4.4 Wave Behaviour

Question Paper

Course	DP IB Physics
Section	4. Waves
Topic	4.4 Wave Behaviour
Difficulty	Hard

Time allowed: 60

Score: /45

Percentage: /100

Question 1a

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.

a)
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]

[3 marks]

Question 1b

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.

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

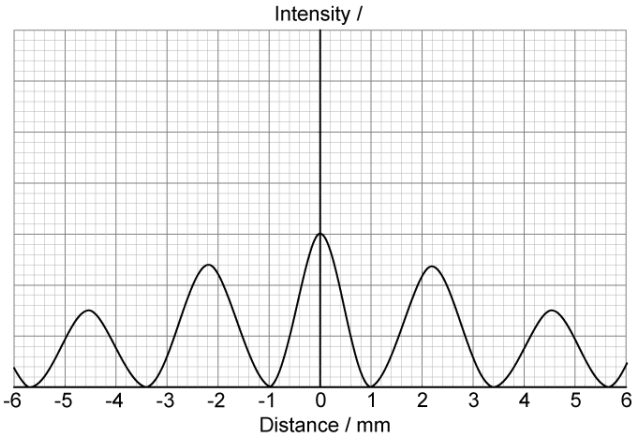
[4]

[4 marks]

Question 1c

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.



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

[4]

[4 marks]

Question 1d

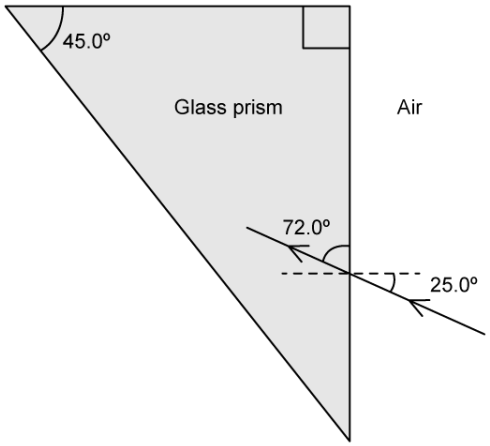
(d)
Determine the phase angle between the waves meeting at the point that is 2.8 mm from the centre of the screen.

[2]

[2 marks]

Question 2a

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.

(a)
Calculate the critical angle from the glass to the air.

[2]

[2 marks]

Question 2b

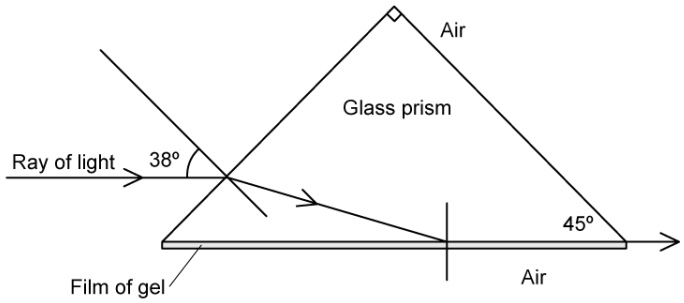
(b)
On the diagram from part (a), draw the continuation of the path of the ray of light until it emerges back into the air, labelling the values of the angles between the ray and any normals.

[2]

[2 marks]

Question 2c

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.



(c)
Calculate the refractive index of the gel.

[3]

[3 marks]

Question 2d

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.

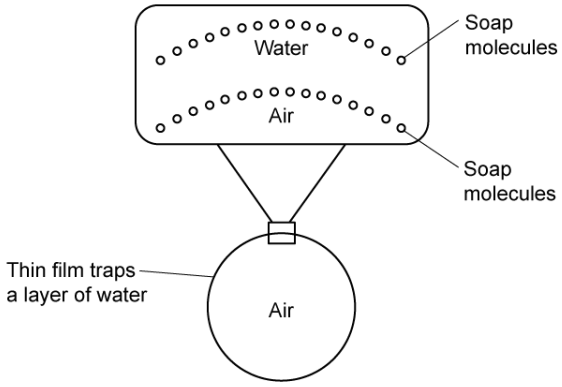
(d)
Without calculation, explain how the critical angle for the glass–gel boundary differs from the critical angle for the gel–air boundary.

