Save My Exams

IB · DP · Physics

2 hours 14 questions

Structured Questions

4.4 Wave Behaviour

4.4.1 Reflection, Refraction & Transmission / 4.4.2 Reflection / 4.4.3 Refraction / 4.4.4 Determining Refractive Index / 4.4.5 Single-Slit Diffraction / 4.4.6 Interference & Path Difference / 4.4.7 Double-Slit Equation

Easy (5 questions)	/47
Medium (5 questions)	/49
Hard (4 questions)	/45
Total Marks	**/141**

Scan here to return to the course
or visit savemyexams.com

Easy Questions

1 (a) State what is meant by:

(i) The law of reflection.

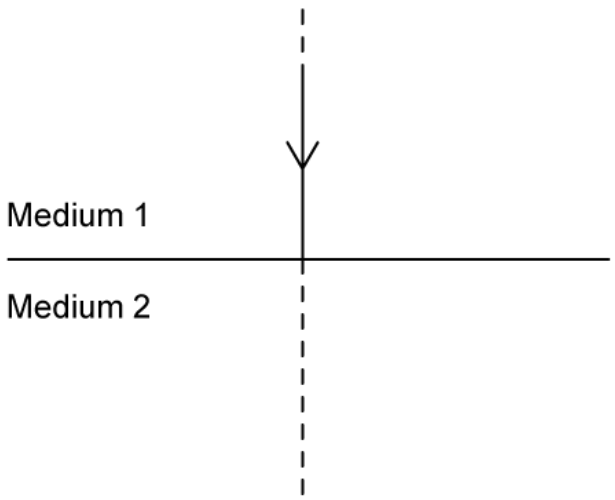
[1]

(ii) Refraction.

[1]

(2 marks)

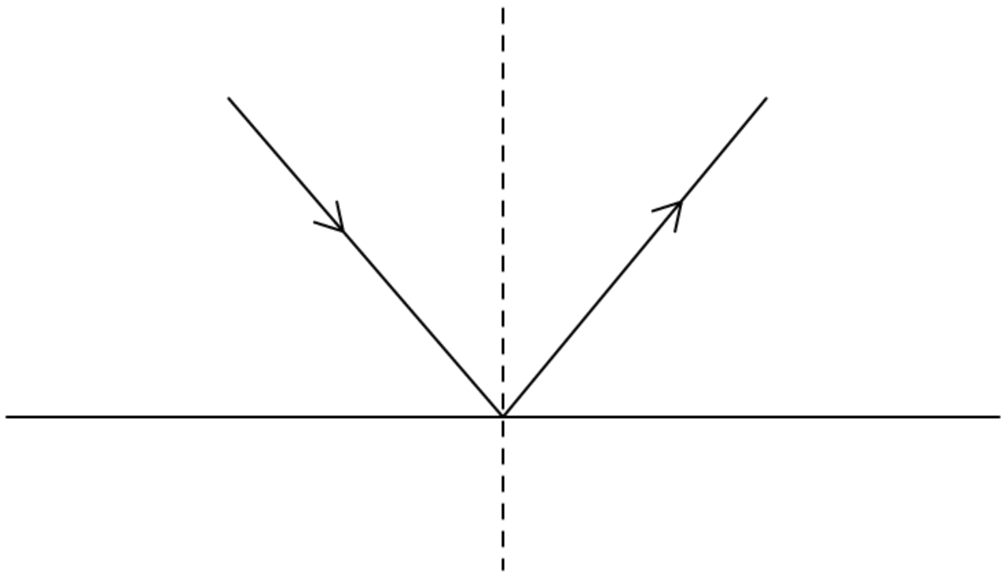
(b) The following diagram shows an incident ray perpendicular to the boundary between two media.



Complete the ray diagram by drawing the transmitted ray.

(2 marks)

(c) Ray diagrams can be used to show reflection and refraction. The following diagram shows the reflection of light on a smooth surface.



On the ray diagram label:

(i) The incident ray.

[1]

(ii) The reflected ray.

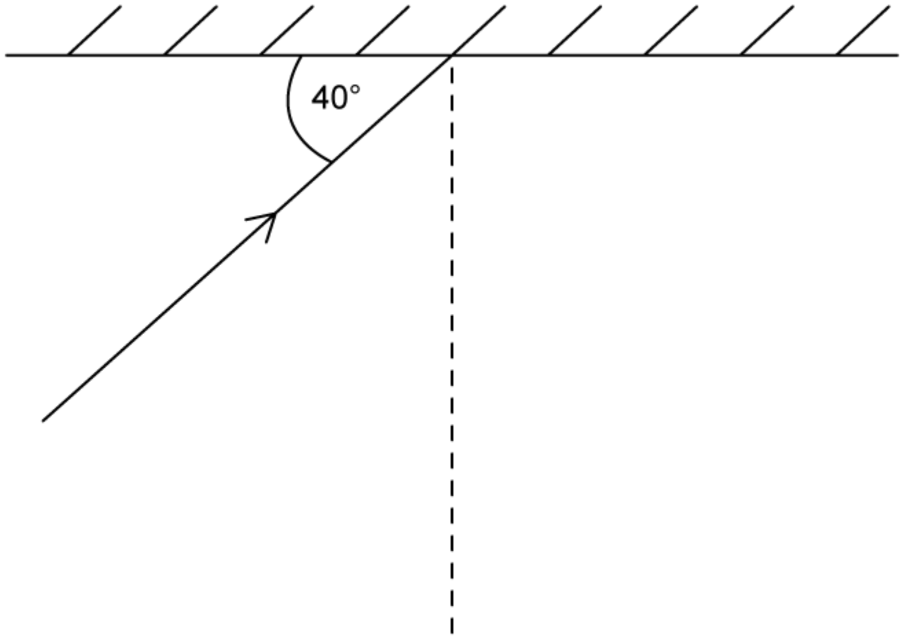
[1]

....

....

(2 marks)

(d) The ray diagram shows an incident ray on a plane mirror.



Calculate the angle of reflection.

....

....

....

(3 marks)

2 (a) Refraction occurs when light travels between media with different optical densities.

Describe what happens when light passes from a less dense medium into a more dense medium in terms of:

(i) The relative sizes of the angles of incidence and refraction. [1]

(ii) The direction of the refracted light ray in relation to the normal. [1]

....

....

(2 marks)

(b) The refractive index is calculated using the equation:

$$n = \frac{c}{v}$$

Write in the missing information to complete the following table:

Quantity	Symbol	Units
	n	No units
	c	
Speed of light in medium	*v*	

....

....

....

