1 Dolphins use ultrasound when hunting prey. They emit short pulses of ultrasound, known as clicks, and detect the ultrasound reflected from their prey.

(a) Describe how ultrasound travels through water.

(2)

(b) Suggest why the dolphins emit a series of clicks rather than a continuous sound.

(1)

(c) When searching for prey the dolphins emit 16 clicks per second.

(i) Show that the time between clicks when searching for prey is about 0.06 s.

(1)

(ii) Calculate the maximum distance that can be determined by the dolphin when searching for prey.

speed of sound in seawater = 1530 m s^{-1}

(3)

(iii) The dolphin increases the number of clicks per second to 125 when near to capturing its prey.

Suggest why.

(1)

(d) Bats use ultrasound in air when hunting prey. The ultrasound frequency and the duration of the click is the same for both bats and dolphins.

Explain whether bats or dolphins would be able to locate their prey more precisely.

speed of sound in air = 330 m s^{-1}

(3)

(Total for Question = 11 marks)

2 (a) State what is meant by the principle of superposition of waves.

(2)

(b) Electromagnetic waves involve oscillating electric fields.

A student made the following notes about the polarisation of electromagnetic waves. The notes contain a number of errors.

Electromagnetic waves are transverse, with oscillations parallel to the direction of motion.

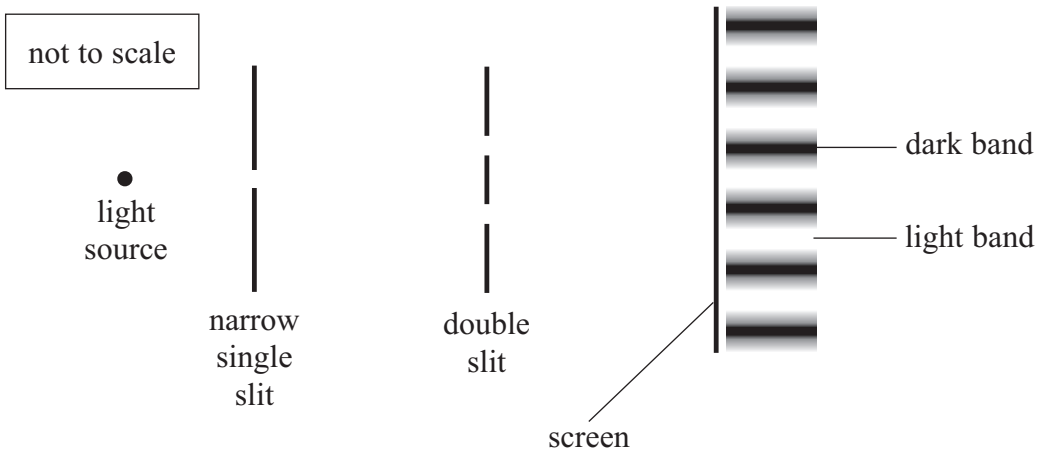
When they pass through a polarising filter all the components of the oscillations perpendicular to the filter's plane of polarisation are rotated.

The oscillations of the polarised wave are all in the same plane which is perpendicular to the direction of energy transfer.

Copy the passage, correcting the errors.

(4)

