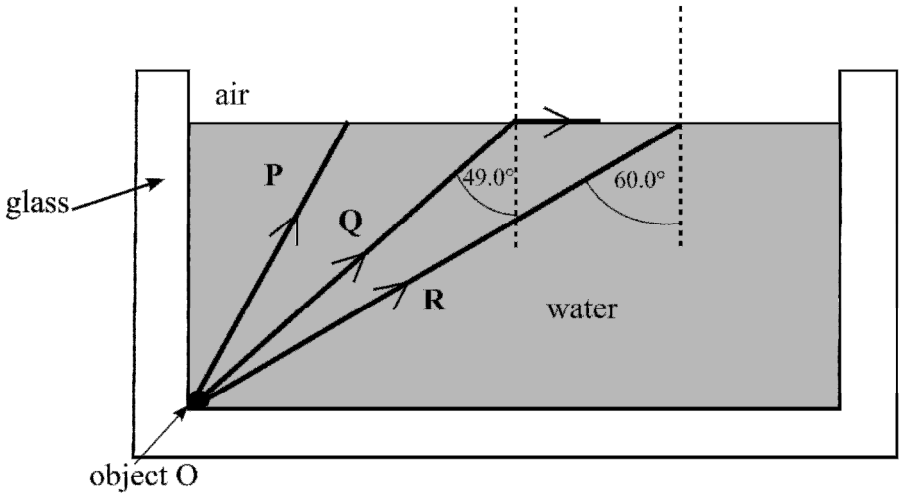
Refraction Past Paper Questions
Jan 2002 to Jan 2009

NOTE : Jan 2009 onwards are new spec'

6 **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

Q6 Jan 2009



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)

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

(3 marks)

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

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

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(2 marks)

6 (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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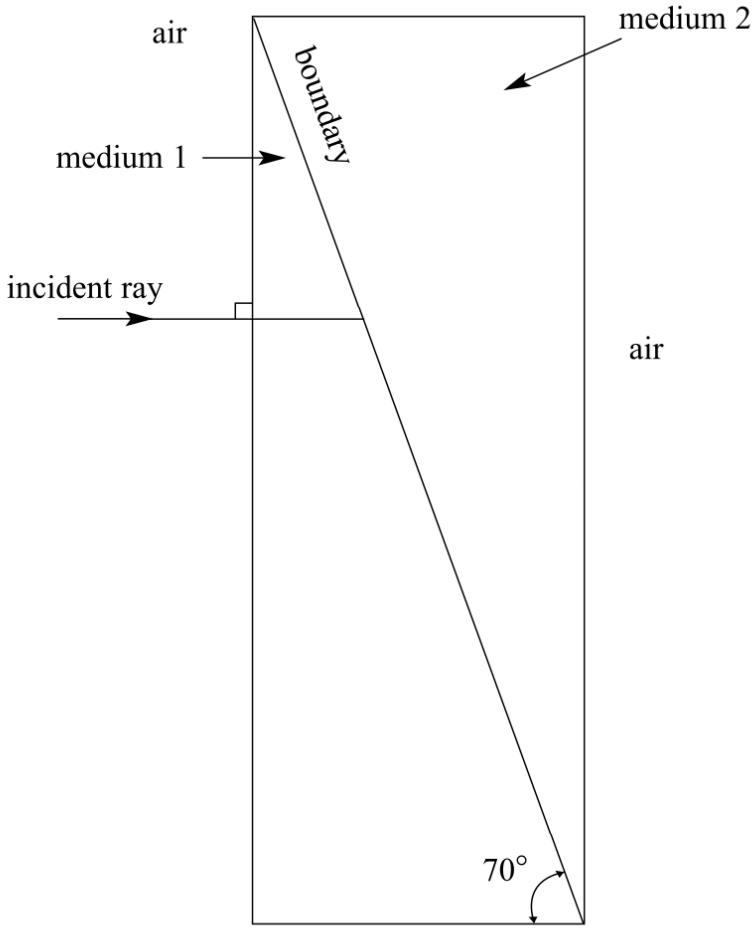
(4 marks)

4 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.

Q4 Jan 2002



(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 marks)

(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.

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

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(4 marks)

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

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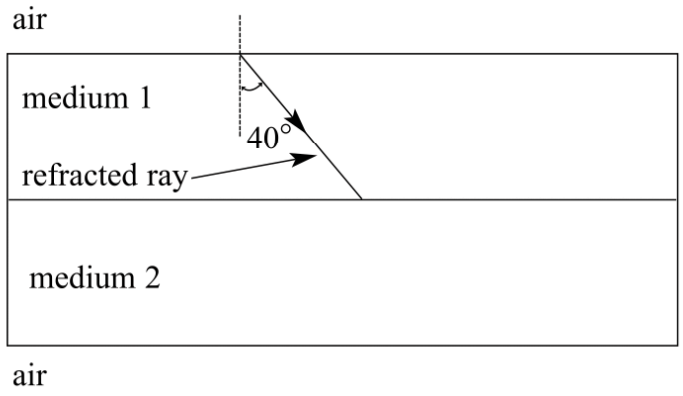
(2 marks)

3 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.