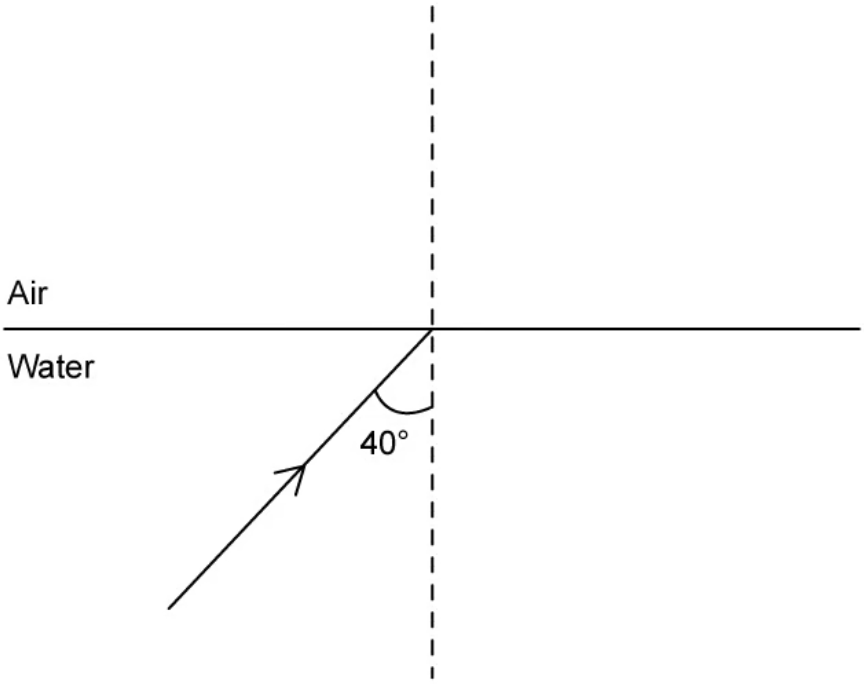
(3 marks)

(c) Define the term critical angle.

....

(1 mark)

(d) Incident light travelling through water approaches the surface of the water and meets the boundary with air. The incident ray has an angle of incidence = 40°.



The refractive index of air is 1.00 and the refractive index of water is 1.33.

Calculate the angle of refraction for the refracted ray.

....

....

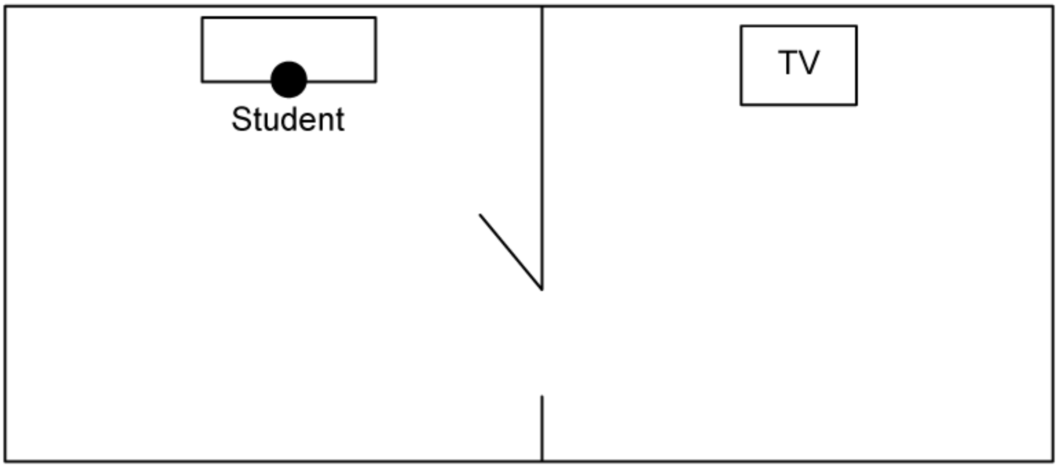
(2 marks)

3 (a) Define diffraction.

....

(1 mark)

(b) The diagram shows a student in a room with an open door and a television in the next room.



The student can hear the sound of the television, but cannot see the picture coming from it.

Complete the following sentences by circling the correct word to explain why this is the case.

Sound waves emitted from the television **diffract / refract** around the opening of the door because the **amplitude / wavelength** is similar in size to the door. The **amplitude / wavelength** of light is much **larger / smaller** than that of the sound waves, so light is not not **diffracted / refracted** around the opening of the door.

....

....

....

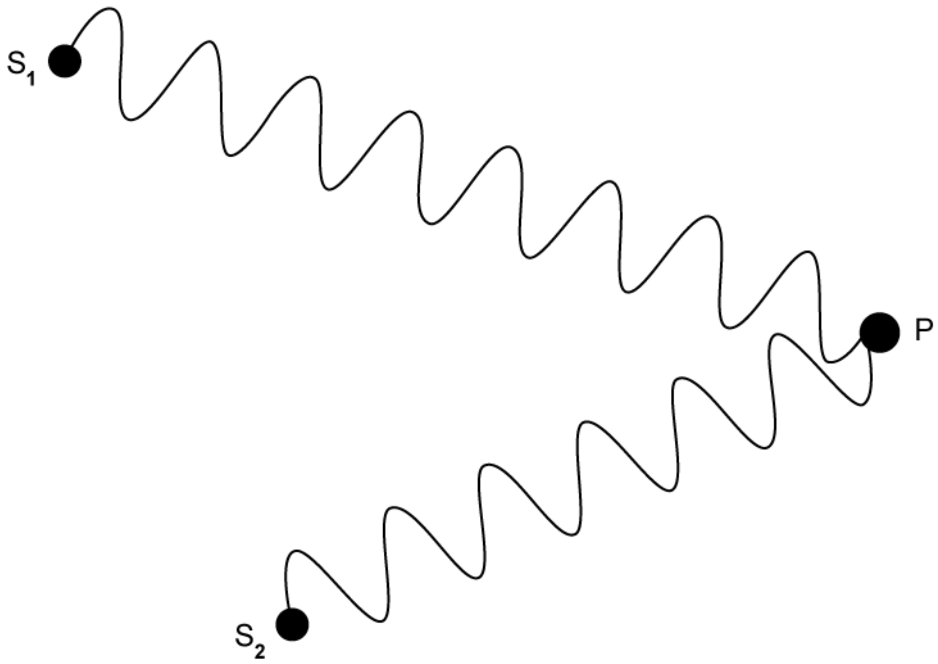
....

(5 marks)

(c) Define coherence.

(1 mark)

(d) The diagram shows two different waves from sources s_1 and s_2 meeting at point P.



For the waves meeting at point P:

(i) Determine the path difference.

[3]

(ii) State whether the interference will be constructive or destructive.

[1]

(4 marks)

4 (a) Outline the conditions for destructive interference.

....