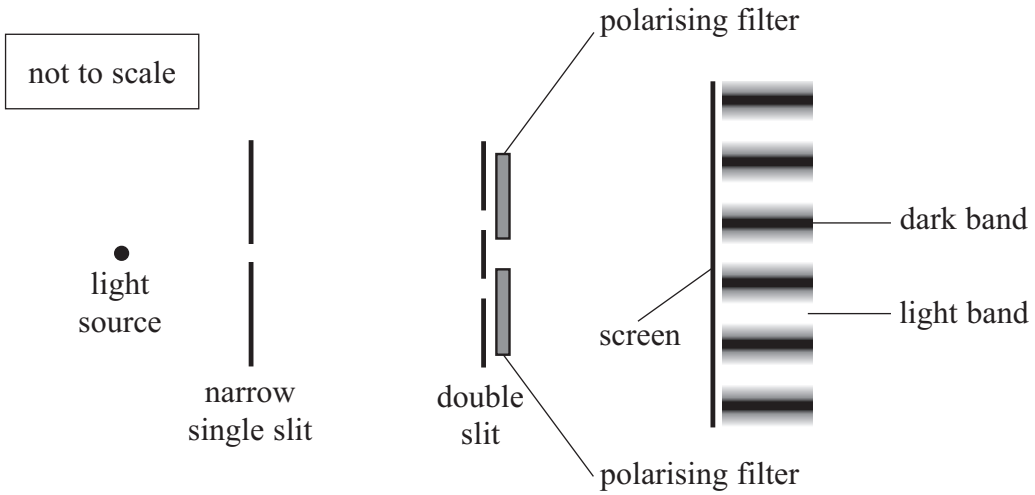
(c) The arrangement in the diagram demonstrates the effect of superposition. When a monochromatic light source is used, a series of dark and light bands is formed on the screen.



*(i) Explain how the dark and light bands are formed by light reaching the screen from the two slits of the double slit.

(3)

(ii) Polarising filters are placed behind the slits as shown. When the planes of polarisation are parallel, the pattern of light and dark bands is still seen.



If one polarising filter is rotated through 90° there are no dark bands and the screen is illuminated evenly.

Explain why there are no dark bands when one filter has a plane of polarisation at 90° to that of the other filter.

(3)

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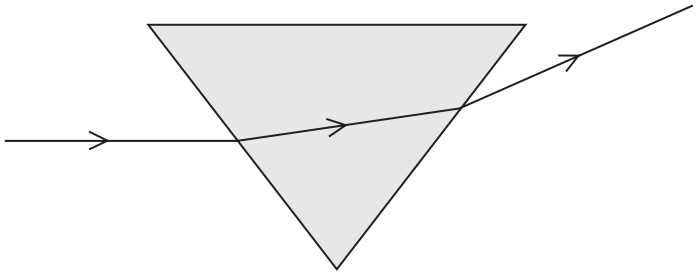
(Total for Question 12 marks)

3 (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.

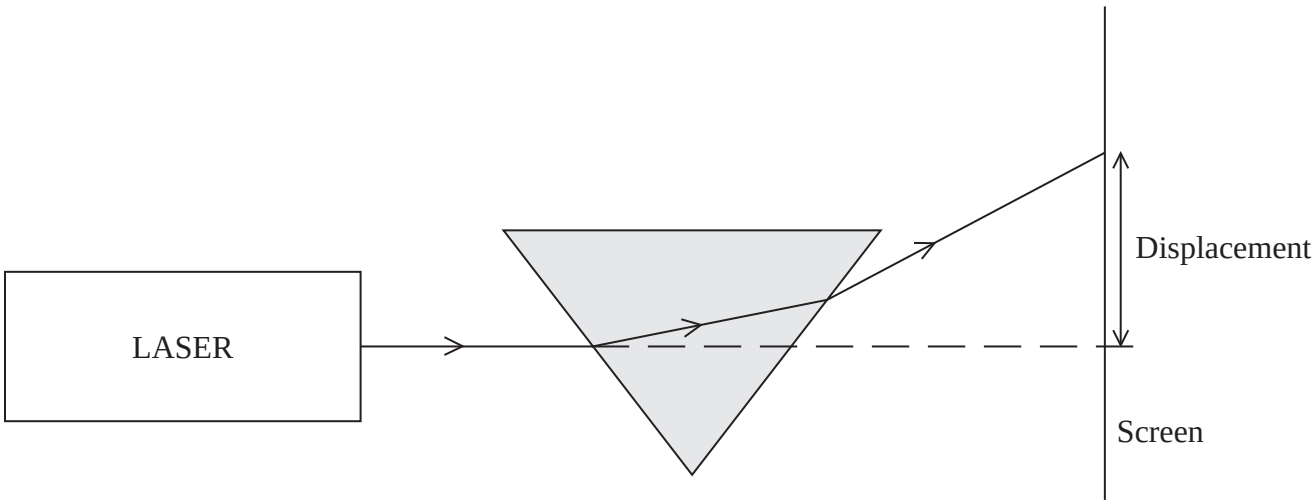


The liquid is replaced with one of a higher sugar concentration.