Q3 Jun 2002



(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 marks)

(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.

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

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(5 marks)

(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.

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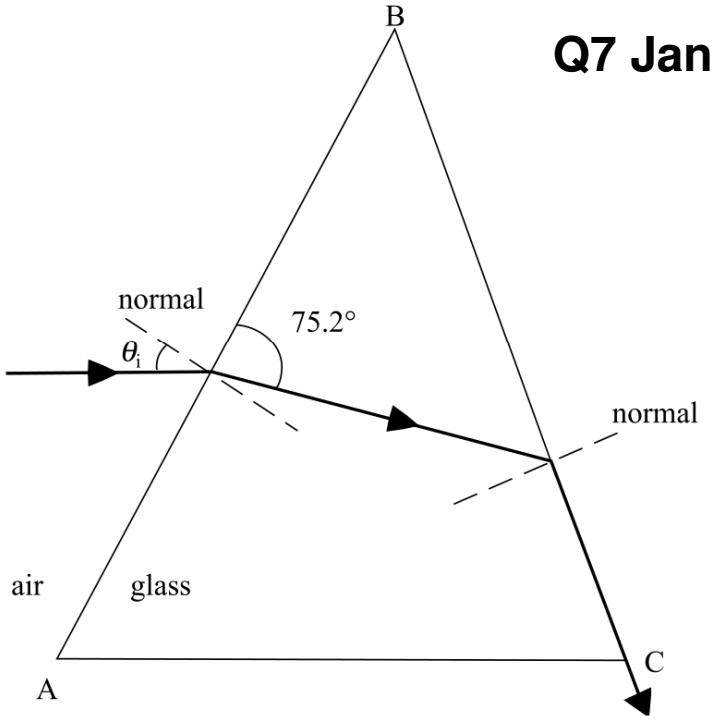
(1 mark)

7 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.

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(3 marks)

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

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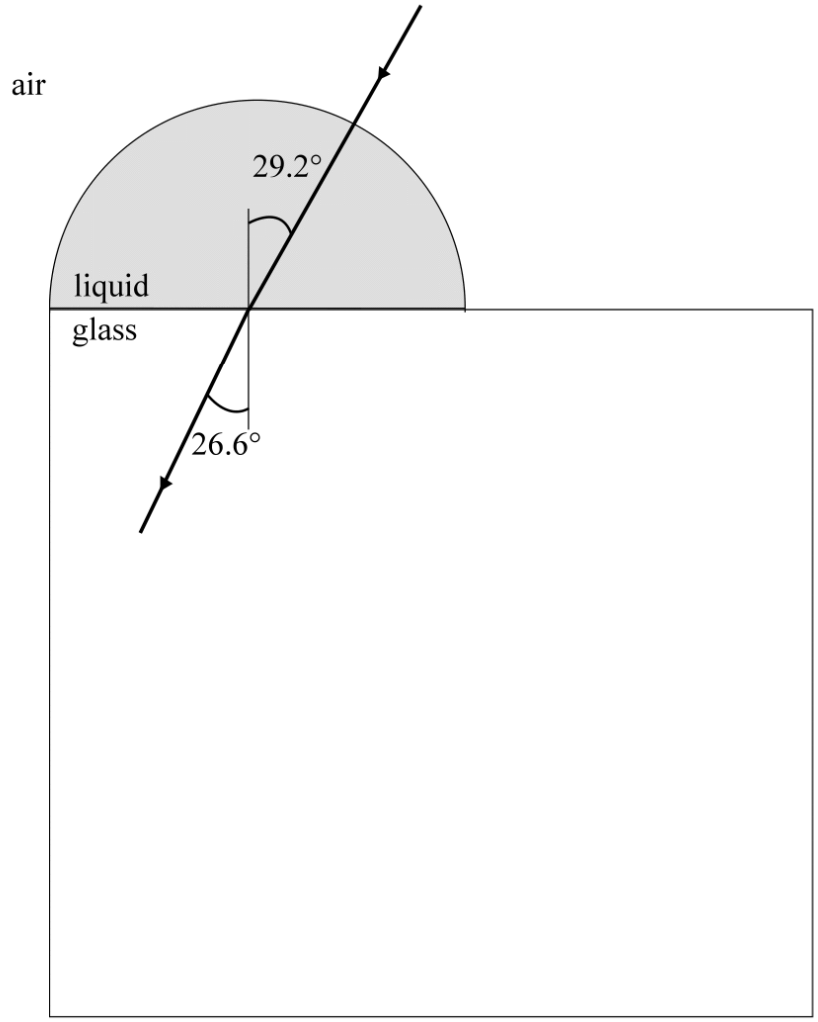
(2 marks)

(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 marks)*

5 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

Q5 Jun 2003



(a) Calculate the speed of light

(i) in the glass,

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(ii) in the liquid droplet.

