1 A student places a stick in a glass vase in front of a candle. The student then fills the vase with water.

When the vase is full of water, the stick appears to be broken and the candle appears distorted because of refraction.

(a) Explain how these effects are caused.

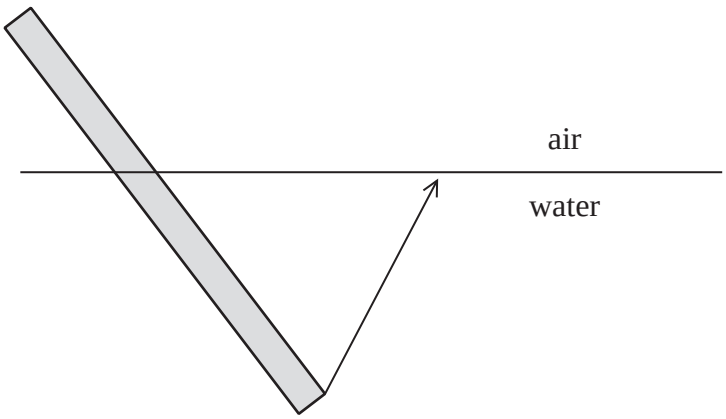
(3)

(b) The refractive index of water is 1.33.
Calculate the speed of light in water.

(2)

Speed of light in water =

(c) The diagram shows a light ray from part of the stick in the water.



(i) By measuring the angle of incidence of the light ray at the surface of the water, determine the angle of refraction in air.
refractive index of water = 1.33

(3)

Angle of refraction =

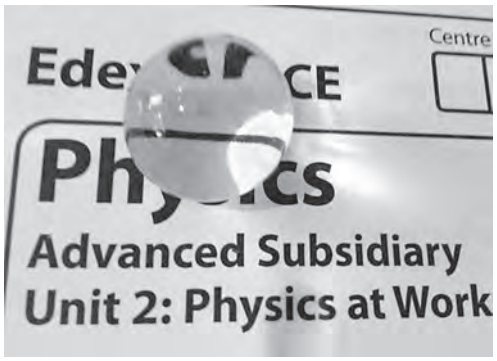
(ii) Add to the diagram to show how that part of the stick appears to be in a different position.

(2)

(Total for Question = 10 marks)

2 Flower arrangers sometimes use gel balls instead of water to fill vases.

The photograph below shows some writing seen through one of these gel balls. The writing is distorted because the gel ball refracts light.



(a) Explain what is meant by refraction.

(2)

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(b) The photographs below show a beaker containing gel balls. When water is added to the beaker, the gel balls below the water surface are no longer visible.

Explain how this shows that the gel has the same refractive index as water.

(2)

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(c) A student decides to use a gel ball to model the formation of a rainbow by raindrops. He wants to see if total internal reflection occurs.

Explain what is meant by total internal reflection.

(2)

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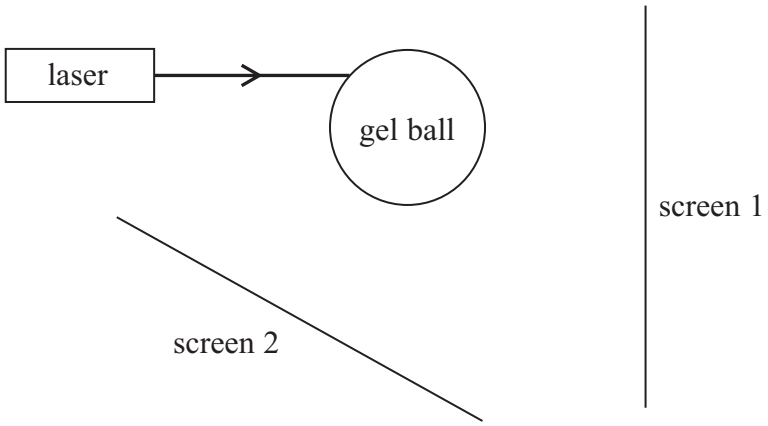
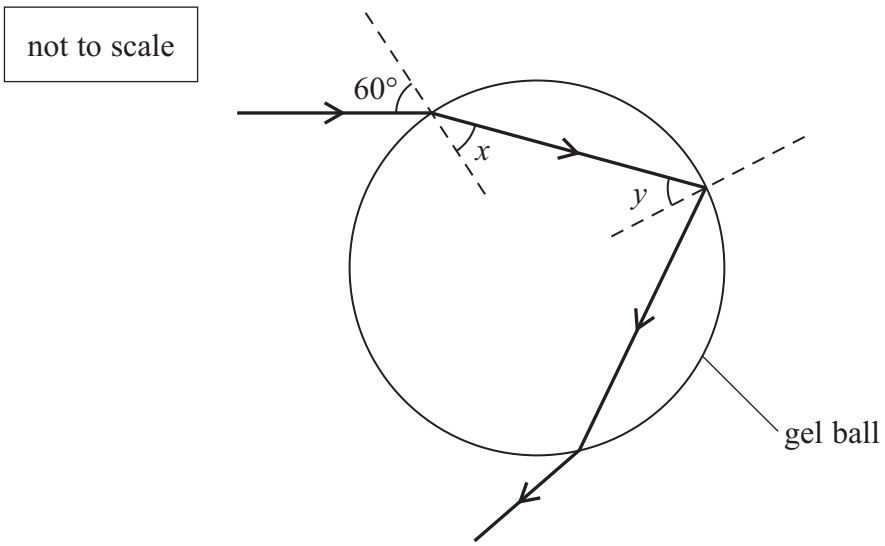
(d) The student shines a narrow laser beam at a gel ball using the arrangement shown.



