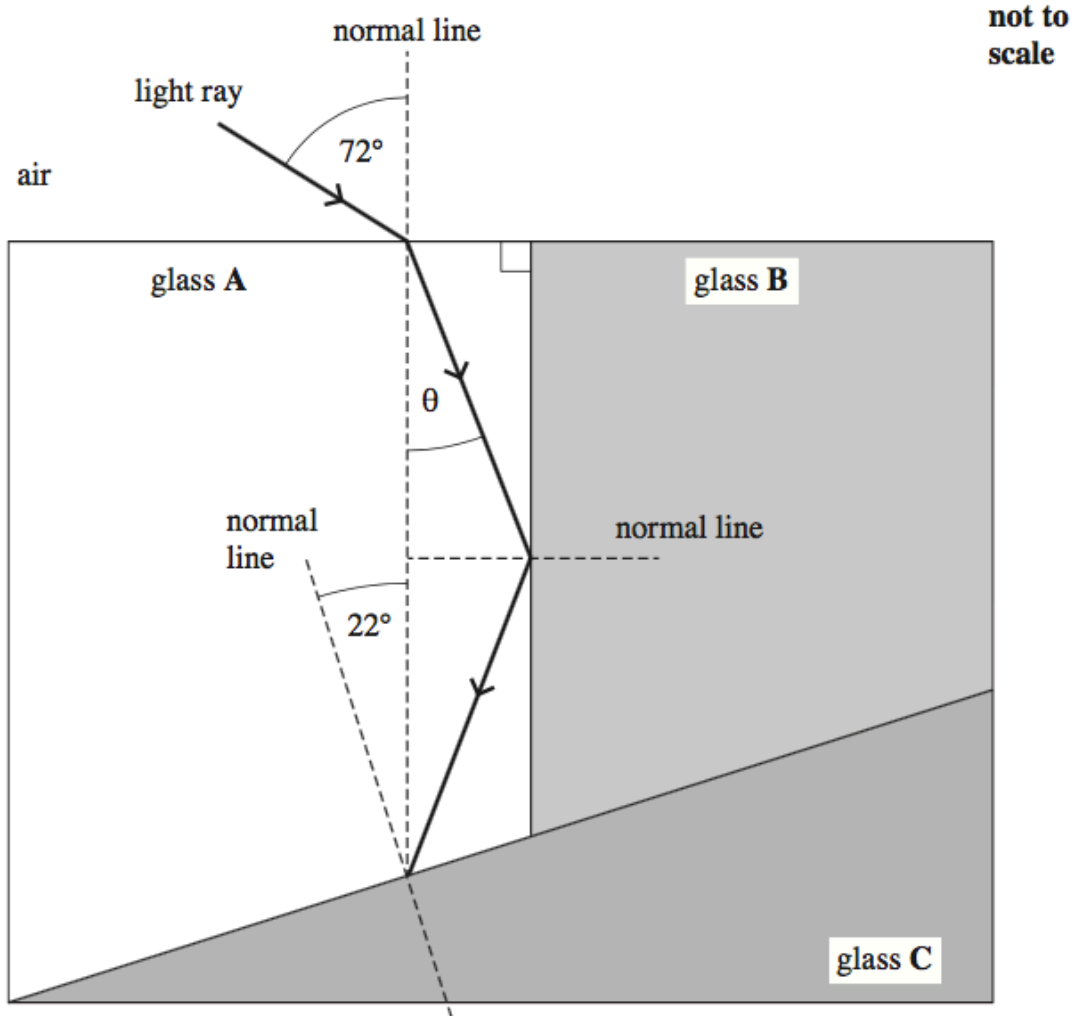
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(2 marks)

9)

Figure 7 shows three transparent glass blocks **A**, **B** and **C** joined together. Each glass block has a different refractive index.

Figure 7



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

condition 1

.....

condition 2

.....

(2 marks)

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

refractive index of glass A = 1.80

speed of light m s^{-1}
(2 marks)

(c) Show that angle θ is about 30° .

(2 marks)

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

Calculate the critical angle between glass A and glass C.

critical angle degrees
(2 marks)

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

.....
.....
.....

(2 marks)

(e) (ii) On **Figure 7** continue the path of the light ray after it strikes the boundary between glass A and glass C.