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(3 marks)

(b) Calculate the refractive index of the liquid.

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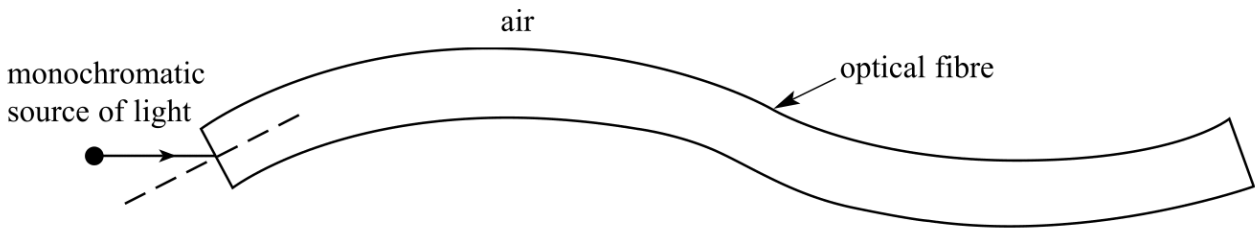
(2 marks)

(c) On the diagram opposite, complete the path of the ray showing it emerge from the glass cube into the air.
No further calculations are required. *(2 marks)*

3 The diagram shows a ray of monochromatic light, in the plane of the paper, incident on the end face of an optical fibre.

Q3 Jan 2004



(a) (i) Draw on the diagram the complete path followed by the incident ray, showing it entering into the fibre and emerging from the fibre at the far end.

(ii) State any changes that occur in the speed of the ray as it follows this path from the source. Calculations are not required.

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(4 marks)

(b) (i) Calculate the critical angle for the optical fibre at the air boundary.

refractive index of the optical fibre glass = 1.57

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(ii) The optical fibre is now surrounded by cladding of refractive index 1.47.
Calculate the critical angle at the core-cladding boundary.

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(iii) State **one** advantage of cladding an optical fibre.

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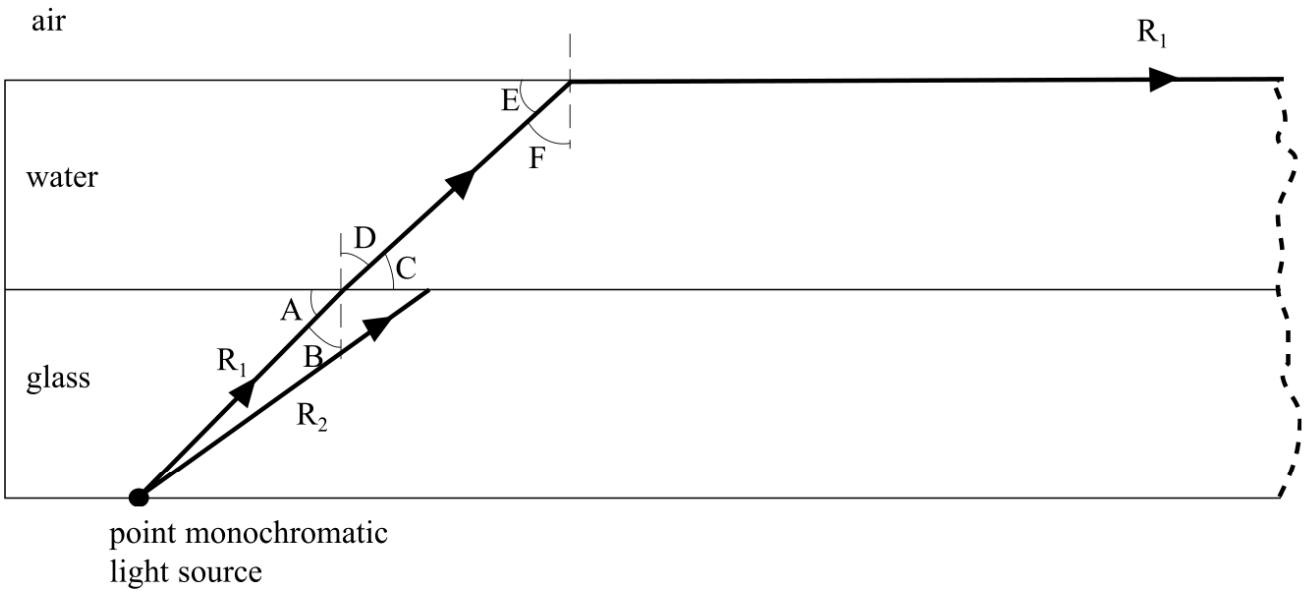
(6 marks)

4 The diagram shows a cross-sectional view of the base of a glass tank containing water. A point monochromatic light source is in contact with the base and ray, R_1, from the source has been drawn up to the point where it emerges along the surface of the water.

