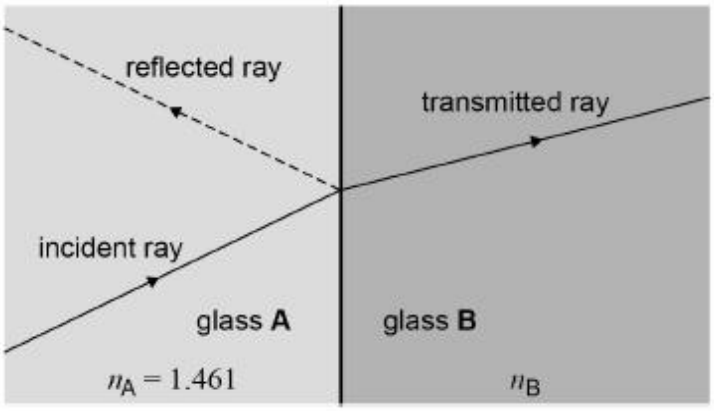
Refraction Questions

Q1.

Figure 1 shows an incident ray of light being partially reflected at the boundary between glass **A** and glass **B**. The refractive index n_A of glass **A** is 1.461

The speed of light in glass **B** is 3.252% less than the speed of light in glass **A**.

Figure 1



Calculate the refractive index n_B of glass **B**.

Give your answer to an appropriate number of significant figures.

speed of light in a vacuum = 2.998×10^8 m s^{-1}

n_B = _____

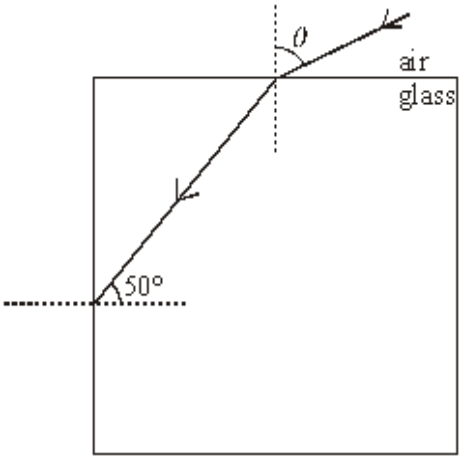
(3)

(Total 3 marks)

Q2.

The diagram shows a cube of glass. A ray of light, incident at the centre of a face of the cube, at an angle of incidence θ, goes on to meet another face at an angle of incidence of 50°, as shown in the figure bellow

critical angle at the glass-air boundary = 45°



(a) Draw on the diagram the continuation of the path of the ray, showing it passing through the glass and out into the air.

(3)

(b) Show that the refractive index of the glass is 1.41

_____

_____

_____

(2)

(c) Calculate the angle of incidence, θ.

_____

_____

_____

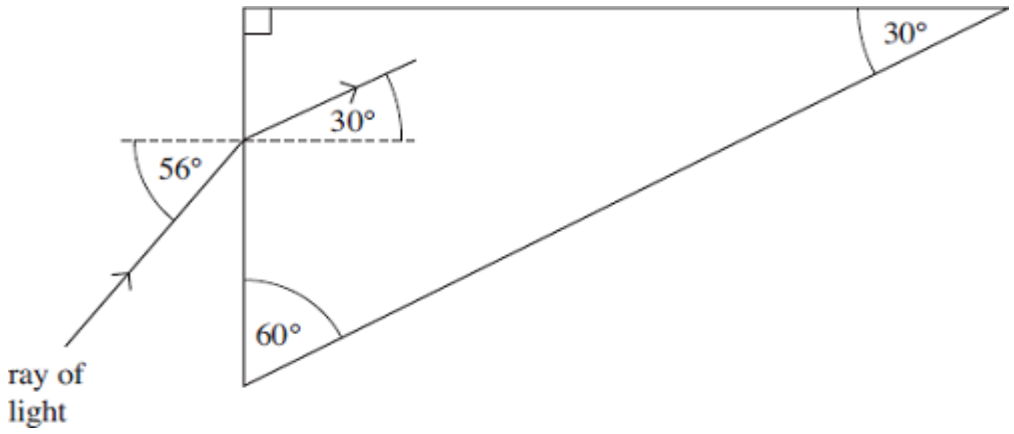
_____

(3)

(Total 8 marks)

Q3.

The figure below 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 is it enters the prism.



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

answer = _____

(2)

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

answer = _____ degrees

(2)

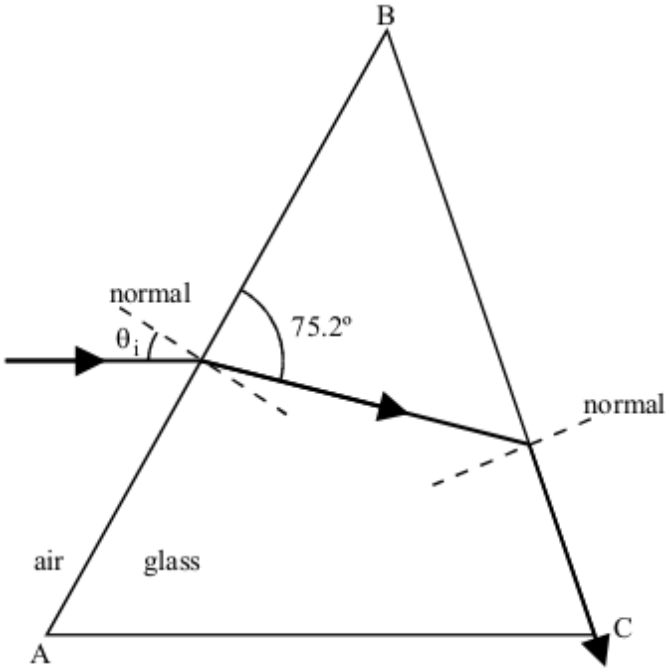
(b) On the figure above, continue the path of the ray of light until it emerges from the prism.

(2)

(Total 6 marks)

Q4.

The diagram shows a ray of light passing from air into a glass prism at an angle of incidence θ_i.
The light emerges from face BC as shown.
refractive index of the glass = 1.55



(a) (i) Mark the critical angle along the path of the ray with the symbol θ_c.

(ii) Calculate the critical angle, θ_c.

_____

_____

_____

_____

(3)

(b) For the ray shown calculate the angle of incidence, θ_i.

_____

_____

_____

_____

(2)

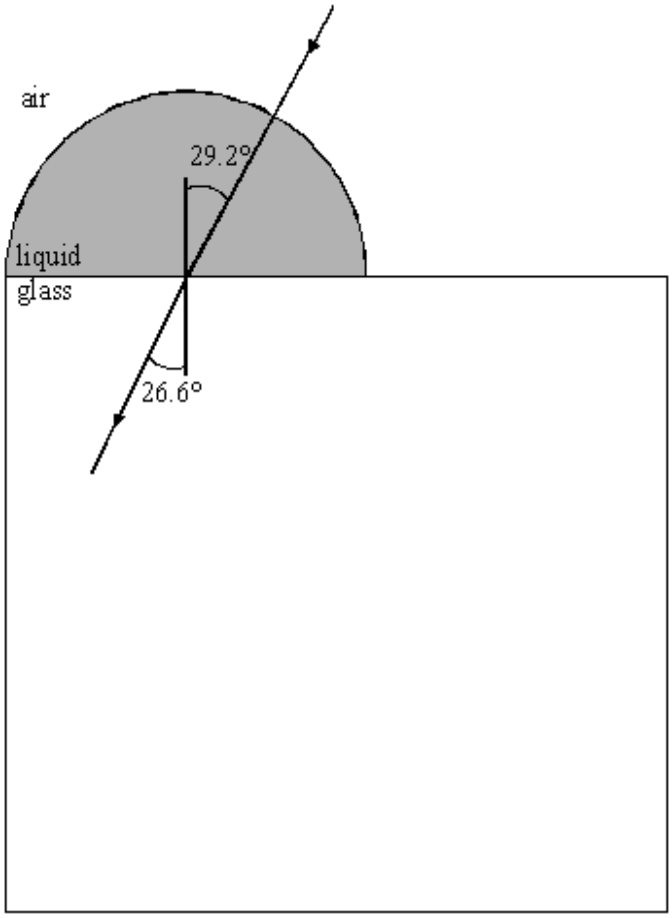
(c) Without further calculations draw the path of another ray of light incident at the same point on the prism but with a smaller angle of incidence. The path should show the ray emerging from the prism into the air.

(3)

(Total 8 marks)

Q5.

The diagram below shows a liquid droplet placed on a cube of glass. A ray of light from air, incident normally on to the droplet, continues in a straight line and is refracted at the liquid to glass boundary as shown.
refractive index of the glass = 1.45



(a) Calculate the speed of light

(i) in the glass,

_____

_____

_____

(ii) in the liquid droplet.