[2]

[2 marks]

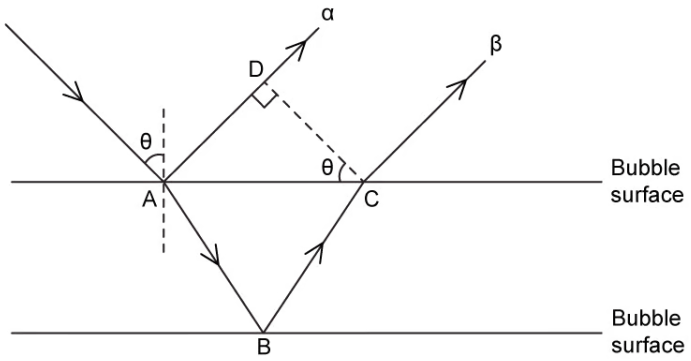
Question 3a

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.

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

[3]

[3 marks]

Question 3b

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

(b)
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]

[3 marks]

Question 3c

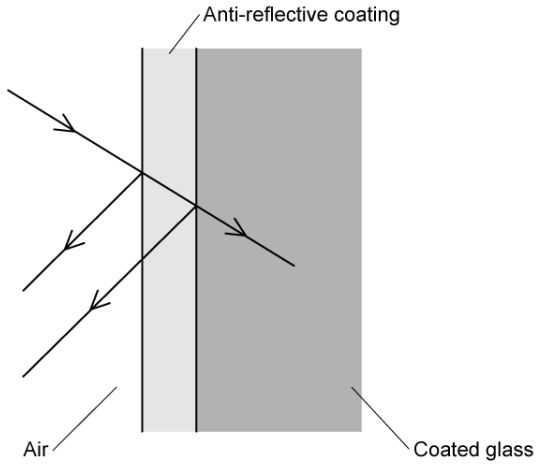
(c)
For a given angle of incidence θ, discuss what will be observed above the surface of the bubble for different colours of light.

[4]

[4 marks]

Question 3d

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).

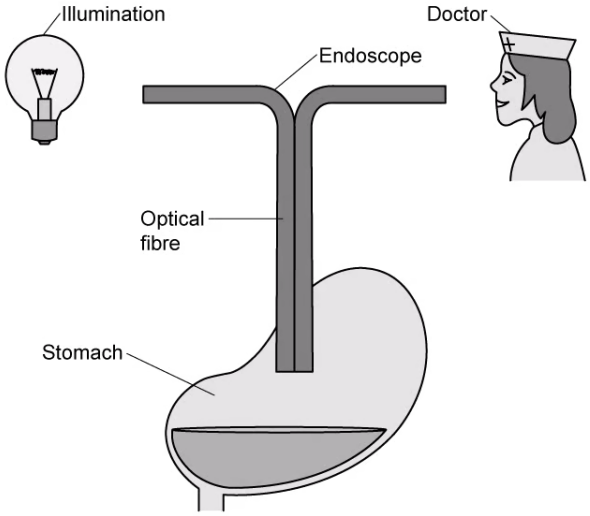
(d)
By considering the conditions for constructive or destructive interference, discuss the limitations of this design.

[4]

[4 marks]

Question 4a

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.



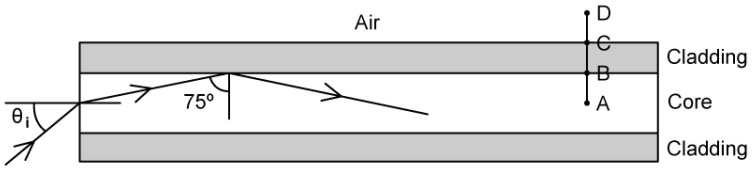
(a)
Draw on the picture the complete path of the light from the illumination to the doctor.

[2]

[2 marks]

Question 4b

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.



(b)
Calculate the angle of incidence θ_i at the air-core boundary.

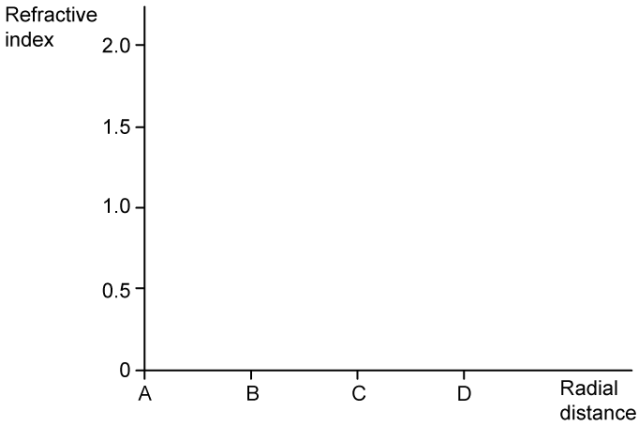
[4]

[4 marks]

Question 4c

(c)

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



[3]

[3 marks]