When the angle of incidence of the laser beam with the gel ball is 60°, light from the laser illuminates screen 2 following the path shown.



(i) Show that the angle x is about 40°.

refractive index of gel 1.33

(2)

(ii) Show that the critical angle for light striking the boundary of gel with air is about 50°.

(2)

(iii) Angle x has the same value as angle y.
Explain whether light from the laser will be observed on screen 1.

(2)

(Total for Question 12 marks)

3 A book entitled *Interesting Projects with a Microwave Oven* suggests using chocolate to measure the speed of light. The chocolate is placed on a non-metallic tray in the oven. The oven is switched on and a pattern is observed in the melting chocolate.

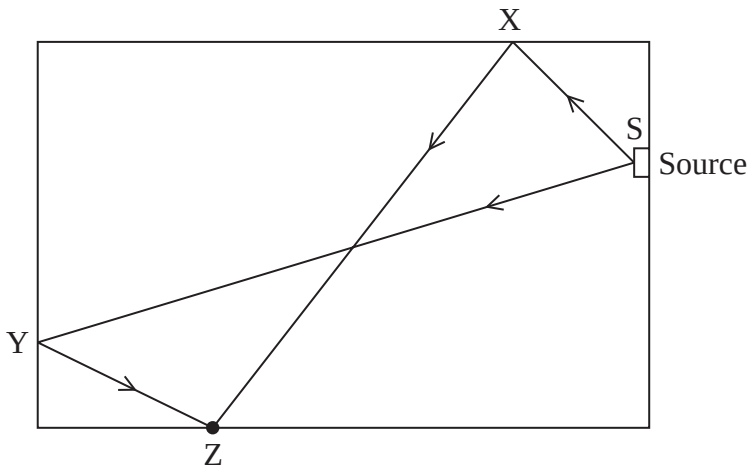
The photograph shows some lighter areas where the chocolate is melting and some darker areas where the chocolate remains hard.

The book states that microwaves are emitted from the source in the oven. The microwaves reflect off the metal walls so that the microwaves reaching any point arrive from different directions. The microwaves produce a standing wave pattern causing hot and cold areas in the oven.

The wavelength was determined to be 12 cm by measuring the distance between adjacent hot and cold areas.

(a) The diagram shows two different paths by which microwaves can reach the point Z.

Not to scale



SX = 9 cm, XZ = 23 cm, SY = 36 cm, YZ = 8 cm

Calculate the phase difference between microwaves from the source at S reaching point Z by the two different paths.

(2)

Phase difference =

(b) Explain how a pattern of hot and cold areas is produced in the chocolate. You should assume that each point of the chocolate is reached by microwaves following two different paths only.

(4)

(c) Explain why the microwaves reaching a point in the chocolate must be coherent for this effect to occur.

(2)

(d) The microwave frequency is stated on the oven as 2450 MHz.

Evaluate the success of this experiment at determining the speed of light.

(3)

(Total for Question = 11 marks)

4 (a) You are asked to find the refractive index for light passing from air to glass by tracing the path of a ray of light through a glass block.

State the measurements you would take, the graph you would plot and how you would use the graph to determine a value for the refractive index.

(3)

(b) (i) State what is meant by critical angle.