Q4 Jun 2004



(a) (i) Which angle, A to F, is a critical angle?

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(ii) Explain how the path of R_1 demonstrates that the refractive index of glass is greater than the refractive index of water.

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(2 marks)

(b) Using the following information

A = 47.1°
B = 42.9°
C = E = 41.2°
D = F = 48.8°

calculate

(i) the refractive index of water,

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(ii) the ratio, $\frac{\text{speed of light in water}}{\text{speed of light in glass}}$.

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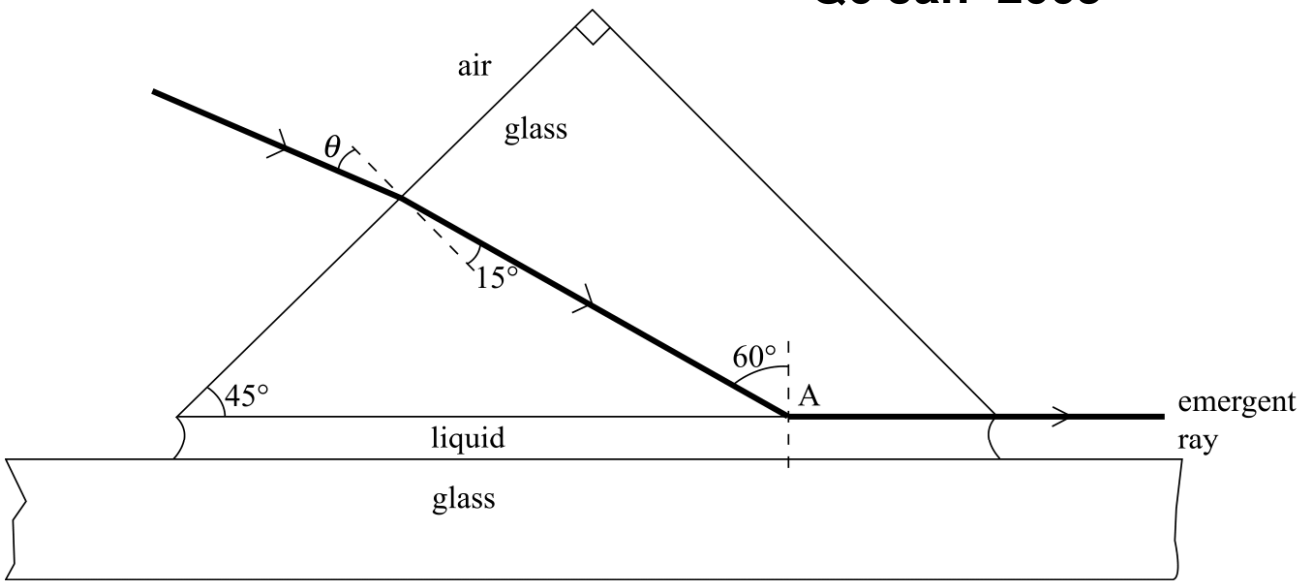
(5 marks)

(c) Ray R_2 emerges from the source a few degrees away from ray R_1 as shown.
Draw on the diagram opposite the continuation of ray R_2.
Where possible show the ray being refracted. *(2 marks)*

6 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

Q6 Jan 2005



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

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(2 marks)

(b) Determine

(i) the angle of incidence, θ,

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(ii) the refractive index of the liquid.

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(5 marks)

(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 marks)*

4 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 **Figure 3**.

critical angle at the glass-air boundary = 45°

Q4 Jun 2005

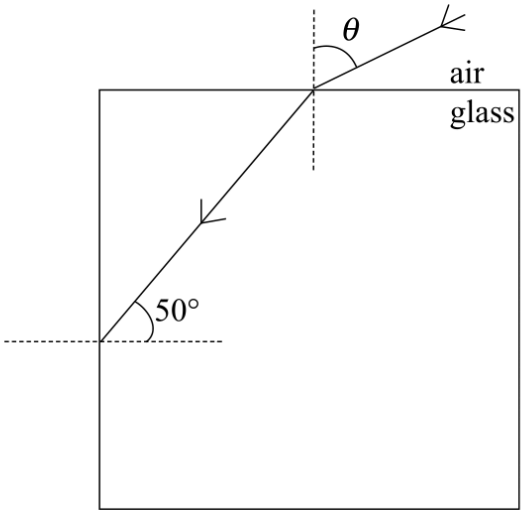

Figure 3

(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 marks)*

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

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(2 marks)

(c) Calculate the angle of incidence, θ.