(1 mark)

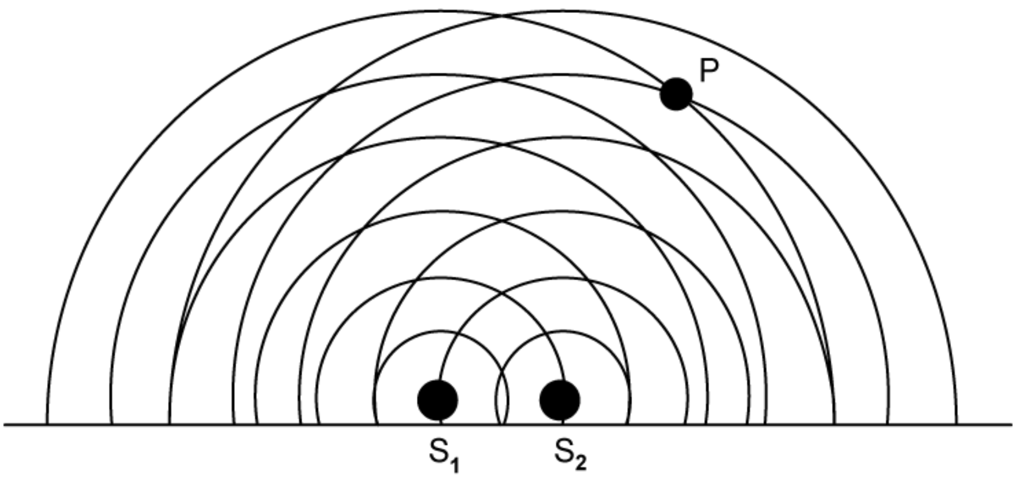
(b) Some light can be described as monochromatic.

State what is meant by the term monochromatic.

....

(1 mark)

(c) The diagram shows the wave fronts emitted from two point sources s_1 and s_2.



The waves meet at point P.

(i) By considering the number of waves, determine the path difference.

[3]

(ii) State whether constructive or destructive interference would occur at point P.

[1]

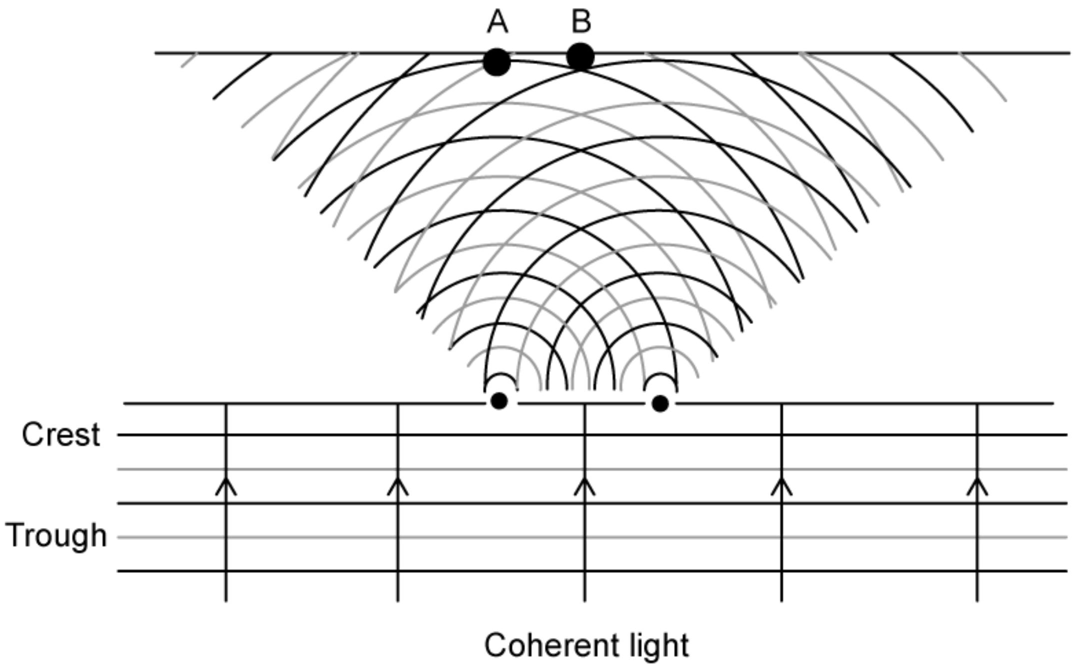
....

....

....

(4 marks)

(d) The diagram shows two sources of coherent light producing a double-slit interference pattern.



State whether the interference is constructive or destructive at point:

(i) A.

[1]

(ii) B.

[1]

(2 marks)

5 (a) The distance between the bright fringes in a double-slit interference pattern can be determined by the double-slit equation

$$s = \frac{\lambda D}{d}$$

Draw a line to match the quantity to the correct symbol.

Separation distance between slits	D
Wavelength of incident wave	d
Separation distance between fringes	λ
Separation distance between slits and screen	s

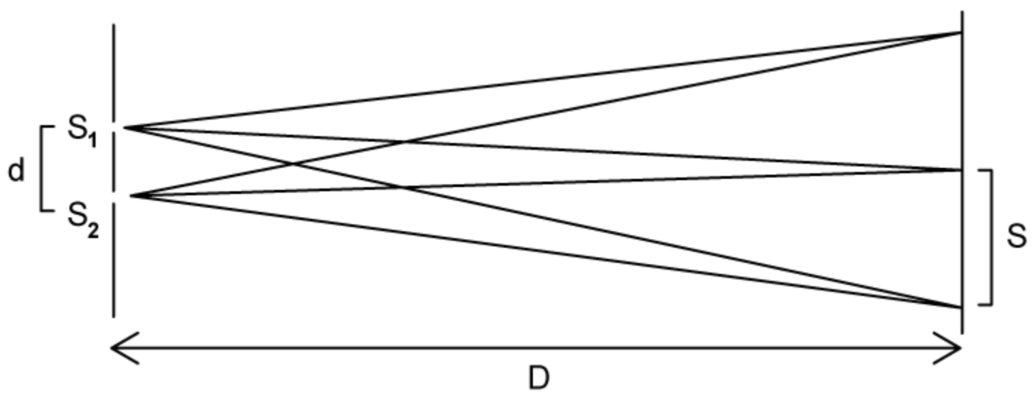
....

....

....

(3 marks)

(b) Red laser light is used to form a double-slit interference pattern on a screen.



The distance between the bright fringes depends on the wavelength of the incident light.

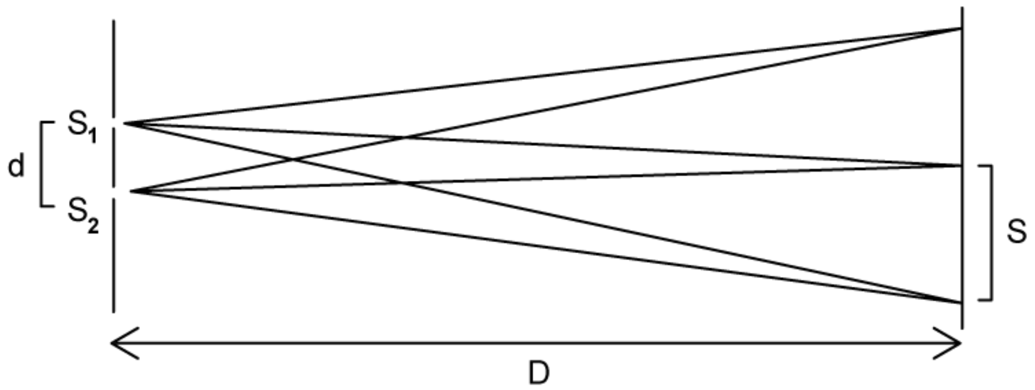
Outline how the interference pattern would be affected if blue laser light were used instead.

....

....

(2 marks)

(c) Red laser light of wavelength λ = 650 nm is used to form a double-slit interference pattern on the screen as shown.