_____

_____

_____

_____

(3)

(b) Calculate the refractive index of the liquid.

_____

_____

_____

_____

_____

(2)

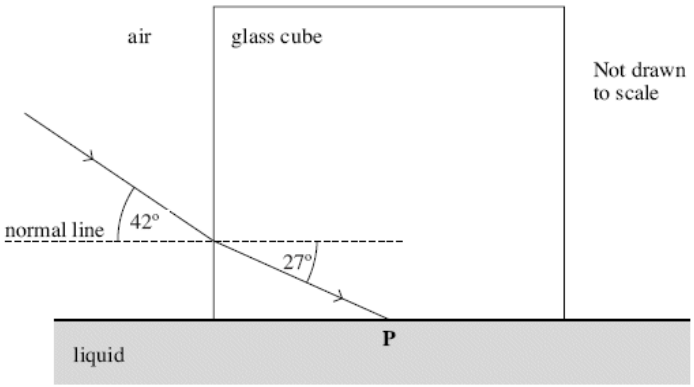
(c) On the diagram above, complete the path of the ray showing it emerge from the glass cube into the air.
No further calculations are required.

(2)

(Total 7 marks)

Q6.

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 the figure below. At this point the angle of refraction is 27° and the ray is totally internally reflected at **P** for the first time.



(a) Complete the figure above to show the path of the ray beyond **P** until it returns to air.

(3)

(b) Show that the refractive index of the glass is about 1. 5.

(2)

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

answer = _____ degrees

(1)

(d) Calculate the refractive index of the liquid.

answer = _____

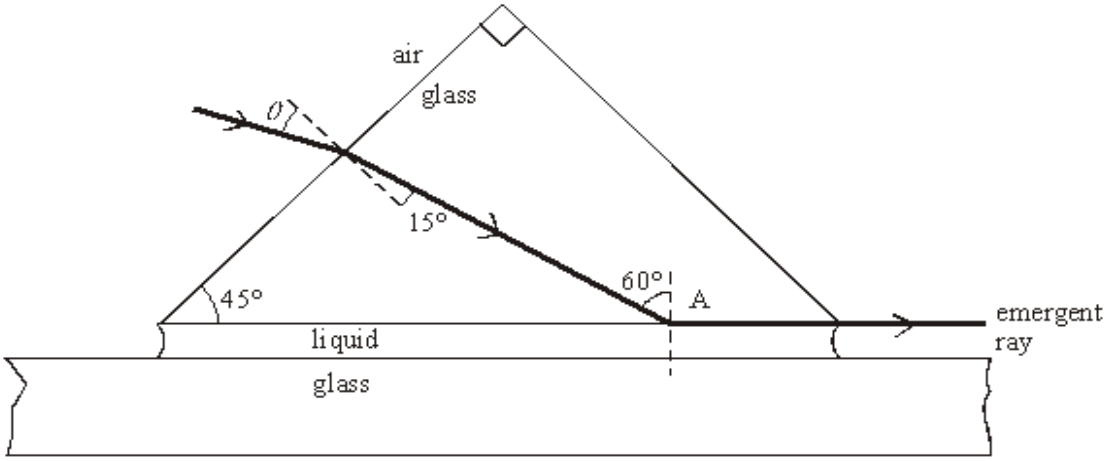
(2)

(Total 8 marks)

Q7.

The diagram, which is not to scale, shows the cross-section of a 45° right angled glass prism supported by a film of liquid on a glass table. A ray of monochromatic light is incident on the prism at an angle of incidence θ and emerges along the glass - liquid boundary as shown.

refractive index of glass = 1.5



(a) Calculate the speed of light in the glass.

(2)

(b) Determine

(i) the angle of incidence, θ,

(ii) the refractive index of the liquid.

(5)

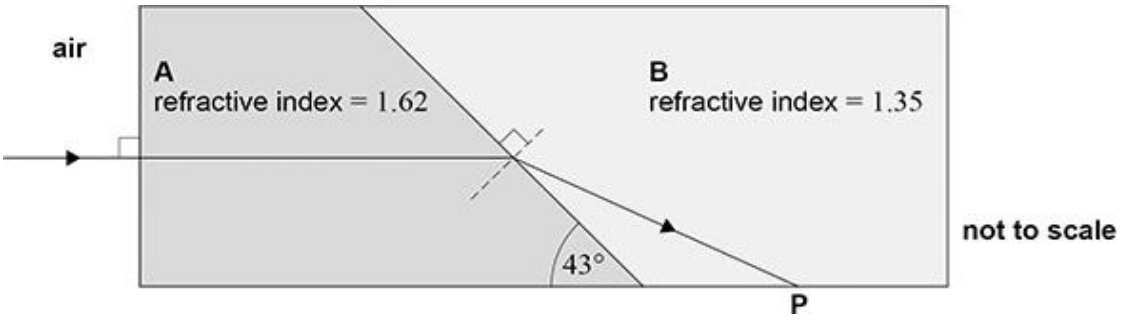
(c) The liquid is now changed to one with a lower refractive index. Draw a possible path for the ray beyond the point A and into the air.

(2)

(Total 9 marks)

Q8.

Two transparent prisms **A** and **B** of different refractive indices are placed in contact to produce a rectangular block.
The figure below shows the path of a ray, incident normally on **A**, refracting as it crosses the boundary between the prisms.



(a) Explain how the path of the ray shows that the refractive index of **A** is greater than the refractive index of **B**.

_____

_____

_____

_____

(1)

(b) Show that the angle of refraction of the ray in **B** is about $60°$.

(2)

(c) Draw, on the figure above, the path of the ray immediately after it reaches **P**.
Justify your answer with calculations.

(3)
(Total 6 marks)

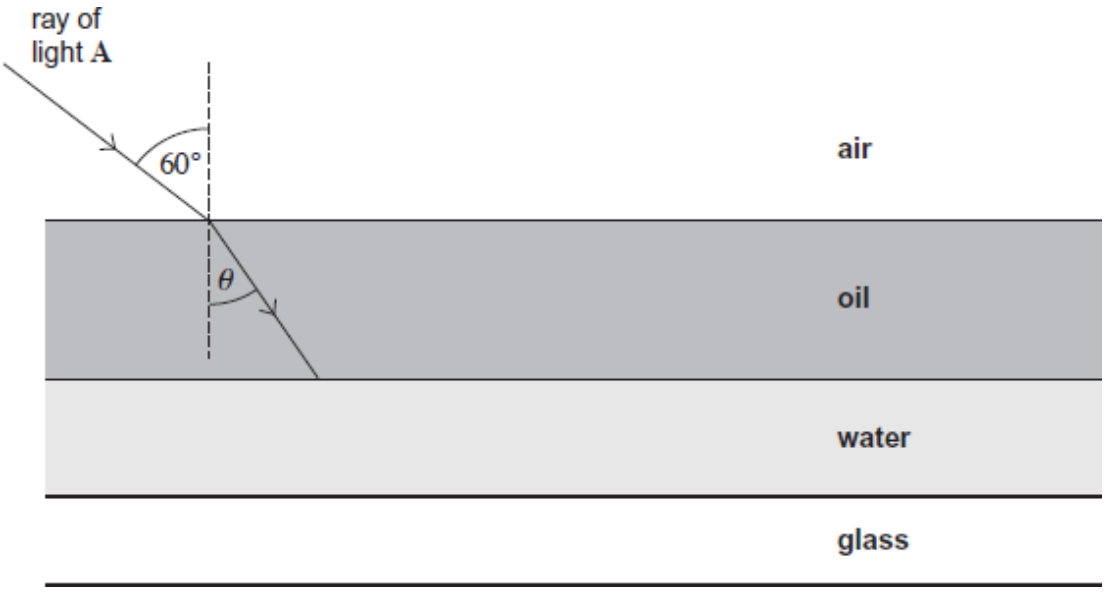
Q9.