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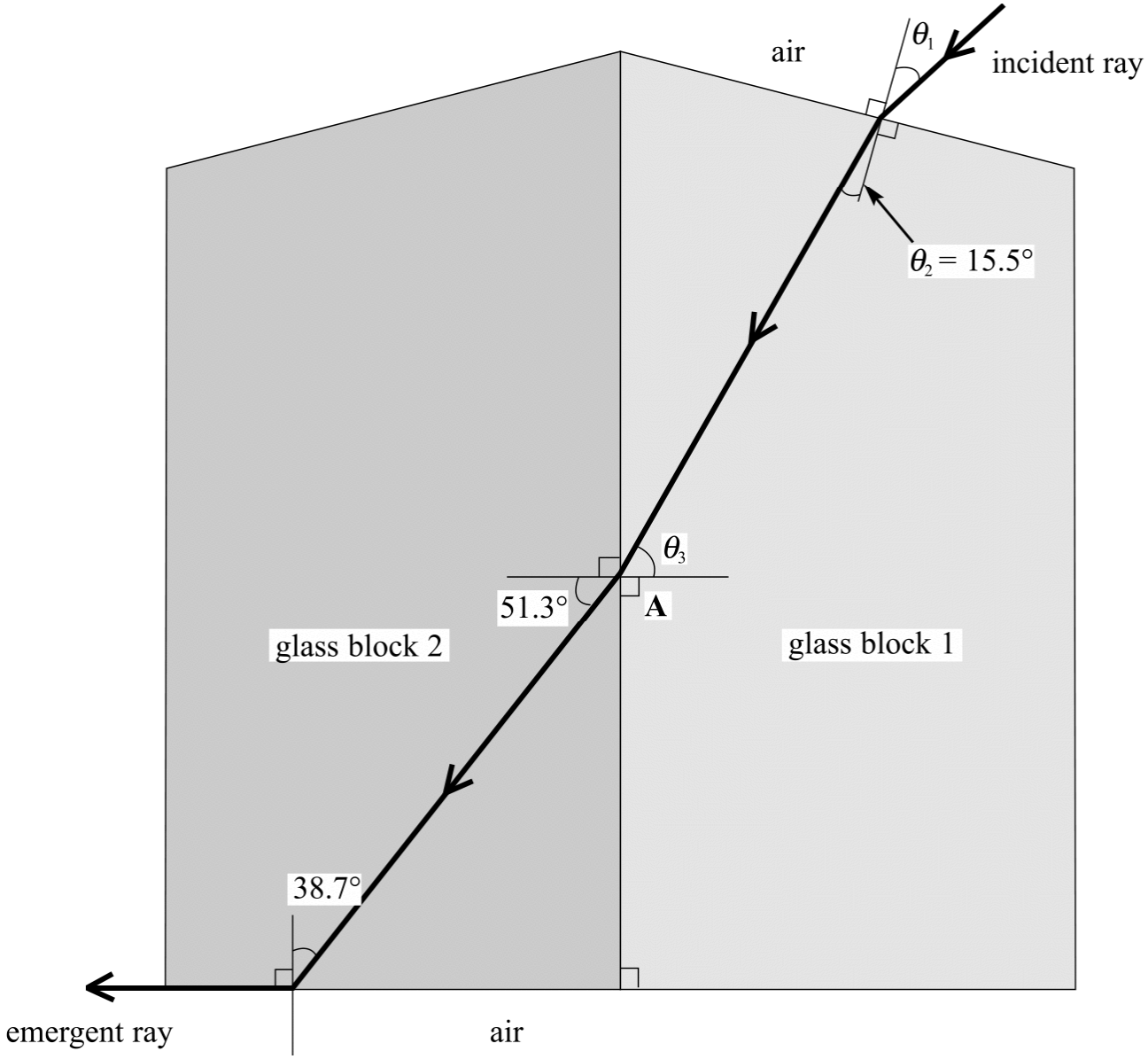
(3 marks)

5 **Figure 1** 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

Q5 Jan 2006

Figure 1



(a) Calculate

(i) the incident angle θ_1,

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

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

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(7 marks)

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

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Explain your reasoning.