The separation distance of the slits d = 0.2 mm, and the distance between the slits and the screen D = 1.2 m.

Calculate the separation distance between the fringes on the screen s.

....

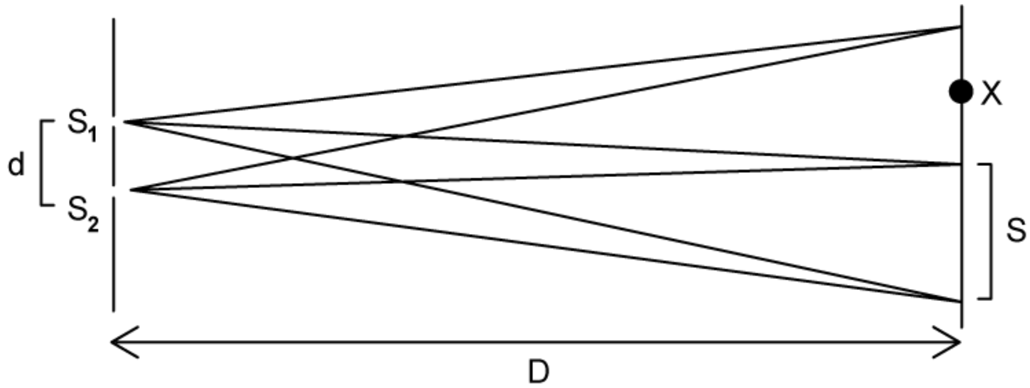
....

....

....

(4 marks)

(d) For the interference pattern shown in part (c):



Explain why there is no bright fringe at point X.

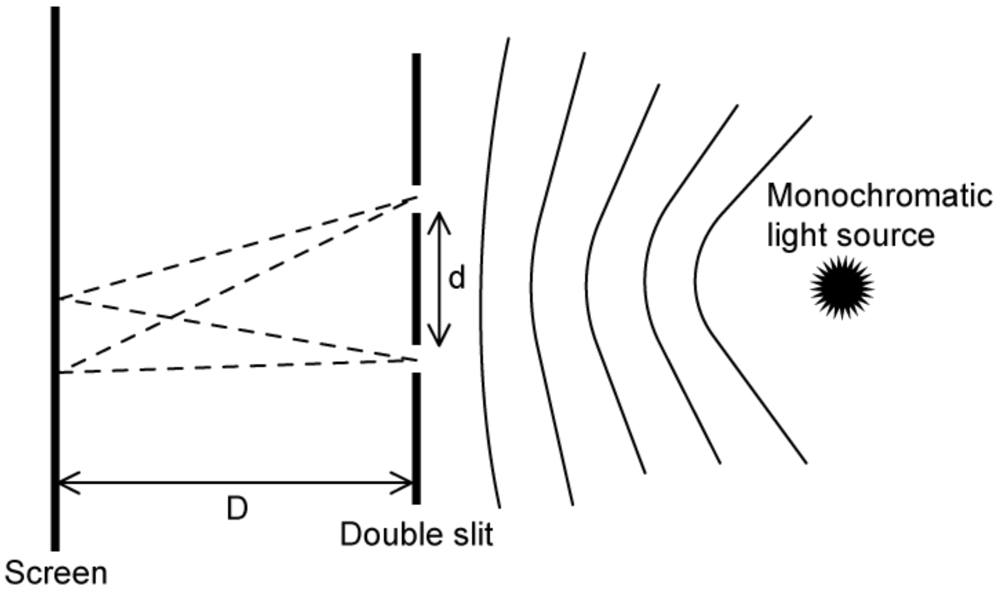
....

....

(2 marks)

Medium Questions

1 (a) A beam of monochromatic light is incident upon two slits. The distance between the slits is 0.4 mm.



A series of bright and dark fringes appear on the screen. Explain how a bright fringe is formed.

(2 marks)

(b) Monochromatic light is incident on the double-slits and the distance from the screen is 0.64 m. The distance between the bright fringes is 9.3×10^{-4} m. Determine the wavelength of the incident light.

(2 marks)

(c) If the wavelength of the incident light is halved and the distance between the slits is doubled, outline the effect on the separation of the fringes of the interference pattern.

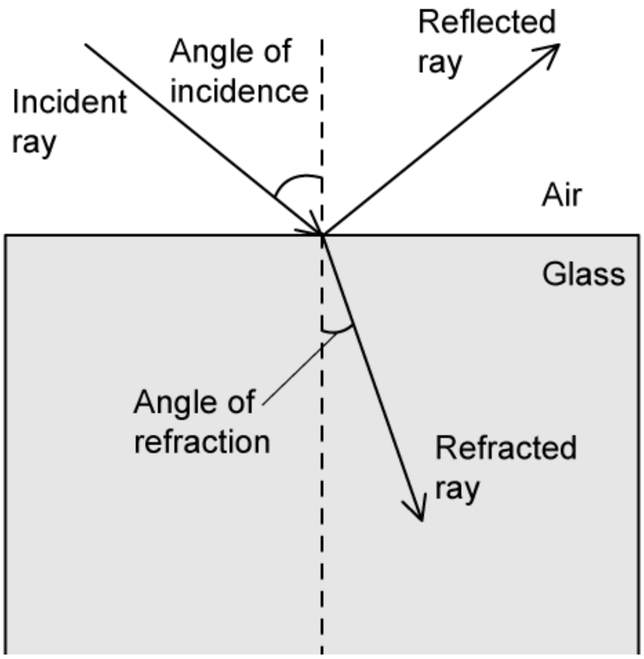
(2 marks)

(d) One of the slits is covered so it emits no light.

Describe how this changes the pattern's appearance and the intensities observed on the screen.

(2 marks)

2 (a) Light is incident upon a piece of glass.



The angle of incidence is less than that of the critical angle. The refractive index of the glass is 1.50.

Explain what is meant by the 'critical angle' and what will occur at angles that are above and below the critical angle.

....

....

....

(3 marks)

(b) The angle of incidence for this situation is 34°.

Determine the angle of refraction to the nearest degree.

....

....

(2 marks)

(c) The refracted light travels within the glass for 5 m.

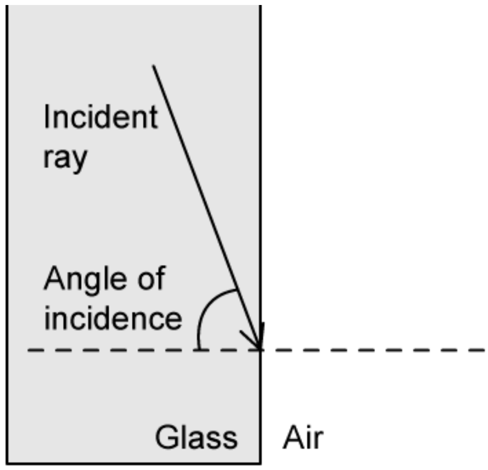
Determine the time that the light will take to travel this distance in the glass.

....

....

(2 marks)

(d) The light continues within the glass until it strikes the side perpendicular to the original side of entry.