Figure 1 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

Figure 1



(a) (i) Calculate the angle of refraction θ in **Figure 1**.

angle _____ degrees

(2)

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

angle _____ degrees

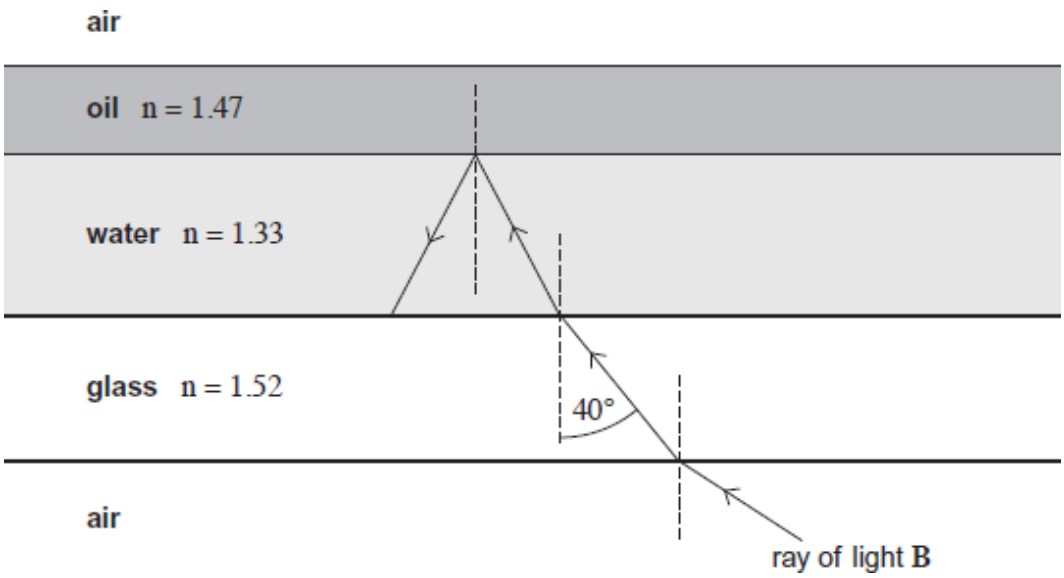
(2)

(iii) On **Figure 1** continue the path of the ray of light **A** immediately after it strikes the boundary between the oil and the water.

(2)

(b) In **Figure 2** 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 2



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.

reason 1 _____

_____

explanation _____

_____

_____

reason 2 _____

_____

explanation _____

_____

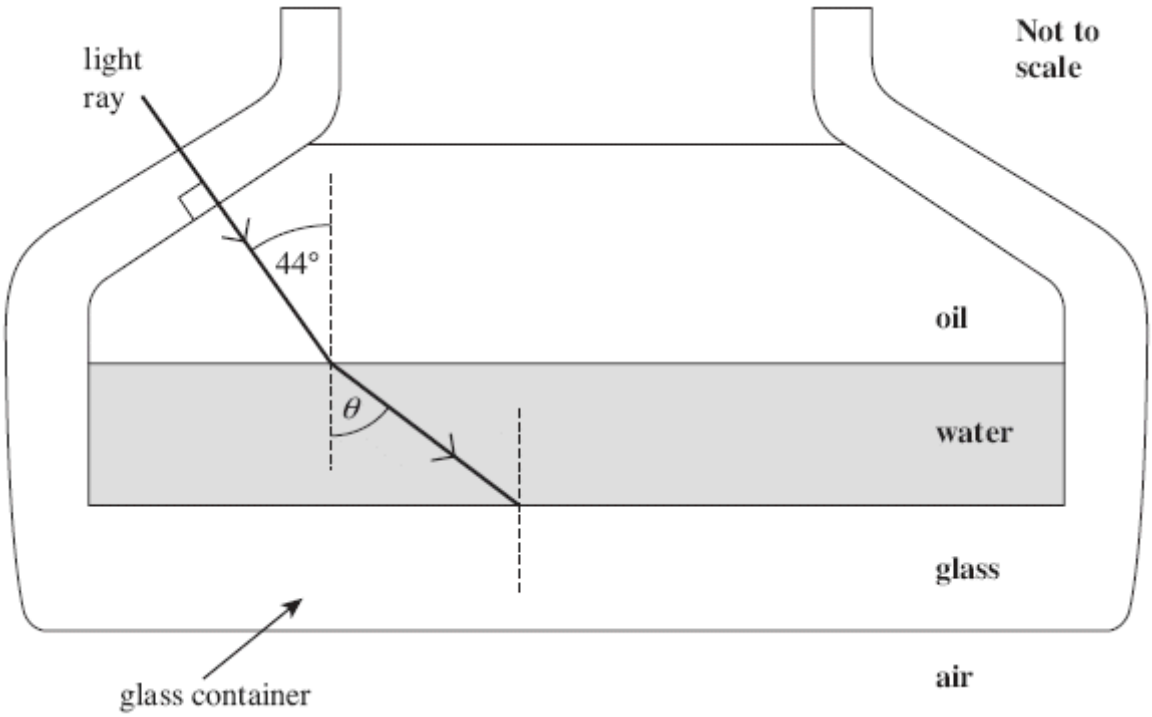
_____

(4)

(Total 10 marks)

Q10.

The figure below 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 the figure above is about 50°.

(2)

(b) The oil and the glass have the same refractive index. On the figure above, 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)

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

_____

_____

_____

(1)

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

answer = _____ degrees

(2)

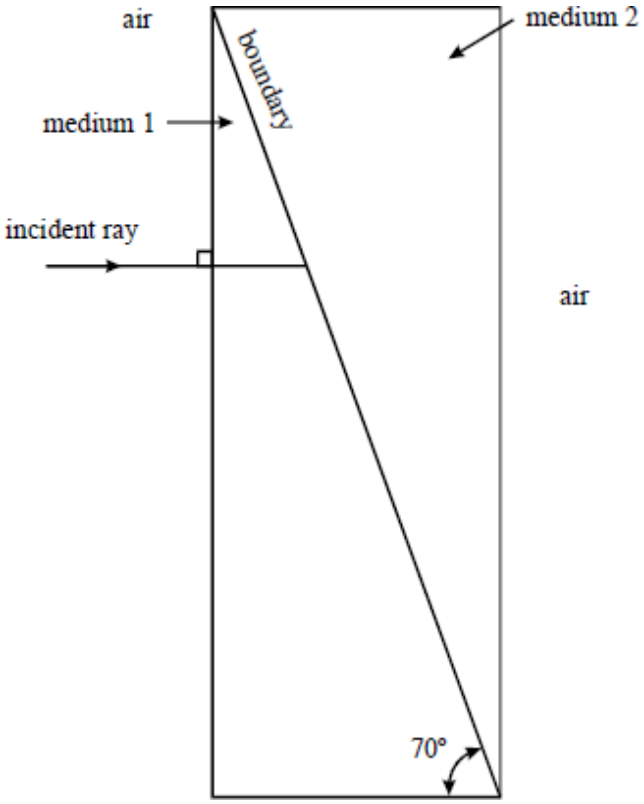
(e) On the figure above, complete the path of the ray after it strikes the boundary between the glass and air.

(2)

(Total 9 marks)

Q11.

Two prisms made from different glass are placed in perfect contact to form a rectangular block surrounded by air as shown. Medium 1 has a smaller refractive index than medium 2.



(a) A ray of light in air is incident normally on medium 1 as shown. At the boundary between medium 1 and medium 2 some light is transmitted and the remainder reflected.

(i) Sketch, without calculation, the path followed by the refracted ray as it enters medium 2 and then emerges into the air.

(ii) Sketch, without calculation, the path followed by the reflected ray showing it emerging from medium 1 into the air.

(4)

(b) The refractive index of medium 1 is 1.40 and that of medium 2 is 1.60.

(i) Give the angle of incidence at the boundary between medium 1 and medium 2.

_____

(ii) Calculate the angle of refraction at this boundary.

_____

_____

_____

_____

_____

(4)

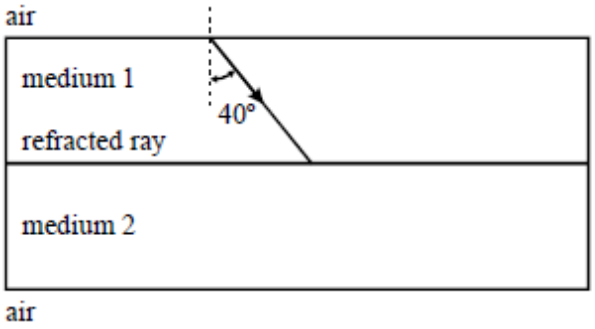
(c) Calculate the critical angle for a ray passing from medium 2 into the air.

(2)

(Total 10 marks)

Q12.

A glass plate surrounded by air is made up of two parallel sided sheets of glass in perfect contact as shown in the figure. Medium 1, the top sheet of glass, has a smaller refractive index than medium 2.



(a) A ray of light in air is incident on the top sheet of glass and is refracted at an angle of 40° as shown in the figure. At the boundary between medium 1 and medium 2 some light is transmitted and the remainder reflected.

On the figure, sketch without calculation, the following:

(i) the path followed by the transmitted ray showing it entering from the air at the top and emerging into the air at the bottom;

(ii) the path followed by the reflected ray showing it emerging from medium 1 into the air.

(4)

(b) The refractive index of medium 1 is 1.35 and that of medium 2 is 1.65.

(i) Calculate the angle of incidence where the ray enters medium 1 from the air.

_____

_____

_____

_____

(ii) Calculate the angle of refraction at the boundary between medium 1 and medium 2.

_____

_____

_____

_____

_____

_____

(5)

(c) Total internal reflection will not occur for any ray incident in medium 1 at the boundary with medium 2.

Explain, without calculation, why this statement is true.