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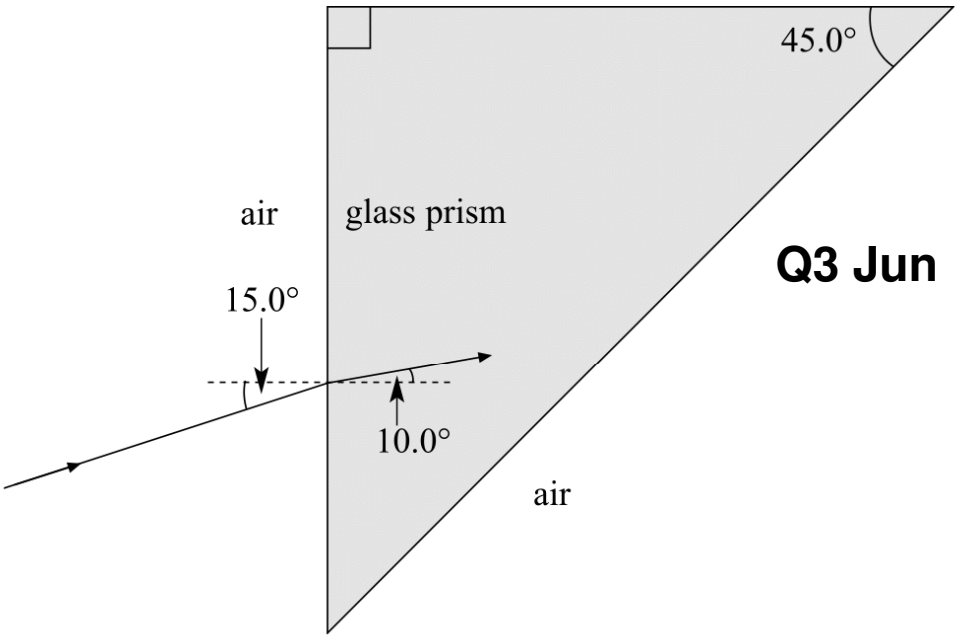
(2 marks)

(c) Using a ruler, draw the path of a ray partially reflected at **A** on **Figure 1**. Continue the ray to show it emerging into the air. No calculations are expected.

(2 marks)

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

Figure 1



Q3 Jun 2006

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

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(1 mark)

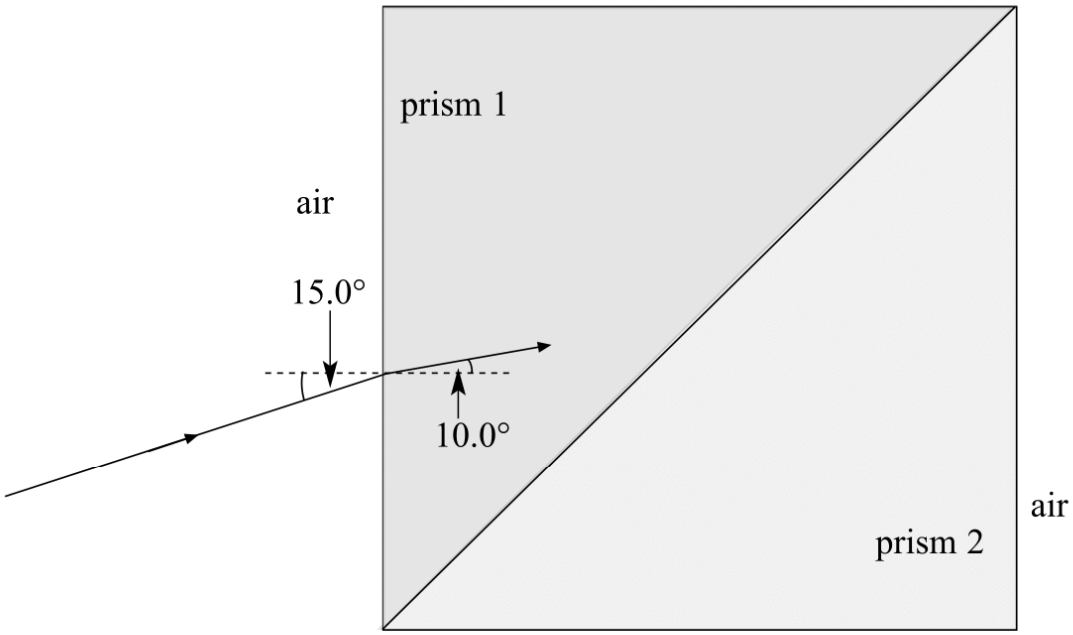
(b) On **Figure 1**, draw the continuation of the path of the ray of light until it emerges back into the air. Write on **Figure 1** the values of the angles between the ray and any normals you have drawn.

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

(2 marks)

(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.

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

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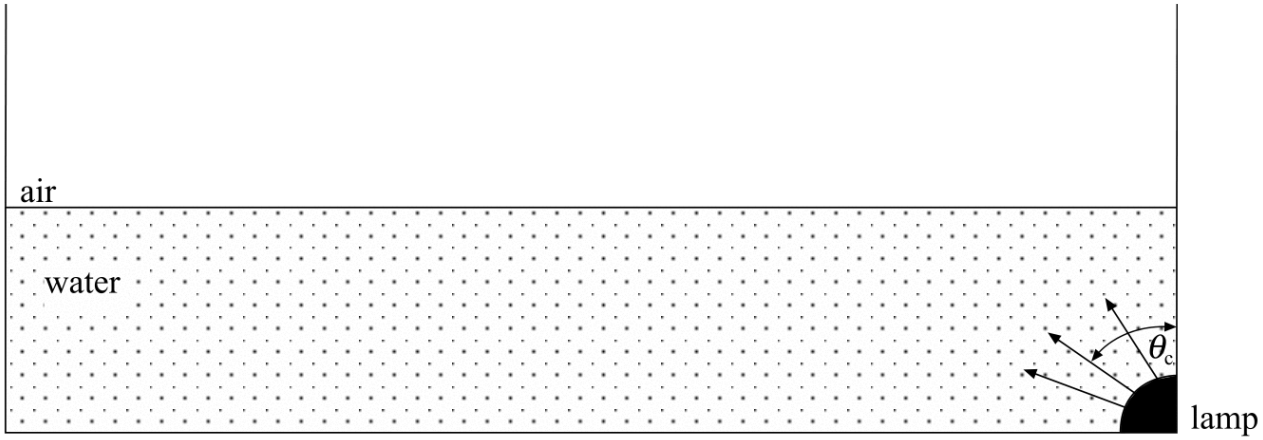
(iii) Draw a path the ray could follow to emerge from prism 2 into the air.