Show that the light will not emerge from the side of the glass.

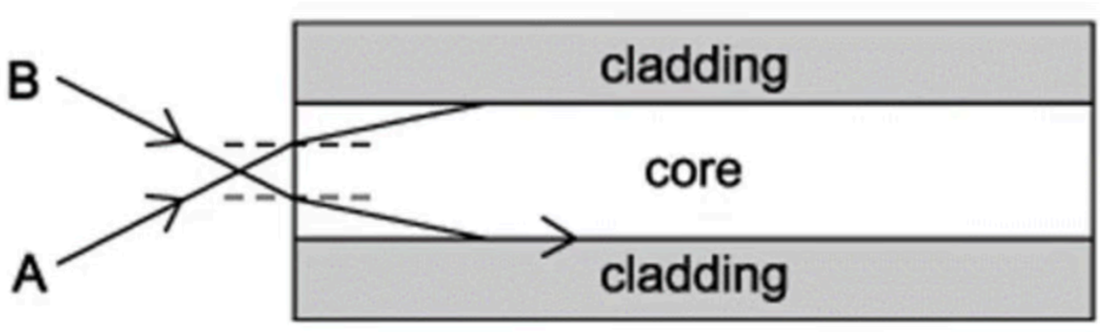
....

....

....

(3 marks)

3 (a) The diagram shows a cross-section through a step-index optical fibre.



Beam A is incident at the end of the optical fibre at an angle of 12.6° to the normal and refracts into the core at 6.89° to the normal.

Calculate the refractive index of the core.

....

....

(2 marks)

(b) Beam A travels through the air-core boundary and experiences total internal reflection.

On the diagram, show the path of this ray down the fibre and label the angle of reflection.

....

....

(2 marks)

(c) Beam **B** is incident at the same end of the fibre. It refracts through the air-core boundary and then refracts again when it hits the core-cladding boundary at an angle of 51.8°, traveling along the boundary.

Calculate the refractive index of the cladding.

....

(2 marks)

(d) A different step-index optical fibre is built with the same core as that in part (a) but with a different material used for the cladding.

The speed of light in the new cladding material is 1.54×10^{8} m s^{-1}.

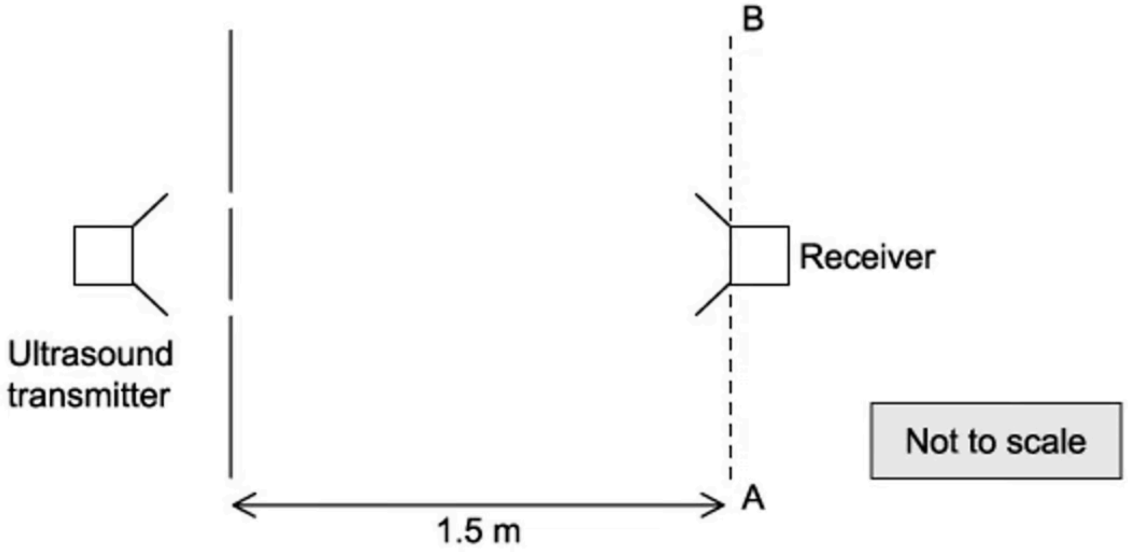
Explain why this new cladding material would not be suitable for sending signals through the step-index optical fibre. Use a calculation to support your answer.

(3 marks)

4 (a) A laboratory ultrasound transmitter emits ultrasonic waves of wavelength 0.7 cm through two slits. A receiver, moving along line AB, parallel to the line of the slits, detects regular rises and falls in the strength of the signal.

A student measures a distance of 0.39 m between the first and the fourth maxima in the signal when the receiver is 1.5 m from the slits.

Figure 1



The ultrasound transmitter is a coherent source.

Explain what is meant by the term coherent source.

....

....

(2 marks)

(b) Explain why the receiver detects regular rises and falls in the strength of the signals as it moves along the line AB.

....

....

....

(4 marks)

(c) Calculate the distance between the two slits.

(3 marks)

(d) One of the slits is now covered. No other changes are made to the experiment.

State and explain the difference between the observations made as the receiver is moved along AB before and after one of the slits is covered.

(3 marks)

5 (a) White light is passed through a single narrow slit and illuminates a screen.

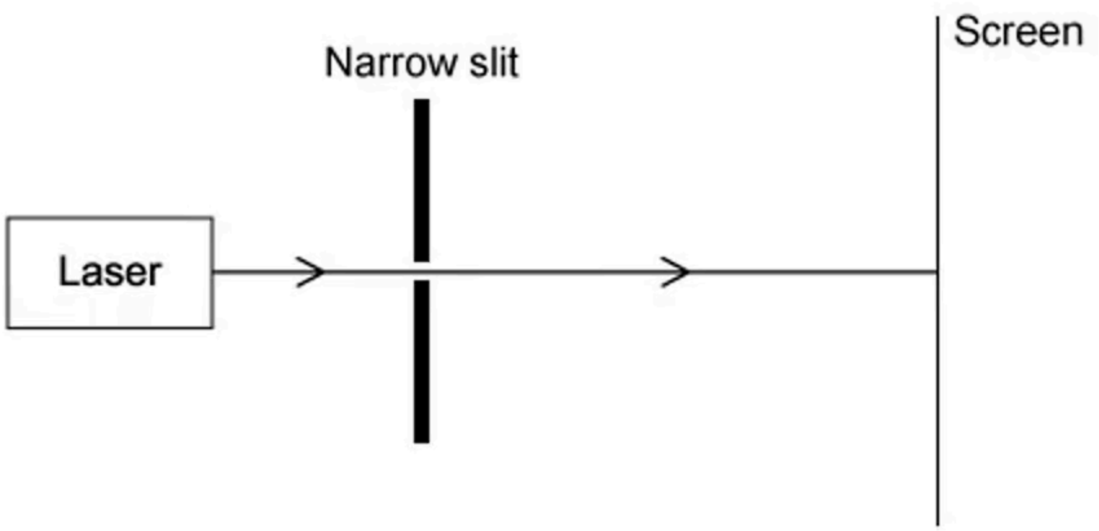
Describe the patten observed on the screen.