_____

_____

_____

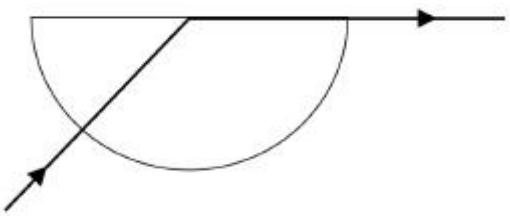
(1)

(Total 10 marks)

Q13.

Figure 1 shows a ray of monochromatic green light incident normally on the curved surface of a semicircular glass block.

Figure 1



(a) The angle of refraction of the ray at the plane surface is 90°.

Refractive index of the glass used = 1.6

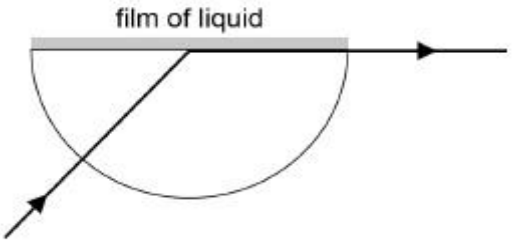
Calculate the angle of incidence of the ray on the flat surface of the block.

angle of incidence = _____ degrees

(1)

(b) A thin film of liquid is placed on the flat surface of the glass block as shown in **Figure 2**.

Figure 2



The angle of incidence is changed so that the angle of refraction of the green light ray at the glass-liquid interface is again 90°. The angle of incidence is now 58°.

Calculate the refractive index of the liquid.

refractive index = _____

(2)

(c) The source of green light is changed for one that contains only red and blue light. For any

material red light has a lower refractive index than green light, and blue light has a higher refractive index than green light. The angle of incidence at the glass-liquid interface remains at 58°.

Describe and explain the paths followed by the red and blue rays immediately after the light is incident on the glass-liquid interface.

_____

_____

_____

_____

_____

_____

_____

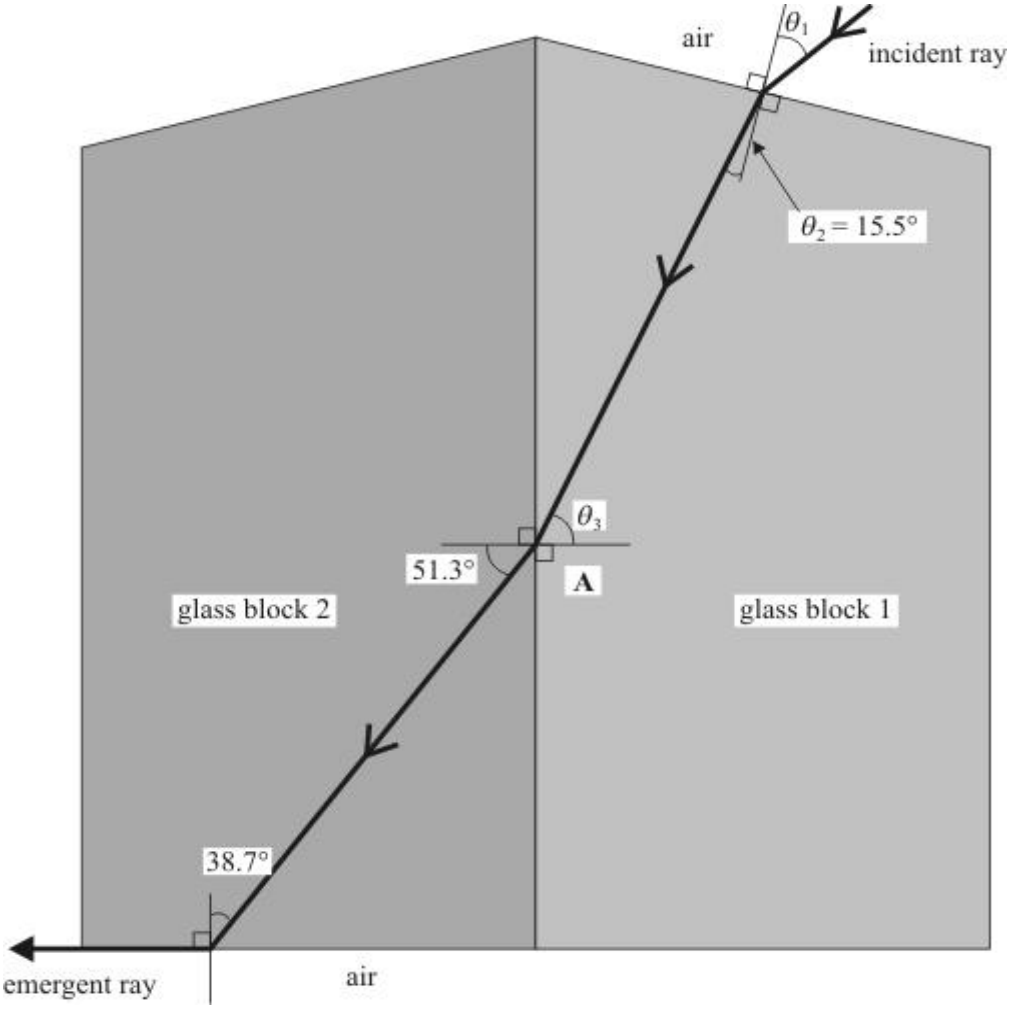
(3)

(Total 6 marks)

Q14.

The figure below shows a ray of light passing from air into glass at the top face of glass block 1 and emerging along the bottom face of glass block 2.

refractive index of the glass in block 1 = 1.45



(a) Calculate

(i) the incident angle θ_1,

_____

_____

_____

(ii) the refractive index of the glass in block 2,

_____

_____

(iii) the angle θ_3 by considering the refraction at point **A**.

(7)

(b) In which of the two blocks of glass will the speed of light be greater?

Explain your reasoning.

(2)

(c) Using a ruler, draw the path of a ray partially reflected at **A** on the figure above. Continue the ray to show it emerging into the air. No calculations are expected.

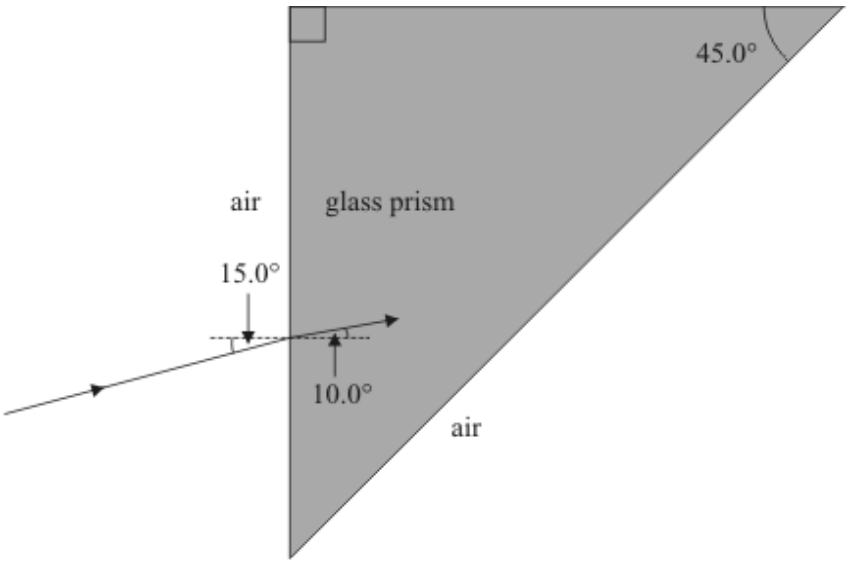
(2)

(Total 11 marks)

Q15.

A ray of light passes from air into a glass prism as shown in **Figure 1**.

Figure 1



(a) Confirm, by calculation, that the refractive index of the glass from which the prism was made is 1.49.

_____

_____

_____

_____

(1)

(b) On **Figure 1**, draw the continuation of the path of the ray of light until it emerges back into the air. Write on **Figure 1** the values of the angles between the ray and any normals you have drawn.