(2)

(ii) Calculate the critical angle for light passing from water to air.

refractive index of water = 1.33

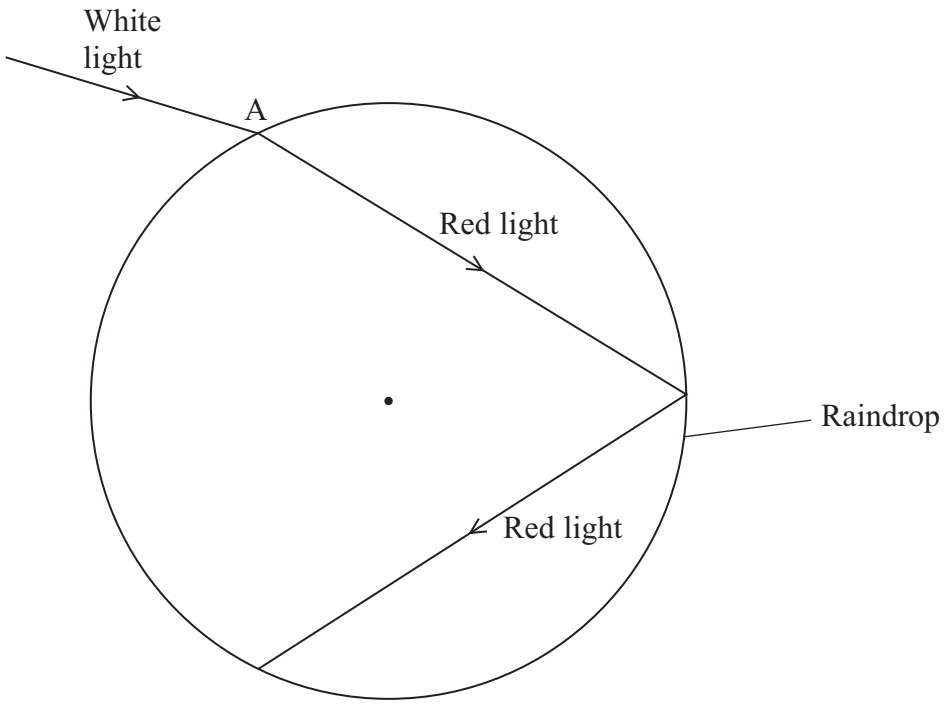
(2)

Critical angle =

(Total for Question = 7 marks)

5 Rainbows are seen when sunlight is dispersed by raindrops. The light is separated into different colours because they each take different paths through raindrops.

A ray of white light is incident on a raindrop. The diagram shows the subsequent path of the red light.



(a) Name the effect that is experienced by the red light at A.

(1)

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(b) (i) On the diagram label an angle of incidence with an *i* and an angle of refraction with an *r*.

(2)

(ii) On the diagram draw the path that a violet ray of light would take, through the raindrop and into the air.

(2)

(c) (i) State what is meant by the critical angle.

(1)

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(ii) Calculate the critical angle for red light in the raindrop.

refractive index for red light in water 1.3

(2)

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Critical angle .....

(d) Red light has a frequency of 4.2×10^{14} Hz and travels at a speed of 2.2×10^{8} m s ^{1} in the raindrop.

Calculate the wavelength of the red light in the raindrop.

(2)

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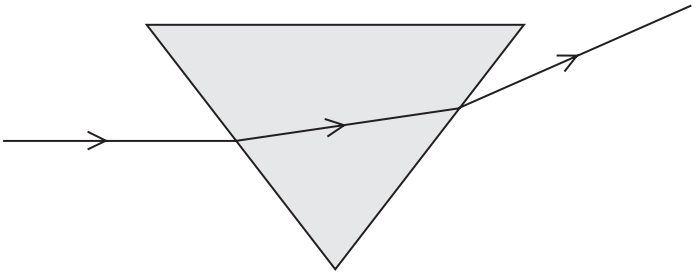
Wavelength .....

(Total for Question 10 marks)

6 (a) Refractometers are used in the food manufacturing industry to measure the concentration of sugar in different drinks. As the concentration of sugar increases, the refractive index of the liquid also increases. A simple refractometer uses a hollow prism shape that can be filled with different liquids.

(i) The simplified diagram below shows a ray of light passing through a prism filled with a liquid.