....

....

(2 marks)

(b) Blue light from a laser is now passed through a single narrow slit. A pattern of bright and dark regions can be observed on the screen which is placed several meters beyond the slit.



Describe the effect on the diffraction pattern if the width of the narrow slit is decreased.

....

....

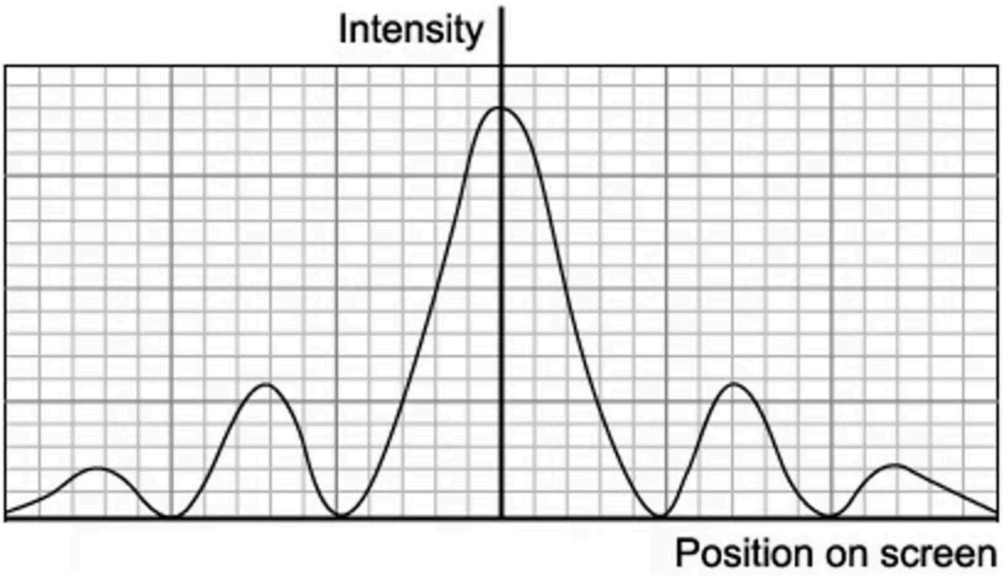
(2 marks)

(c) With the original slit width, state and explain the effect on the width of the fringes on the diffraction pattern if the blue light is replaced with a red light of the same intensity.

....

(3 marks)

(d) The intensity graph for the diffracted blue light is shown in the diagram below.



On the axes of the diagram, sketch the intensity graph for the laser emitting red light.

(3 marks)

Hard Questions

1 (a) A student designs an experiment to replicate Young's double slit demonstration. The student uses a candle as a light source, with a piece of coloured filter paper to produce monochromatic light. They then consider additional apparatus required in order to observe an interference pattern.

Sketch a diagram, labelling all apparatus, as well as any important quantities, to show the setup the student should use to produce and observe an interference pattern.

....

....

....

(3 marks)

(b) The student labels the two slits on the double-slit grating slit X and slit Y. The student then paints over slit X, such that the intensity of light emerging from it is 50% of that emerging from slit Y.

Discuss the effects this change will have on the student's observations.

....

....

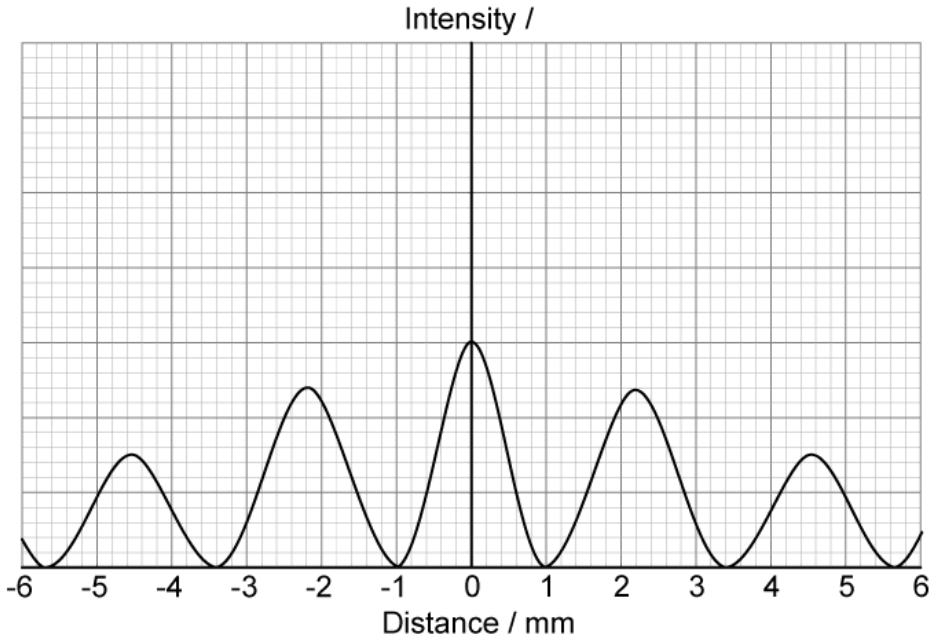
....

....

(4 marks)

(c) The student finishes setting up their apparatus and makes a quick note of two separate measurements, 0.75 mm and 2.0 m.

They then plot a graph of the intensity of light against the distance from the centre of the screen, represented by the origin.



Determine which colour of filter paper the student most likely chose for this experiment.

....

....

....

....

(4 marks)

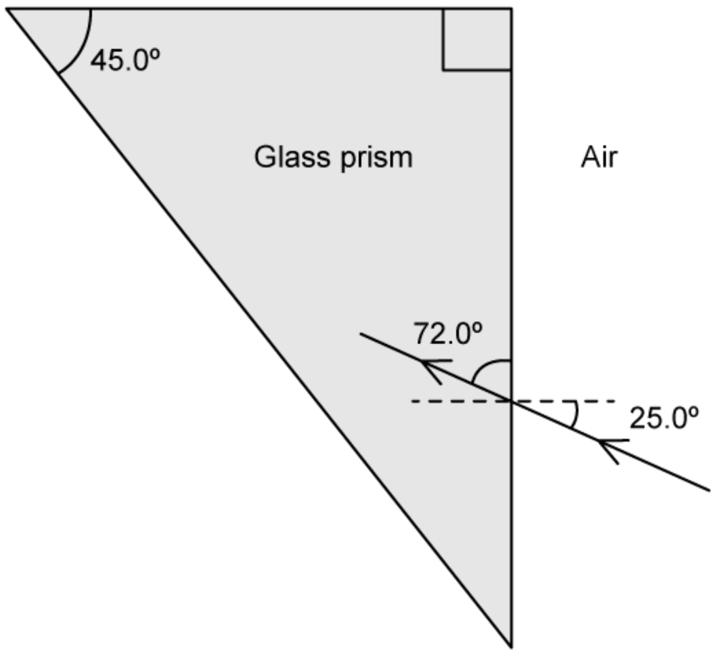
(d) Determine the phase angle between the waves meeting at the point that is 2.8 mm from the centre of the screen.