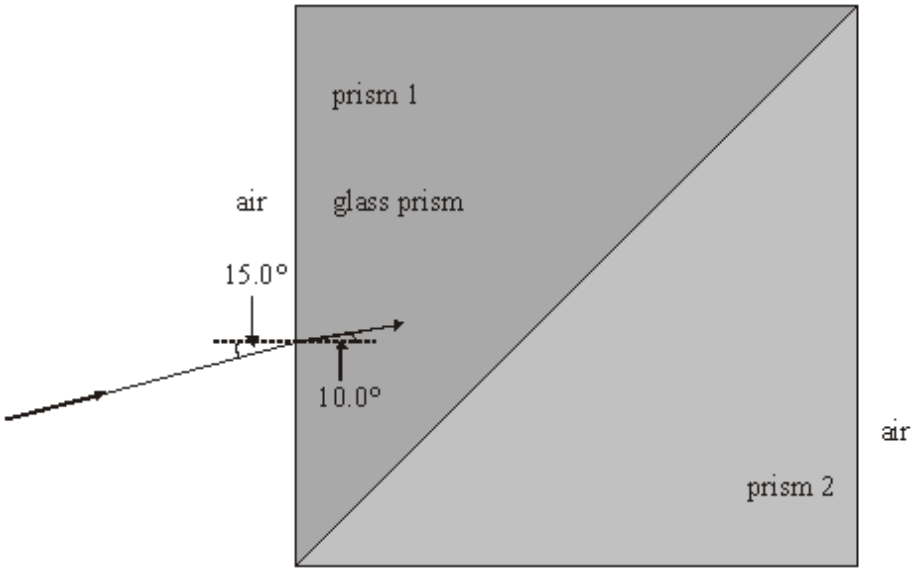
the critical angle from glass to air is less than 45°

(2)

(c) A second prism, prism 2, made from transparent material of refractive index 1.37 is

placed firmly against the original prism, prism 1, to form a cube as shown in **Figure 2**.

Figure 2



(i) The ray strikes the boundary between the prisms. Calculate the angle of refraction of the ray in prism 2.

(ii) Calculate the speed of light in prism 2.

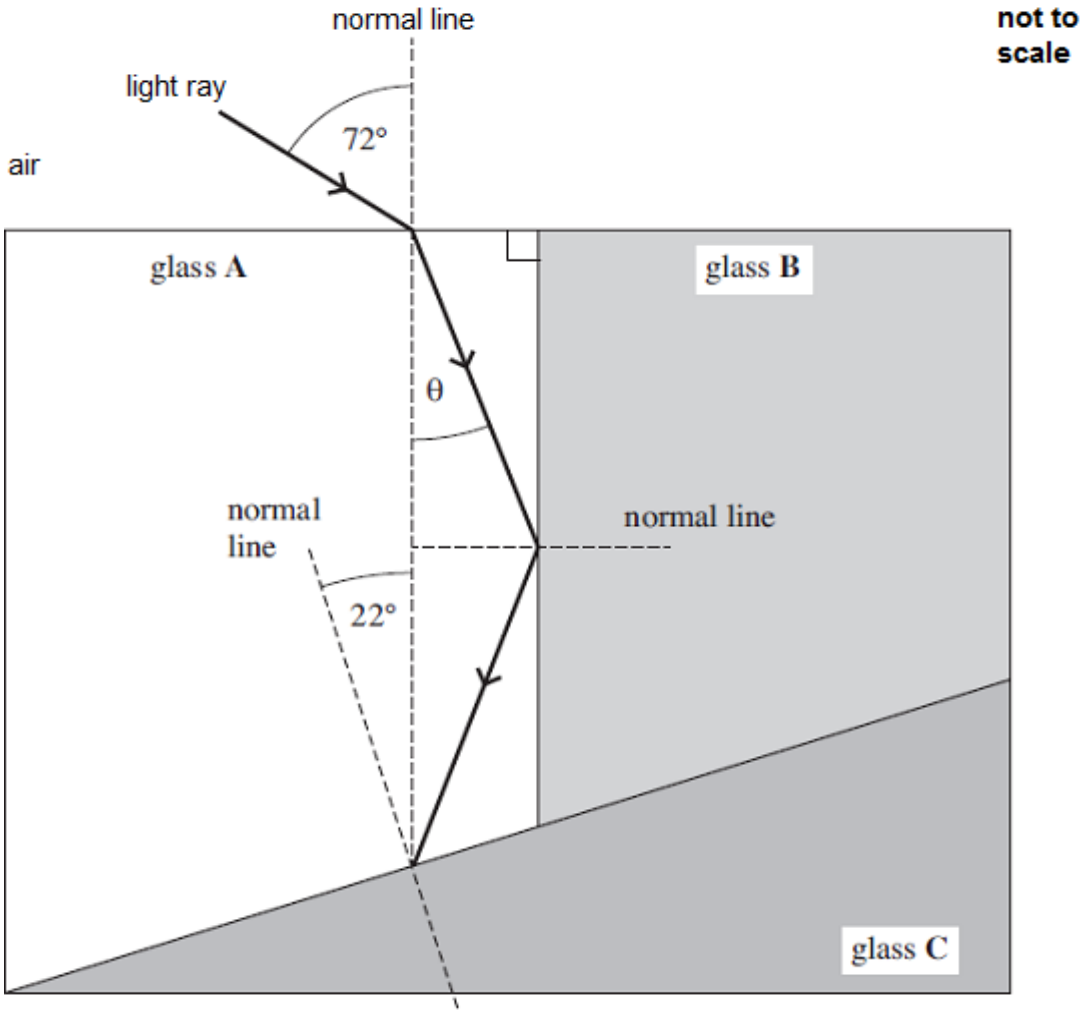
(iii) Draw a path the ray could follow to emerge from prism 2 into the air.

(7)

(Total 10 marks)

Q16.

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 _____

_____

condition 2 _____

_____

(2)

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

refractive index of glass **A** = 1.80

speed of light _____ ms^{-1}

(2)

(c) Show that angle is about 30°.

(2)

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

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

critical angle _____ degrees

(2)

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

_____

_____

_____

(2)

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

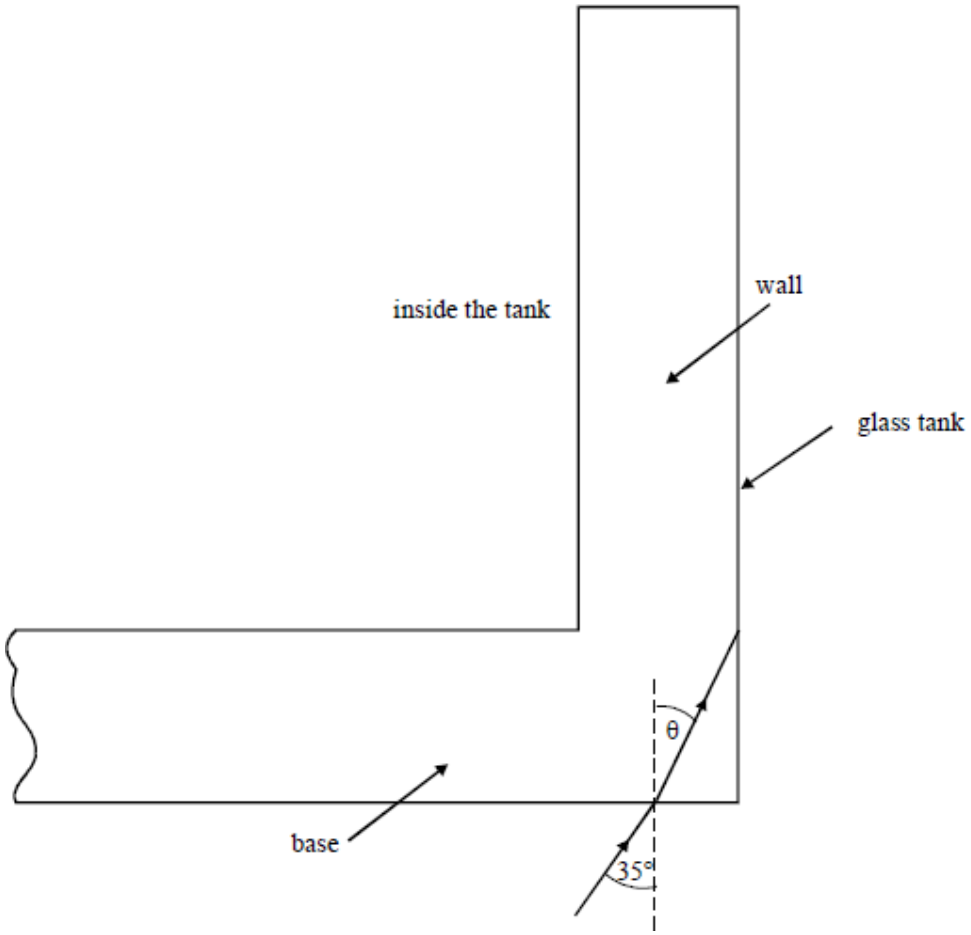
(1)

(Total 11 marks)

Q17.

The diagram shows a cross-section of one wall and part of the base of an empty fish tank,

viewed from the side. It is made from glass of refractive index 1.5. A ray of light travelling in air is incident on the base at an angle of 35° as shown.



(a) Calculate the angle θ.

(2)

(b) (i) Calculate the critical angle for the glass-air interface.

(ii) Hence, draw on the diagram the continuation of the path of the ray through the glass wall and out into the air. Mark in the values of all angles of incidence, refraction and reflection.

(6)

(Total 8 marks)

Q18.

Figure 1 shows a cross-section through a rectangular light-emitting diode (LED). When current passes through the LED, light is emitted from the semiconductor material at P and passes through the transparent material and into the air at Q.