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

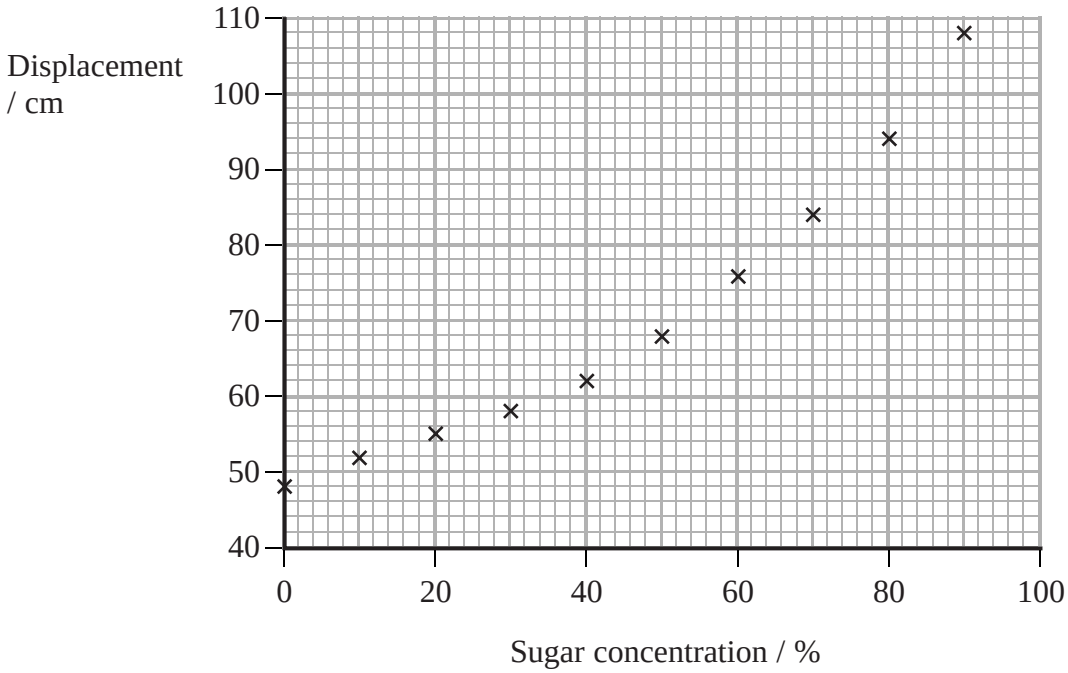
(2)

(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)

4 Dentists often use a white composite material for fillings for teeth. This material is applied as a liquid and then hardened using blue light.

The photograph shows a light gun, used by dentists, that emits the blue light.

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(a) The light gun emits light of radiation flux 8000 W m^{-2}.

A particular tooth needs a filling of cross-sectional area 1.5×10^{-5} m^2. It requires 2.3 J of incident light energy to harden the filling.

Calculate the time for which the light must be applied.

(3)

Time =

(b) The light gun is supplied with a rechargeable battery of capacity 1.4 amp hours. When in use, the output potential difference of the battery is 3.7 V.

(i) Assuming the potential difference is constant, show that the maximum energy supplied by the battery is about 20 000 J.

(2)

(ii) Assuming each filling requires 2.3 J of incident light energy, a fully charged battery can be used to power the light gun to harden 210 fillings.

Calculate the efficiency of the light gun at supplying the energy stored in the battery to the fillings.

(3)

Efficiency =

(Total for Question = 8 marks)