....

....

(2 marks)

2 (a) A ray of light passes from air into a glass prism.



As the light ray passes through the prism, it emerges back into the air.

Calculate the critical angle from the glass to the air.

....

....

(2 marks)

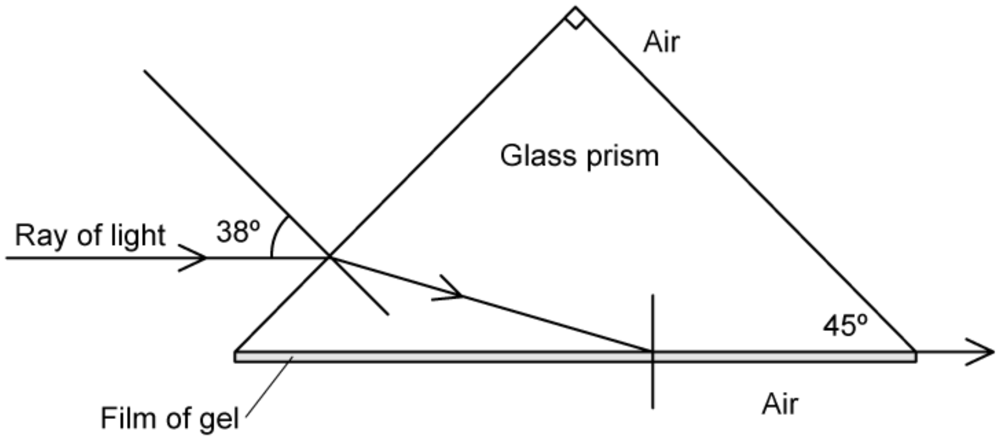
(b) On the diagram from part (a), draw the continuation of the path of the ray of light until it emerges back into the air, labelling the values of the angles between the ray and any normals.

....

....

(2 marks)

(c) The prism is rotated and one side is coated with a film of transparent gel. A ray of light strikes the prism, at an angle of incidence of 38°, and continues through the glass to strike the glass–gel boundary at the critical angle.



Calculate the refractive index of the gel.

....

....

....

(3 marks)

(d) A ray of light now strikes the prism at an angle of incidence which means that it now refracts straight through the gel at the glass–gel boundary.

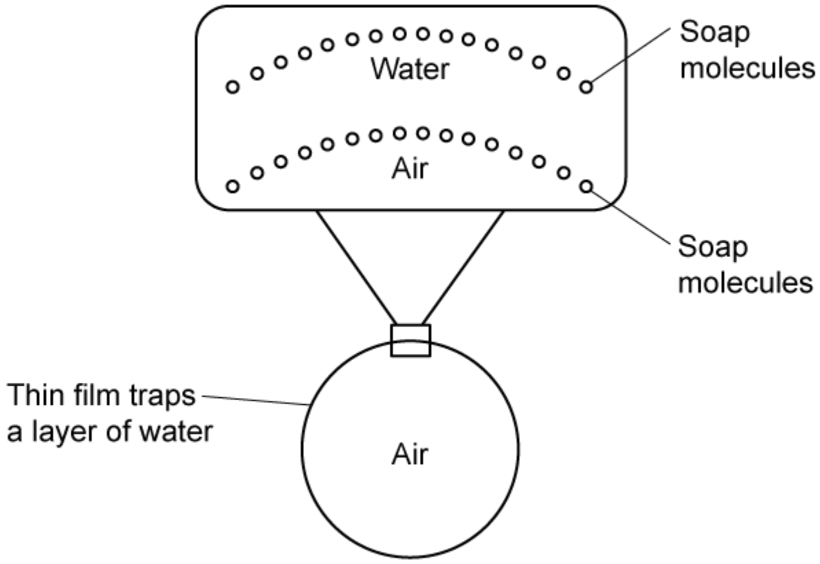
Without calculation, explain how the critical angle for the glass–gel boundary differs from the critical angle for the gel–air boundary.

....

....

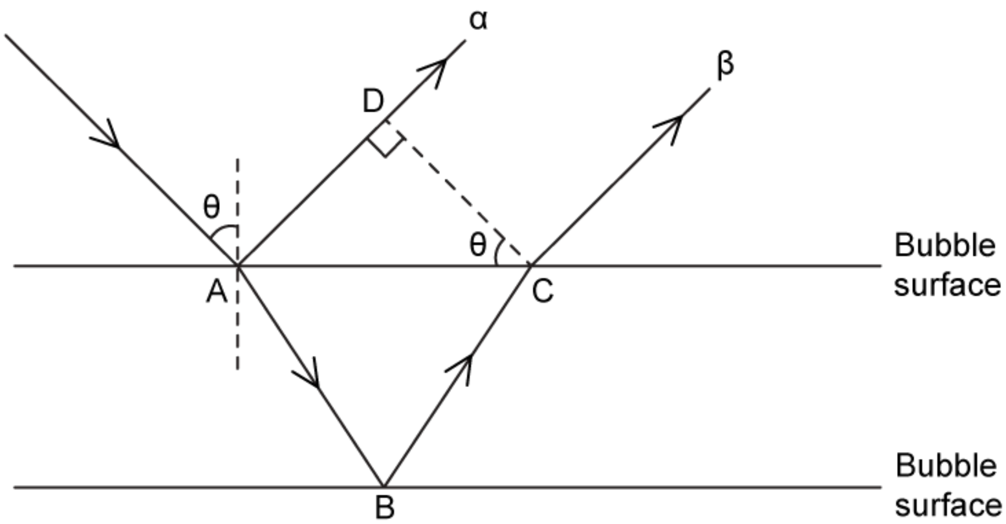
(2 marks)

3 (a) A soap bubble is known as a 'thin film'. There is a thin layer of water trapped between soap molecules on either side.



Light that hits the bubble behaves in very predictable ways, resulting in visually interesting and colourful effects.

Blue light of wavelength 400 nm is incident at an angle θ on a bubble where it splits into a ray that is reflected (ray α) and a ray which refracts into the bubble (ray β). Ray β reflects from the other side of the film, and then leaves the bubble again.



Upon reflection, ray α undergoes a phase shift of π radians. Ray β does not undergo any phase shift upon reflection.

Determine an expression for the path difference between ray α and ray β, justifying your answer.

....

....

....

(3 marks)

(b) Thin-film interference occurs when reflected light from two different boundaries interfere.

With reference to the path difference, describe the conditions for constructive and destructive thin-film interference of ray α and β from part a.

....

....

....

(3 marks)

(c) For a given angle of incidence θ, discuss what will be observed above the surface of the bubble for different colours of light.

....