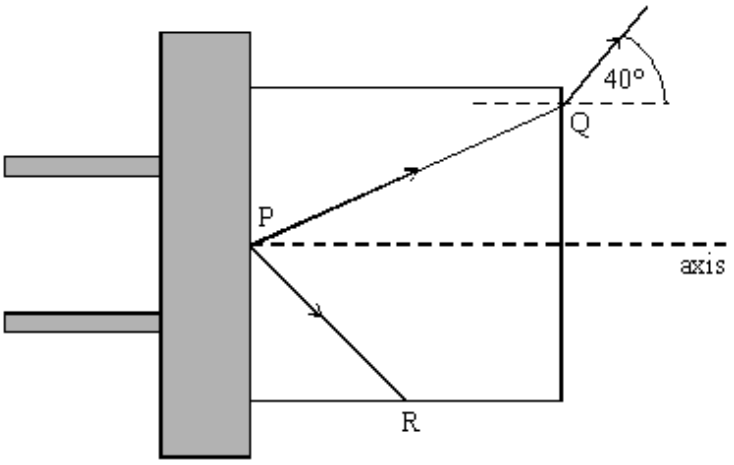


Figure 1

(a) (i) The refractive index of the transparent material of the LED is 1.5. Calculate the critical angle of this material when the LED is in air.

_____

_____

_____

(ii) **Figure 1** shows a light ray PQ incident on the surface at Q. Calculate the angle of incidence of this light ray at Q if the angle of refraction is 40°.

_____

_____

_____

_____

(iii) **Figure 1** also shows a second light ray PR incident at R at an angle of incidence of 45°. Use **Figure 1** to explain why this light ray cannot escape into the air.

_____

_____

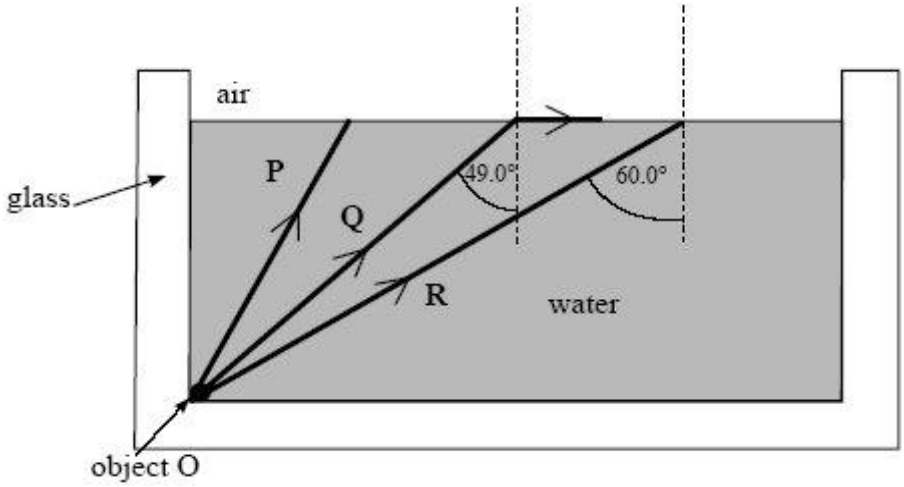
_____

(7)

(Total 7 marks)

Q19.

The diagram below 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.



(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)

(ii) Draw on the diagram above the path of light ray **P** from the water-air surface.

(3)

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

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

_____

_____

(2)

(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.

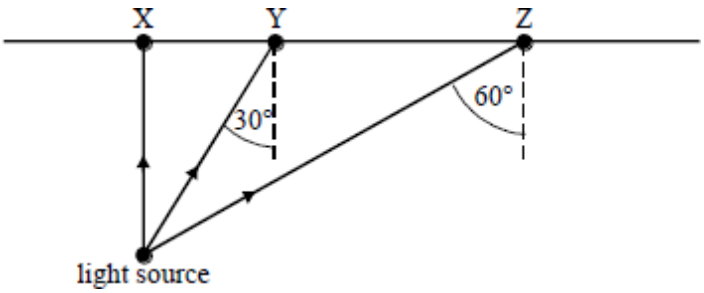
the refractive index of the glass = 1.50

(4)
(Total 10 marks)

Q20.

A small intense light source is 1.5 m below the surface of the water in a large swimming pool,

as shown in the diagram.



(a) Complete the paths of rays from the light source which strike the water surface at X, Y and Z.

(b) Calculate the diameter of the disc through which light emerges from the surface of the water.

speed of light in water = 2.25×10^8 m s^{-1}
speed of light in air = 3.00×10^8 m s^{-1}

_____

_____

_____

_____

_____

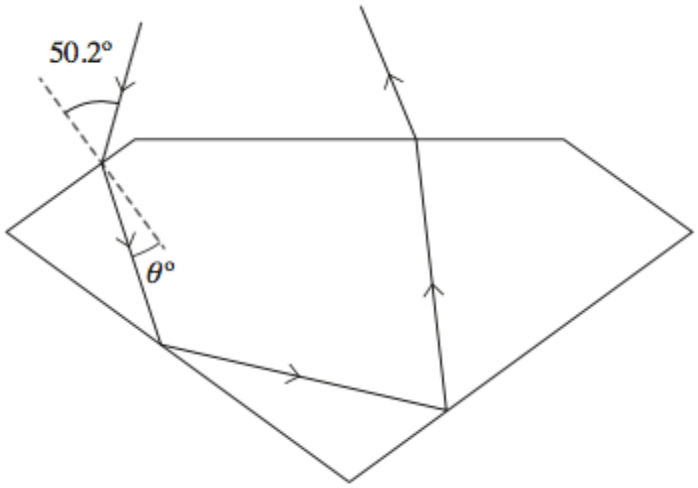
_____

(Total 7 marks)

Q21.

Diamond jewels sparkle because light that enters the diamond at different incident angles is reflected back to an observer. **Figure 1** shows the path of one of these incident rays through a diamond.

Figure 1



(a) (i) Calculate the critical angle for diamond.

Refractive index of diamond = 2.42

critical angle = _____ degree

(2)

(ii) The ray shown in **Figure 1** enters at an angle of incidence of 50.2°.
Calculate the angle of refraction θ.

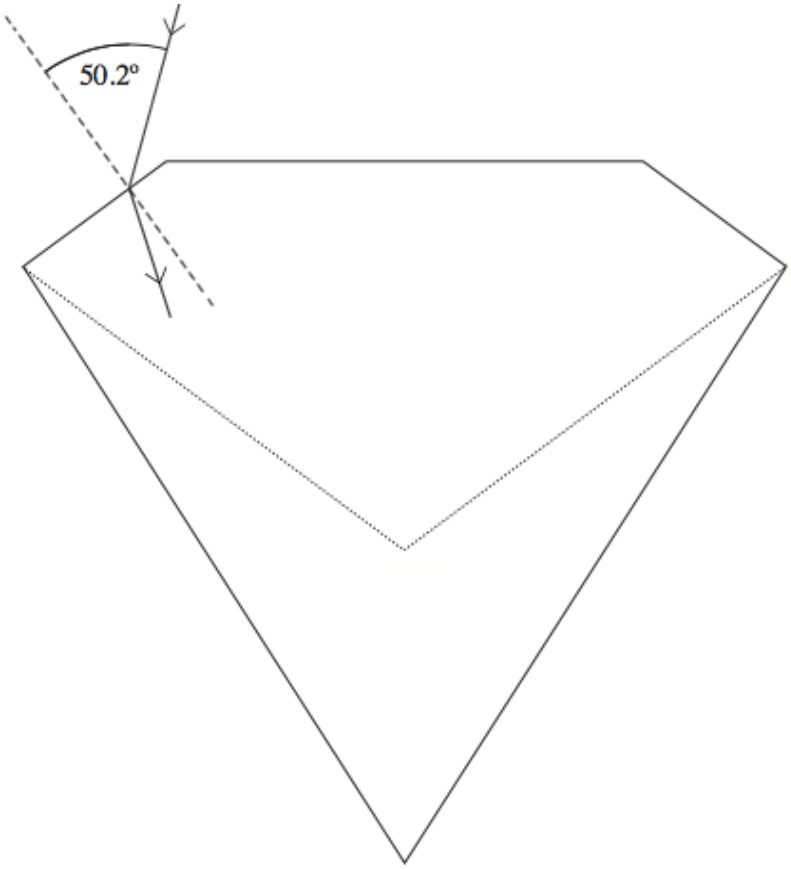
θ = _____ degree

(2)

(iii) The angles of a diamond are chosen to maximise the amount of light reflected.
Figure 2 shows a diamond with different angles to that of a normally shaped

diamond. The dotted lines show the normal shape of a diamond.

Figure 2



Draw on **Figure 2** the path of the ray until it leaves the diamond.