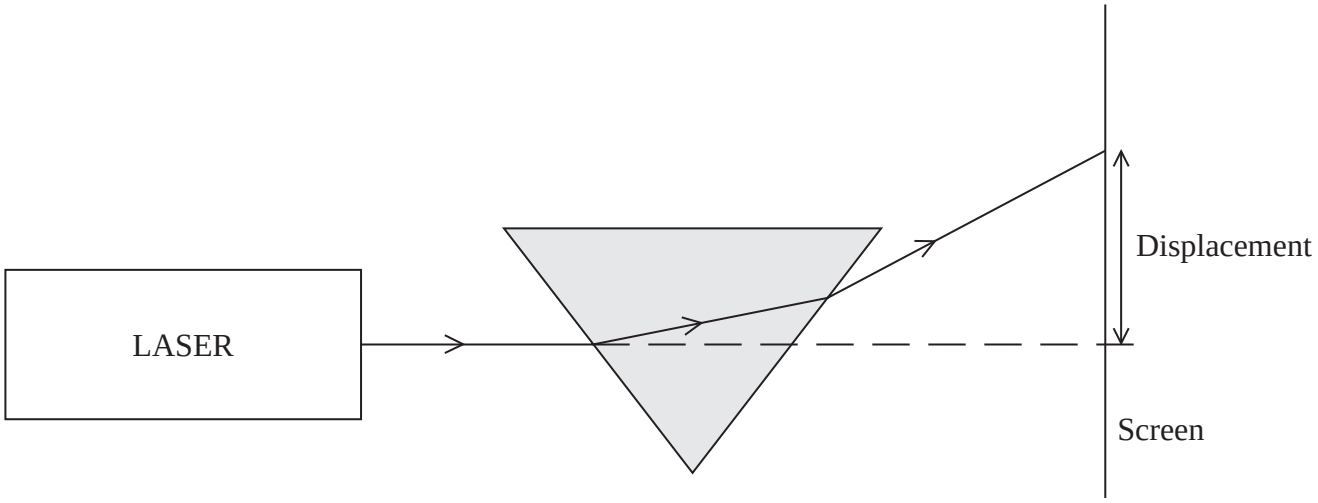


The liquid is replaced with one of a higher sugar concentration.

Using the same incident ray, draw the new path through the liquid and out of the prism.

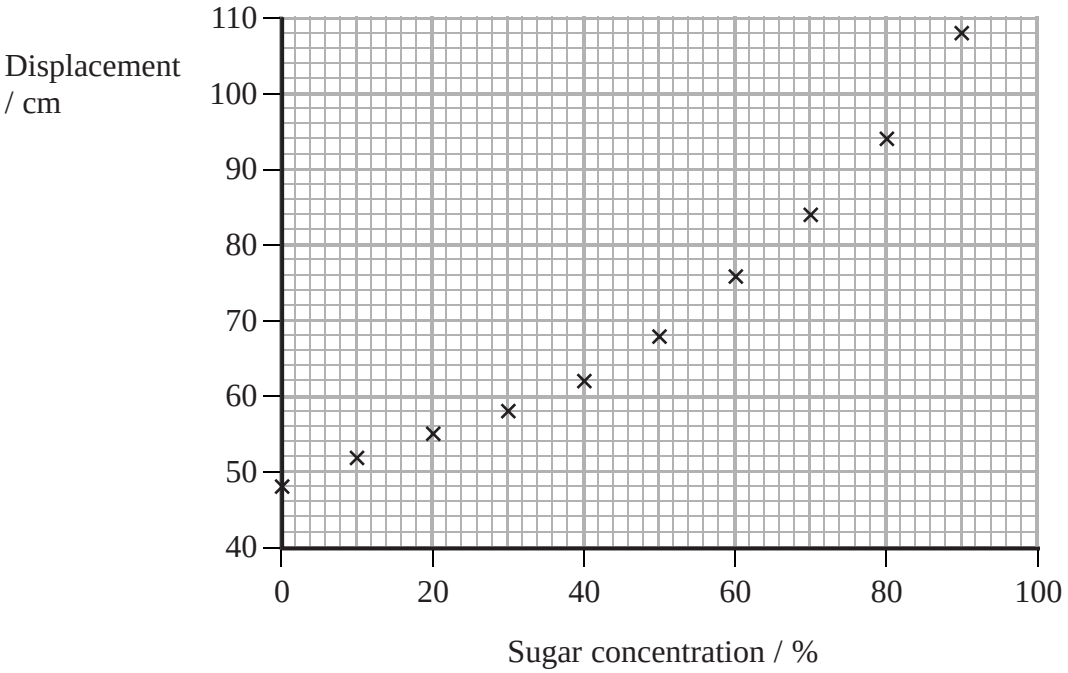
(2)

(ii) In practice, a laser beam is shone through the empty prism. The position of the emergent ray is marked on a screen. The prism is filled with a liquid of a known sugar concentration and the displacement on the screen is recorded.



This is repeated for a number of different known concentrations.

The graph shows how the displacement varies with the sugar concentration.



Describe how the displacement varies with sugar concentration.

(2)

(iii) A sample of unknown concentration produced a displacement of 88 cm.

Draw the line of best fit on the graph and use it to find the sugar concentration of the sample.

(2)

Concentration =

(iv) Give a reason why the distance between the screen and the prism must be kept constant.

(1)

(b) Another method of measuring sugar concentrations uses polarised light.

(i) Explain what is meant by polarised light.

(2)

*(ii) When polarised light passes through a sugar solution, the plane of polarisation rotates through an angle.

Explain how to measure this angle of rotation.

(4)

(Total for Question = 13 marks)