(7 marks)

6 **Figure 1** shows a pool of water of depth 1.0 m which has a lamp set into the bottom corner as shown. The angle θ_c marked on the diagram is the critical angle for a water-air boundary.

refractive index of water = 1.33

Figure 1 **Q6 Jan 2007**



(a) Calculate

(i) the speed of light in water,

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(ii) the critical angle θ_c.

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(3 marks)

(b) On **Figure 1** draw the continuation of the paths taken by the three rays shown. No further calculations are required. *(3 marks)*

(c) A layer of oil is poured over the surface of the water. Without calculation explain how the critical angle for the water-oil boundary differs from the critical angle, θ_c, for the water-air boundary.

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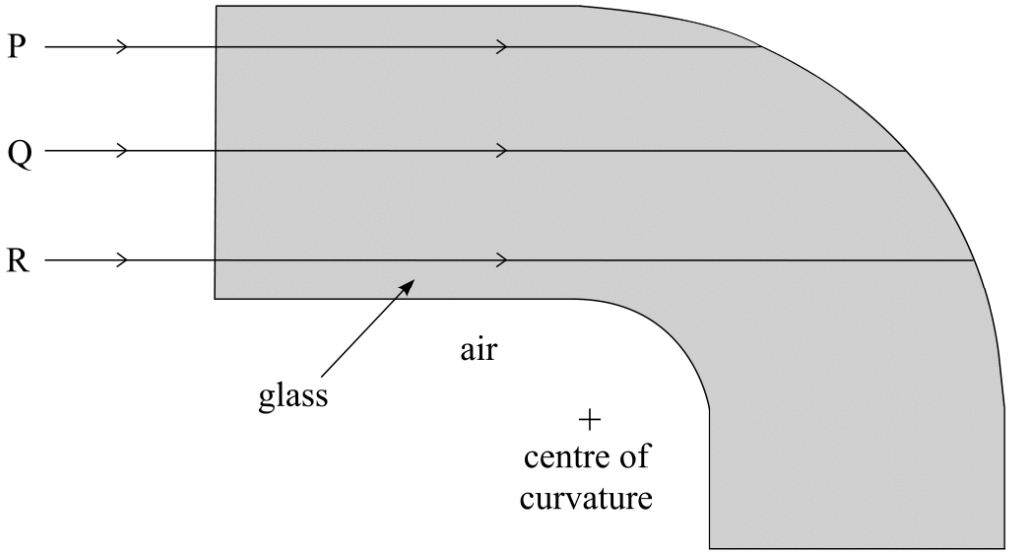
(2 marks)

4 **Figure 1** shows a glass optical fibre bent through 90° and surrounded by air. Three light rays PQR, initially travelling parallel to the axis of the fibre, are incident normally on the flat end of the fibre. They then strike the internal surface of the fibre at the glass-air boundary. Ray Q is incident at the critical angle.

Q4 Jan 2008

Figure 1



(a) (i) Explain what is meant by *critical angle*.

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(ii) Calculate the critical angle for a boundary between the glass and air.
refractive index of the glass = 1.54

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(4 marks)

(b) Draw, using a ruler, on **Figure 1** the path taken by rays P, Q and R on striking the internal surface.

(3 marks)

(c) (i) Describe what would happen to ray Q if the glass shown in **Figure 1** had been surrounded during manufacture with a glass cladding of lower refractive index.

You may be awarded additional marks to those shown in the brackets for the quality of written communication in your answer.

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(ii) State **one** reason why a glass cladding is normally used.