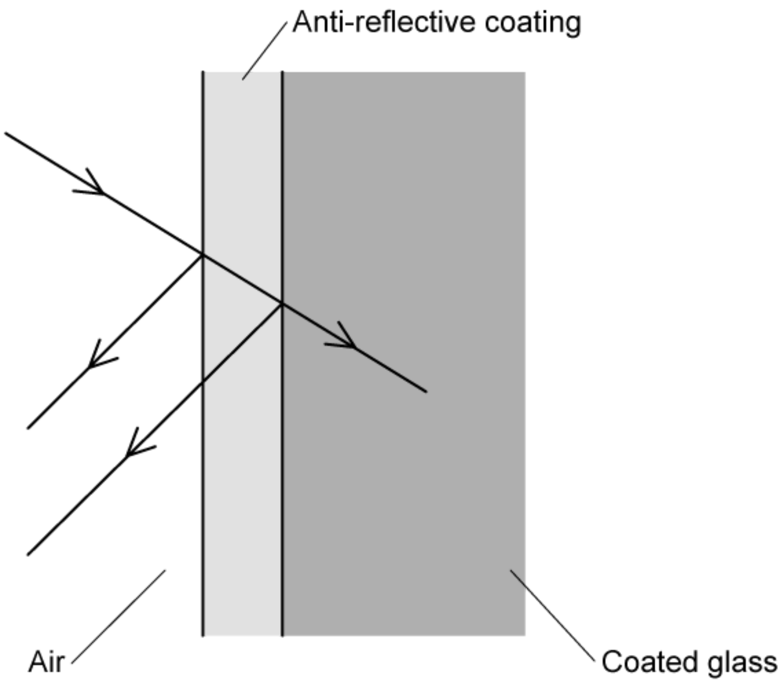
....

....

....

(4 marks)

(d) Anti-reflective coatings use thin-film interference effects to make it appear that light is not reflected from the surface and instead passes straight through it. A simplified version of anti-reflective coated glass is shown in the diagram:



The coating is designed such that there is a phase shift of π radians at the first boundary (between the air and the coating) as well as at the second boundary (between the coating and the glass).

By considering the conditions for constructive or destructive interference, discuss the limitations of this design.

....

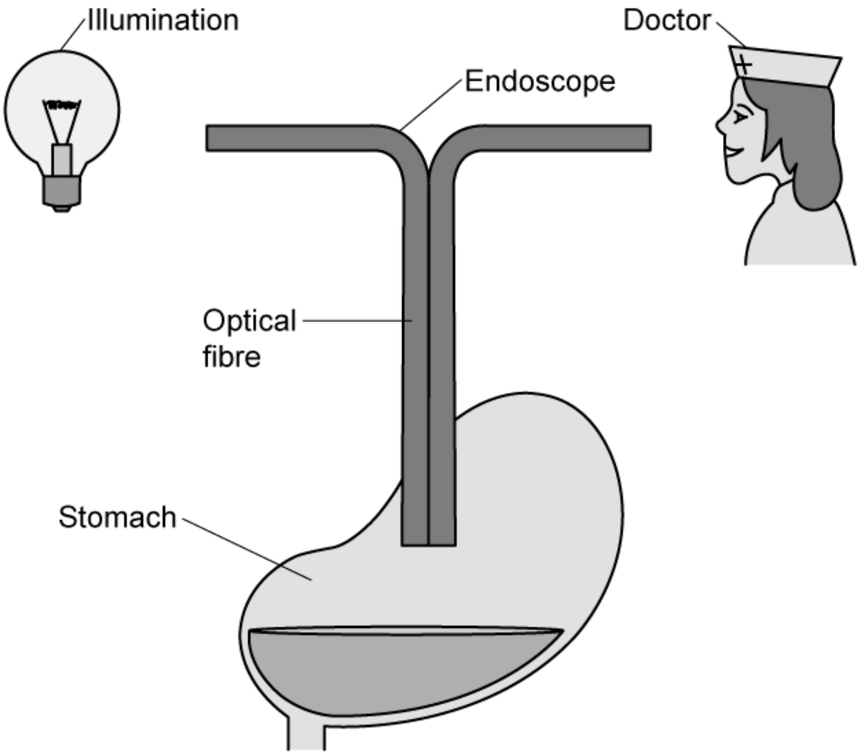
....

....

....

(4 marks)

4 (a) The tube of an endoscope behaves like an optical fibre to examine the interior of the body for medical diagnosis. One end of the fibre is illuminated and an image of the inside of the stomach is viewed by the doctor.



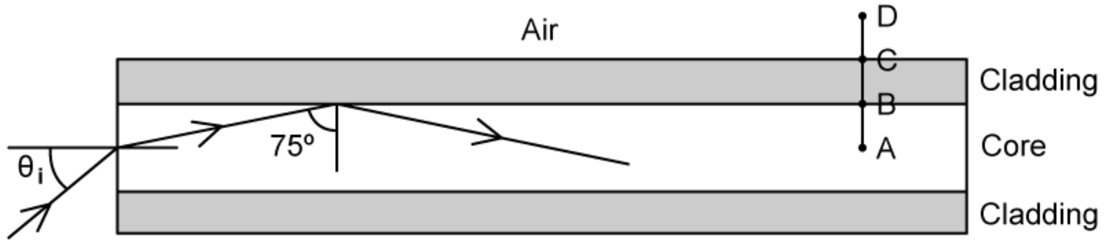
Draw on the picture the complete path of the light from the illumination to the doctor.

....

....

(2 marks)

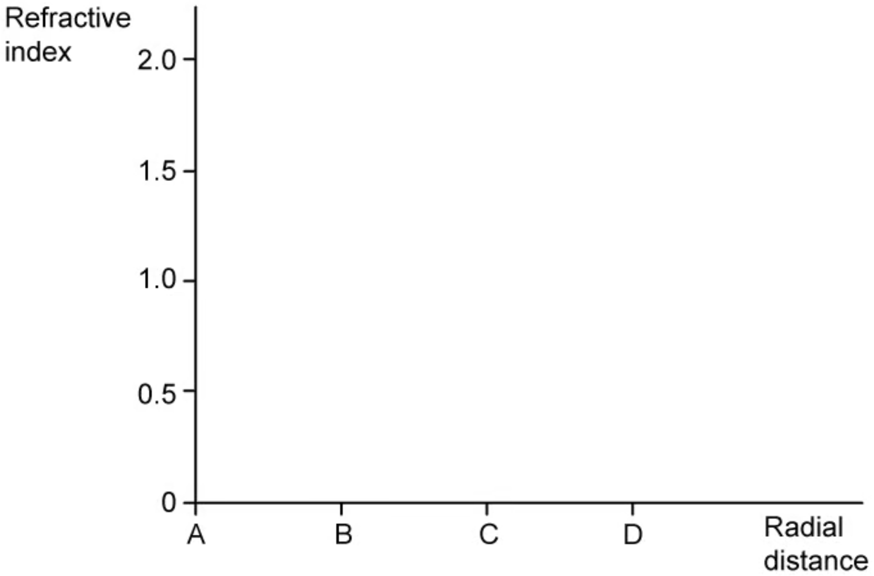
(b) The diagram shows a cross–section through an optical fibre used in an endoscope. The critical angle is 7% lower than the 75° angle to the normal at the core–cladding boundary. The refractive index of the cladding is 1.4.



Calculate the angle of incidence θ_i at the air–core boundary.

(4 marks)

(c) Complete the graph to show how the refractive index changes with radial distance along the line ABCD in Figure 2.



(3 marks)