(2)

(iv) Moissanite is a transparent material with a refractive index of 2.67.

Discuss whether this material, if made to the diamond shape shown in **Figure 1**, would reflect light back more or less than diamond.

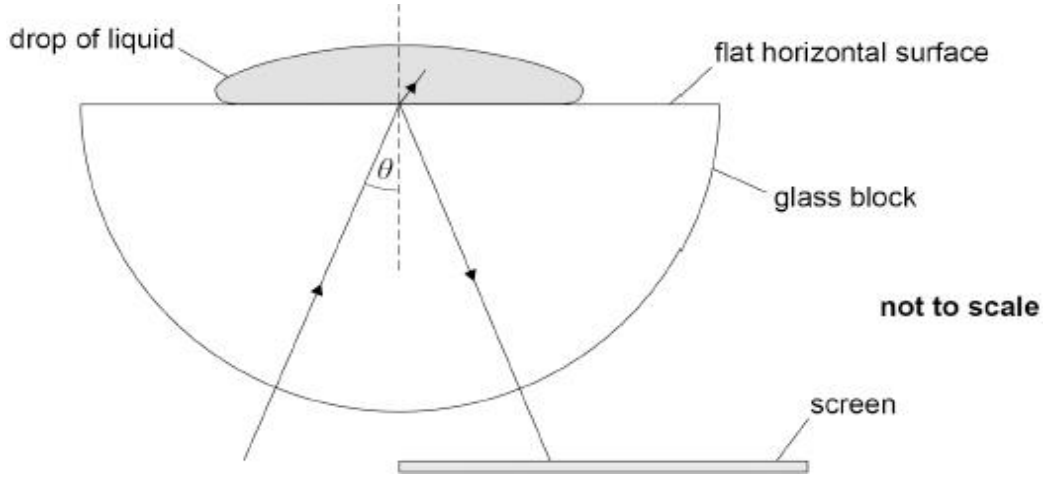
(2)

(Total 8 marks)

Q22.

Figure 1 shows a type of refractometer.
A semi-circular glass block is arranged so that its semi-circular faces are vertical. A drop of liquid is placed at the centre of the flat horizontal surface of the block.

Figure 1



Light enters the block through the curved surface and is incident on the midpoint of the horizontal surface at angle of incidence θ.
Light that reflects at the glass–liquid boundary is detected on a screen that lies parallel to the horizontal surface.

(a) Explain why the light ray in **Figure 1** does not change direction as it enters the block.

_____

_____

(1)

(b) The refractometer is calibrated using a drop of liquid.
When θ = 15°, light is partially refracted at the glass–liquid boundary.

Calculate the angle of refraction at this boundary.

refractive index of glass block = 1.84
refractive index of liquid = 1.33

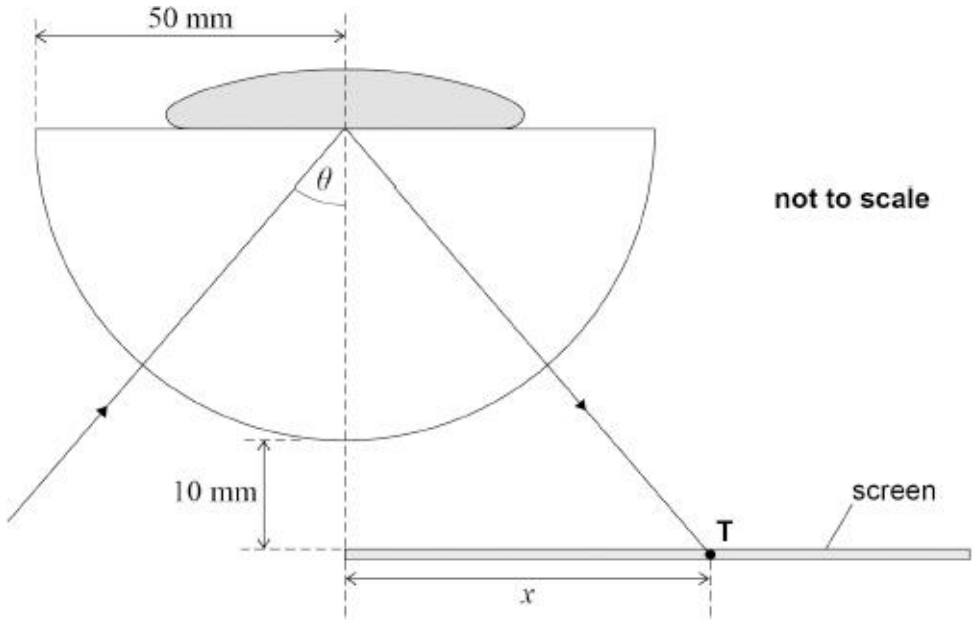
angle of refraction = _____ °

(2)

The refractometer is used to determine the critical angle θ_c at the glass–liquid boundary.

Figure 2 shows dimensions of the arrangement.

Figure 2



The intensity of the light ray on the screen is observed as θ is increased from 15°. When $\theta = \theta_c$ the intensity of the light ray is seen to increase sharply at a point **T** on the screen.

The distance between the left-hand edge of the screen and **T** is x.

(c) Explain why the intensity of the light ray on the screen increases at **T**.

_____

_____

_____

_____

(2)

(d) The liquid is replaced with a drop of sugar solution.
The refractive index of the sugar solution is greater than 1.33

Deduce how this change affects the position at which the sharp increase in intensity is observed on the screen.

_____

_____

_____

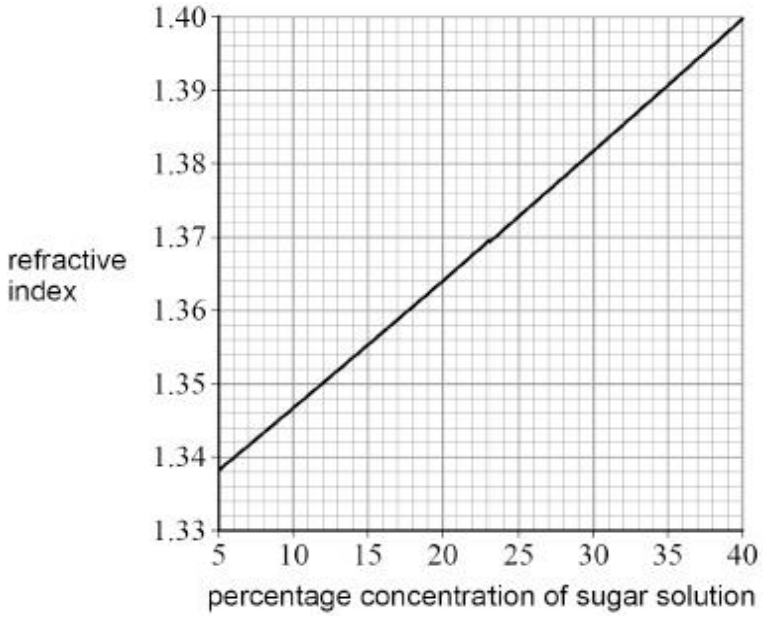
_____

(2)

(e) The refractometer in **Figure 2** is used to determine the concentration of a sugar solution.

Figure 3 shows the variation of refractive index with concentration of sugar solution.

Figure 3



For a drop of a particular sugar solution, x = 69 mm.

Determine the percentage concentration of the sugar solution.

refractive index of glass block = 1.84

percentage concentration = _____

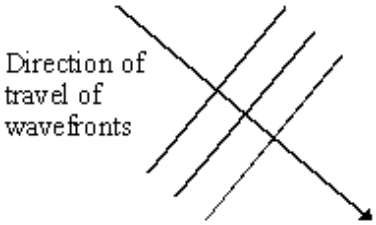
(3)

(Total 10 marks)

Q23.

The diagram below shows three wavefronts of light directed towards a glass block in the air. The direction of travel of these wavefronts is also shown.

Complete the diagram to show the position of these three wavefronts after partial reflection and refraction at the surface of the glass block.





(Total 3 marks)

Q24.

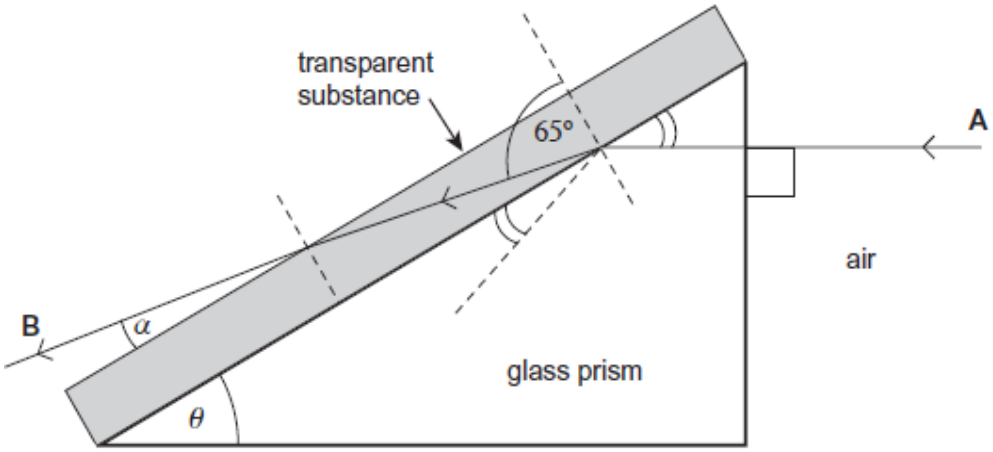
(a) Tick (✓) the appropriate boxes in the table to indicate how the wavelength, frequency and speed of light are affected when a ray of light travels from air into glass.