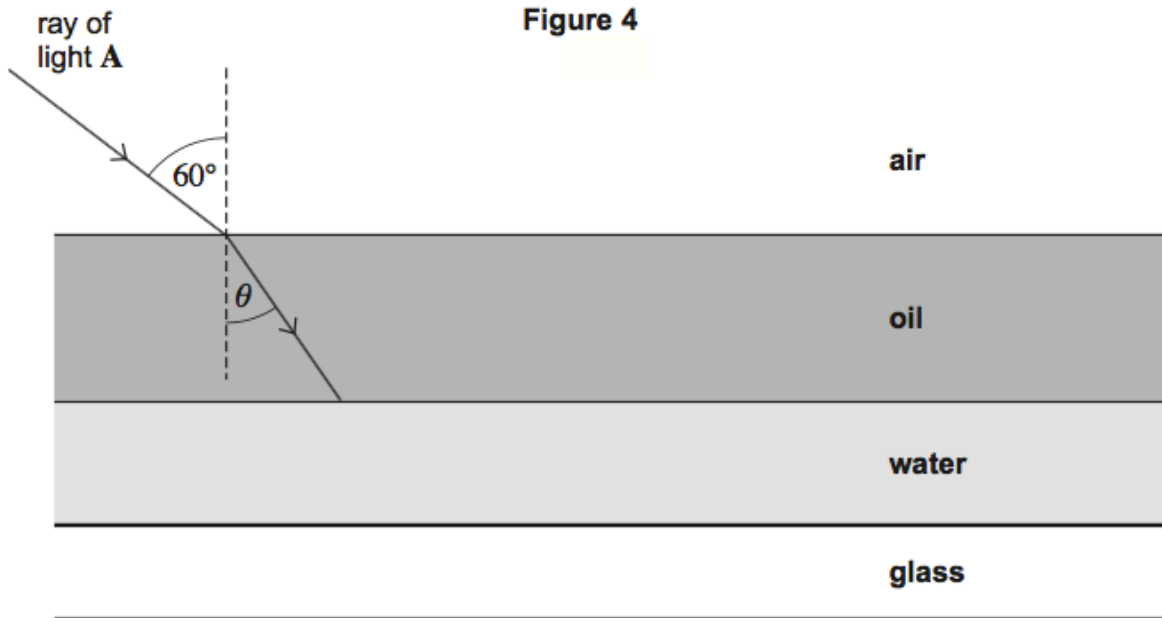
(1 mark)

10)

Figure 4 shows a ray of light **A** incident at an angle of 60° to the surface of a layer of oil that is floating on water.

refractive index of oil = 1.47

refractive index of water = 1.33



(a) (i) Calculate the angle of refraction θ in **Figure 4**.

[2 marks]

angle degrees

(a) (ii) Calculate the critical angle for a ray of light travelling from oil to water.

[2 marks]

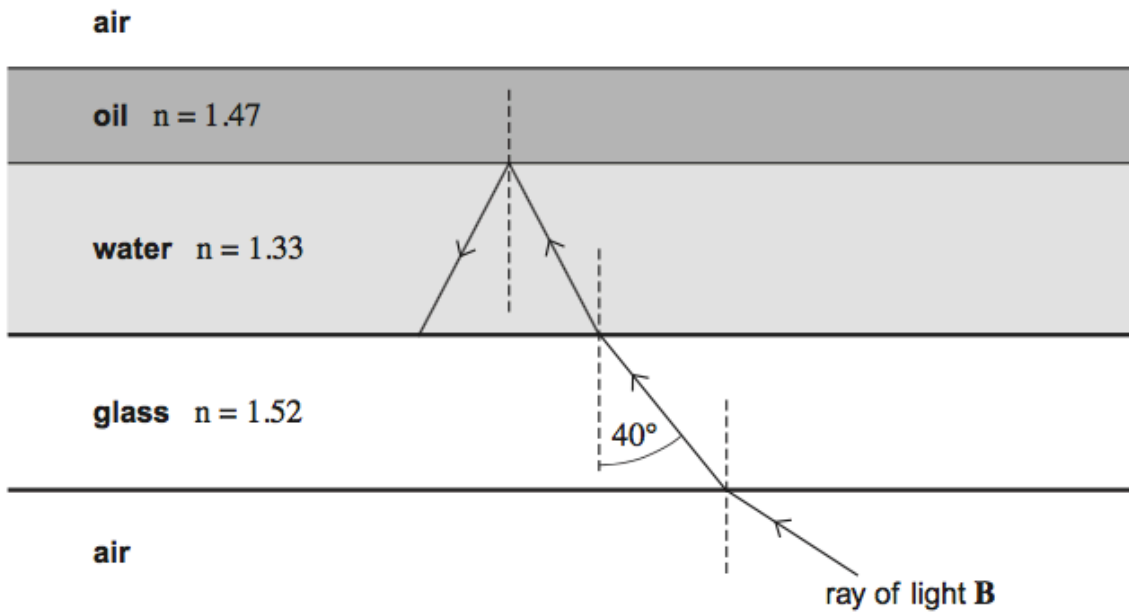
angle degrees

(a) (iii) On **Figure 4** continue the path of the ray of light **A** immediately after it strikes the boundary between the oil and the water.

[2 marks]

- (b) In **Figure 5** a student has incorrectly drawn a ray of light **B** entering the glass and then entering the water before totally internally reflecting from the water–oil boundary.

Figure 5



The refractive index of the glass is 1.52 and the critical angle for the glass–water boundary is about 60° .

Give **two** reasons why the ray of light **B** would **not** behave in this way. Explain your answers.

[4 marks]

reason 1

.....

explanation

.....

.....

reason 2

.....

explanation

.....

.....