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(iii) Calculate the critical angle for a boundary between the glass core and the glass cladding.

refractive index of the glass used for the cladding = 1.46

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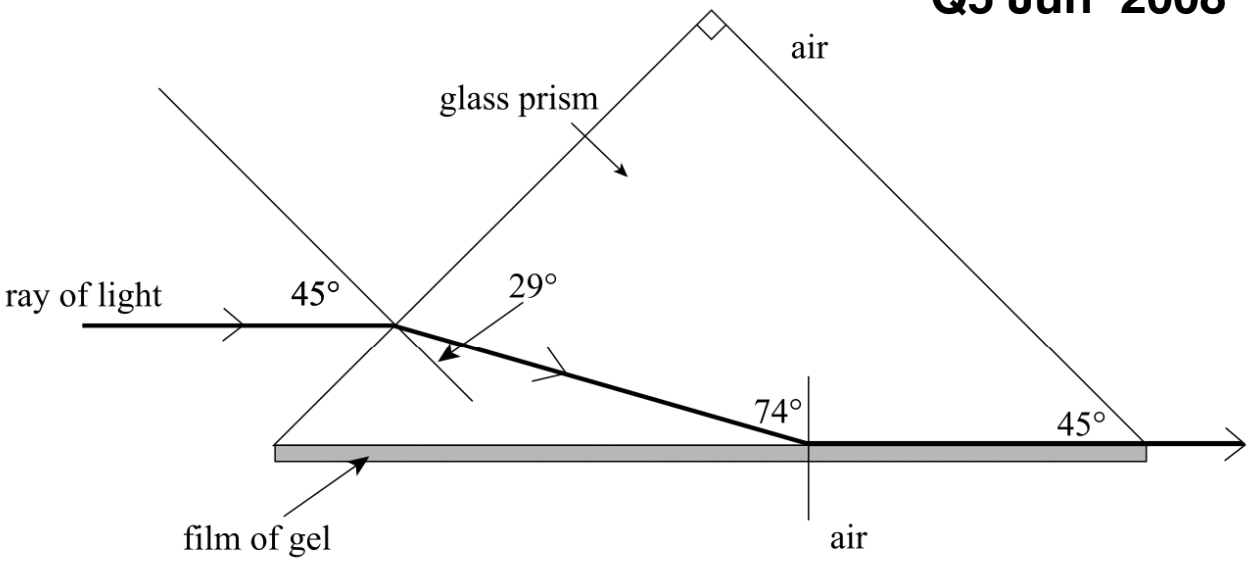
(6 marks)

5 **Figure 2** shows a 45° right angled glass prism in air, coated on one side with a film of transparent gel. A ray of light strikes the prism, at an angle of incidence of 45°, and continues through the glass to strike the glass-gel interface at the critical angle.

Figure 2

Q5 Jun 2008



5 (a) Calculate the refractive index of

5 (a) (i) the glass,

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5 (a) (ii) the gel.

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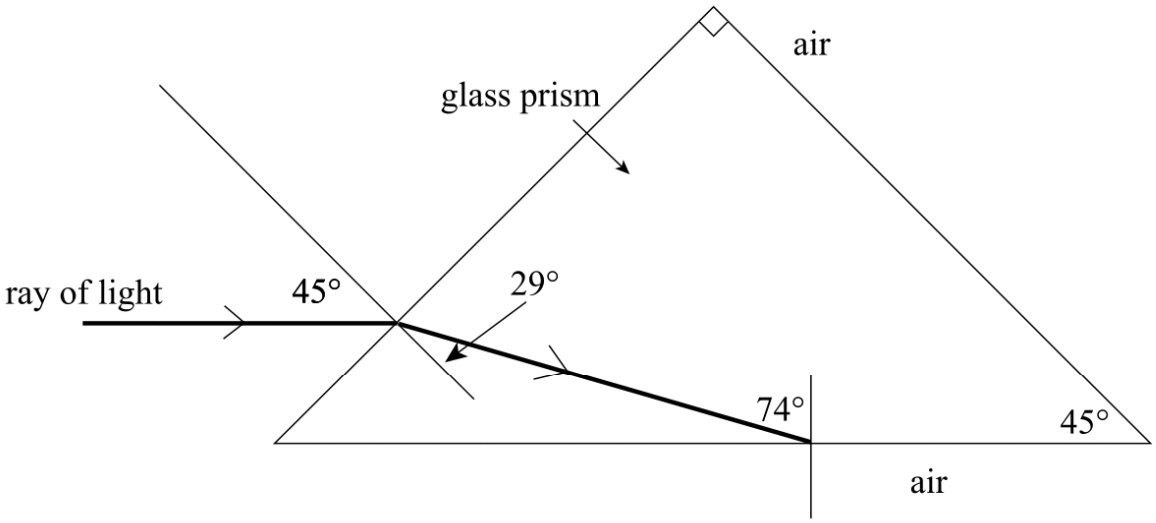
(5 marks)

5 (b) On **Figure 3** draw, using a ruler, the path of the ray of light with the gel removed. Mark the values of all relevant angles.

Figure 3



(4 marks)

5 (c) A ray of light passes through a straight, 5.00 m long, optical fibre of refractive index 1.59. Calculate the time taken for a ray of light to travel along the axis of the fibre.

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(2 marks)