	Wavelength	Frequency	Speed
increases			
stays the same			
decreases			

(2)

(b) **Figure 1** shows a right-angled glass prism in contact with a transparent substance on one of the faces. One of the other angles of the prism is θ.

Figure 1



refractive index of glass prism = 1.70

refractive index of transparent substance = 1.09

angles are not shown to scale

(i) A ray **A** enters perpendicularly to one face of the prism. It is partially refracted and partially reflected at the interface between the glass and the transparent substance. The angle of refraction is 65.0°. The ray eventually leaves at an angle α to the surface of the transparent substance.

Determine the angle α.

angle α = _____ degree

(2)

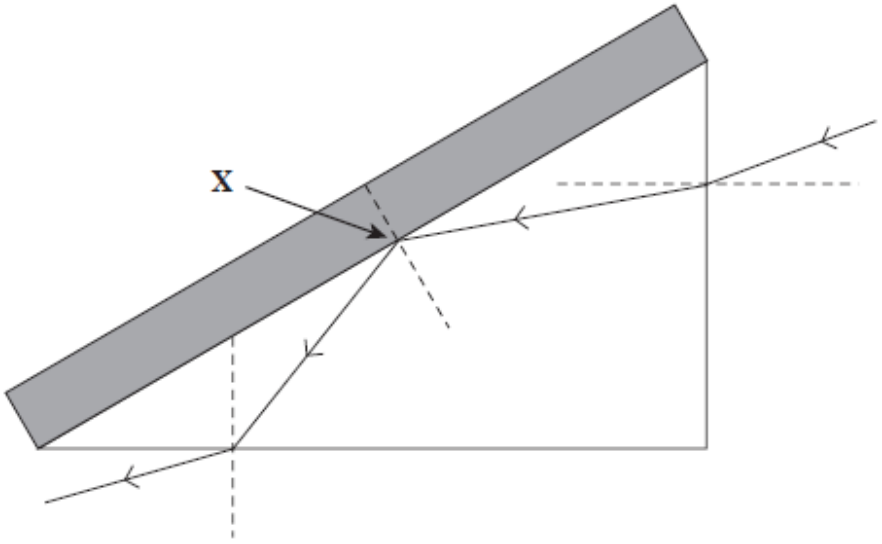
(ii) Determine the angle θ in **Figure 1**.

angle θ = _____ degree

(2)

(c) **Figure 2** shows another ray entering the prism.

Figure 2



(i) Identify the effect that takes place at **X** in **Figure 2**.

_____

(1)

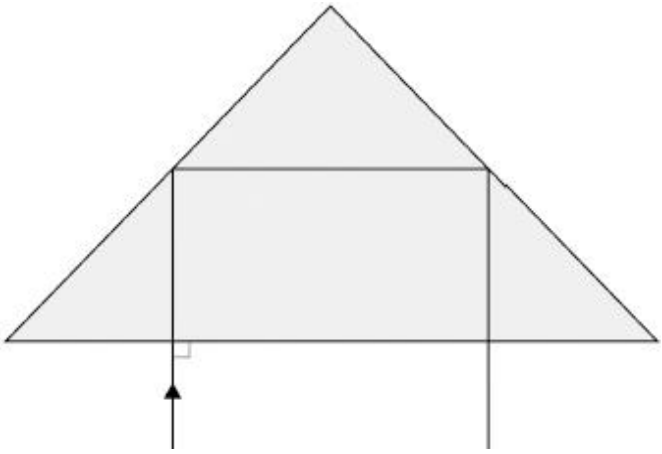
(Total 7 marks)

Q25.

Porro prisms are used in binoculars to reverse the path of the light. The prism is in the shape of a right-angled isosceles triangle.

Figure 1 shows a ray of light, at normal incidence on the longest side, passing through a glass Porro prism.

Figure 1



The critical angle for light in the prism is 41.5°.

(a) Show that the glass used to make the prism has a refractive index of about 1.5

(1)

(b) Explain why the ray emerges parallel to the incident ray.

_____

_____

_____

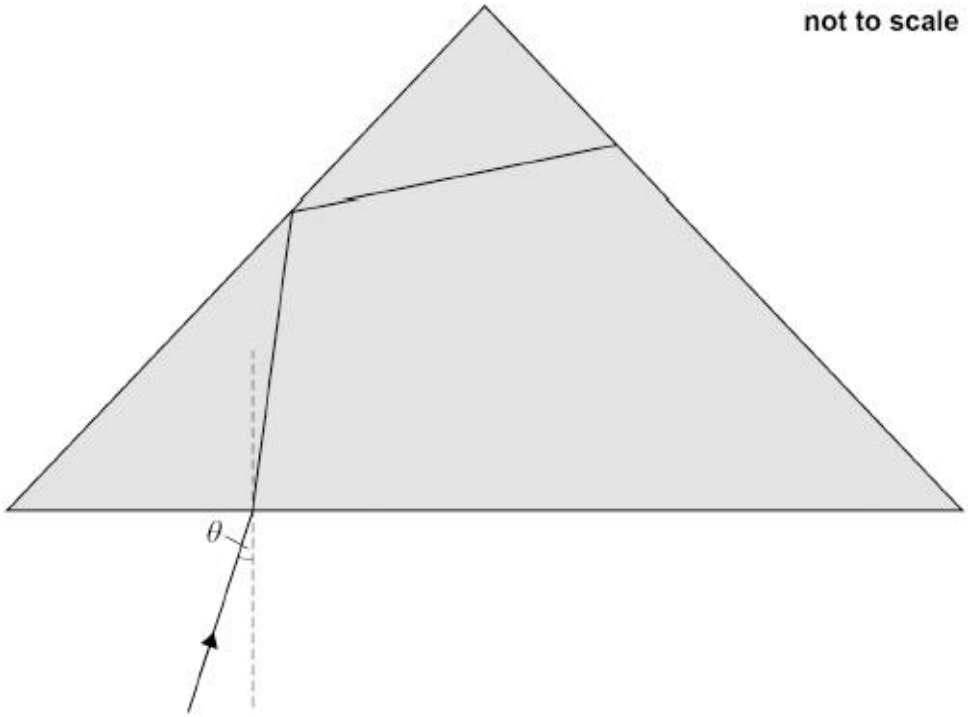
_____

_____

(2)

Figure 2 shows a ray of light entering the prism at an angle of incidence θ and reflecting off one of the shorter sides.

Figure 2



θ is the largest angle of incidence for which all of the light leaves through the longest side.

(c) Draw on **Figure 2** the path of the ray of light as it continues inside the prism and emerges from the longest side.

(3)

(d) When the angle of incidence is greater than θ, some of the light escapes the prism through one of the shorter sides.
Assume that the refractive index is 1.5 and the critical angle is 41.5°.

Show that θ is about 5°.
You can use **Figure 2** in your answer.

(4)

(e) A manufacturer wants to make a prism with a larger value of θ.

Two alternative changes to the original design of the prism are suggested:

1. use a prism of the original glass in the shape of an equilateral triangle, as shown in **Figure 3**

2. use a prism of the original shape made from glass with a smaller refractive index, as shown in **Figure 4**.

Figure 3

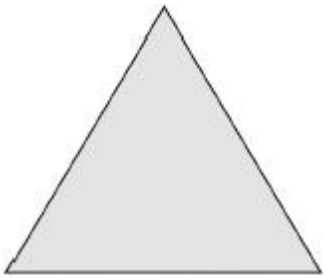
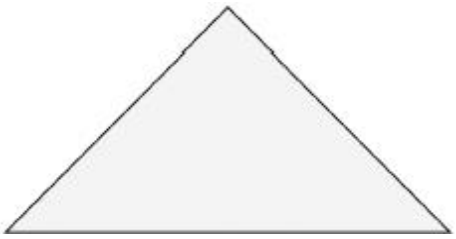


Figure 4



Discuss whether either of the two suggestions would work.

1 _____

_____

_____

_____

_____

_____

_____

2 _____

_____

_____

_____

_____

_____

_____

(4)

(Total 14 marks)