Advanced Higher Physics

Wave Phenomena

Homework

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Gravitational acceleration	g	$9{\cdot}8\ \mathrm{m\ s^{-2}}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ \mathrm{kg}$
Radius of Earth	R_E	$6{\cdot}4 \times 10^{6}\ \mathrm{m}$	Charge on electron	e	$-1{\cdot}60 \times 10^{-19}\ \mathrm{C}$
Mass of Earth	M_E	$6{\cdot}0 \times 10^{24}\ \mathrm{kg}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\ \mathrm{kg}$
Mass of Moon	M_M	$7{\cdot}3 \times 10^{22}\ \mathrm{kg}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\ \mathrm{kg}$
Mean Radius of Moon Orbit		$3{\cdot}84 \times 10^{8}\ \mathrm{m}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\ \mathrm{J\ s}$
Universal constant of gravitation	G	$6{\cdot}67 \times 10^{-11}\ \mathrm{m^3\ kg^{-1}\ s^{-2}}$	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}\ \mathrm{F\ m^{-1}}$
Speed of light in vacuum	c	$3{\cdot}0 \times 10^{8}\ \mathrm{m\ s^{-1}}$	Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \mathrm{H\ m^{-1}}$
Speed of sound in air	v	$3{\cdot}4 \times 10^{2}\ \mathrm{m\ s^{-1}}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Glycerol	1·47
Glass	1·51	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49		

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 10590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/ $\mathrm{kg\ m^{-3}}$	*Melting Point*/ K	*Boiling Point*/ K	*Specific Heat Capacity*/ $\mathrm{J\ kg^{-1}\ K^{-1}}$	*Specific Latent Heat of Fusion*/ $\mathrm{J\ kg^{-1}}$	*Specific Latent Heat of Vaporisation*/ $\mathrm{J\ kg^{-1}}$
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623	$9{\cdot}02 \times 10^{2}$	$3{\cdot}95 \times 10^{5}$	....
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853	$3{\cdot}86 \times 10^{2}$	$2{\cdot}05 \times 10^{5}$	....
Glass	$2{\cdot}60 \times 10^{3}$	1400	....	$6{\cdot}70 \times 10^{2}$	....	....
Ice	$9{\cdot}20 \times 10^{2}$	273	....	$2{\cdot}10 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	....
Glycerol	$1{\cdot}26 \times 10^{3}$	291	563	$2{\cdot}43 \times 10^{3}$	$1{\cdot}81 \times 10^{5}$	$8{\cdot}30 \times 10^{5}$
Methanol	$7{\cdot}91 \times 10^{2}$	175	338	$2{\cdot}52 \times 10^{3}$	$9{\cdot}9 \times 10^{4}$	$1{\cdot}12 \times 10^{6}$
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377	$3{\cdot}93 \times 10^{3}$	....	....
Water	$1{\cdot}00 \times 10^{3}$	273	373	$4{\cdot}19 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	$2{\cdot}26 \times 10^{6}$
Air	1·29	....	....	....	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^{4}$	....	$4{\cdot}50 \times 10^{5}$
Nitrogen	1·25	63	77	$1{\cdot}04 \times 10^{3}$	....	$2{\cdot}00 \times 10^{5}$
Oxygen	1·43	55	90	$9{\cdot}18 \times 10^{2}$	....	$2{\cdot}40 \times 10^{5}$

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

1. (*a*) A travelling wave is represented by the expression

$$y = 3{\cdot}5 \sin(62{\cdot}8t - 1{\cdot}25x)$$

where x and y are expressed in metres and t in seconds.

(i) Calculate the following for the travelling wave:

(A) the frequency in Hz;

(B) the wavelength.

(ii) The intensity of the wave doubles.

(A) Which of the quantities in the equation changes in value?

(B) Write down the equation which describes the wave with double the intensity. **7**

(*b*) An emergency vehicle, travelling at $22\,\text{m}\,\text{s}^{-1}$, emits sound of frequency 1020 Hz. The vehicle approaches a stationary pedestrian, as shown in Figure 15.

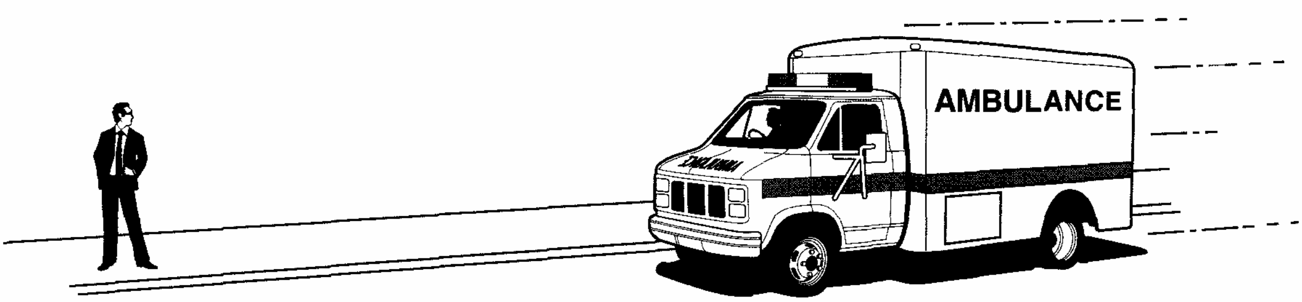

Figure 15

The frequency detected by a stationary observer when a sound source moves relative to the observer is given by

$$f = f_s \frac{v}{v \pm v_s}$$

where the symbols have their usual meanings.

Calculate the frequency heard by the stationary pedestrian as the emergency vehicle approaches. **2**

2. (*a*) A water wave travelling in the negative x direction has frequency 3·0 Hz, velocity 0·050 m s^{-1} and initial amplitude 0·040 m.

(i) Write down an expression for the displacement y of a point on the water surface in terms of x and time t.

(ii) After some time the amplitude of the wave has fallen to 0·020 m.

By what factor has the intensity of the wave changed compared to its initial value? **4**

(*b*) When a continuous sound wave of constant frequency is reflected from a wall, a stationary wave is produced.

Explain in terms of the incident and reflected waves how nodes **and** anti-nodes are formed. **2**

(*c*) (i) A car horn produces a note of frequency 200 Hz.

The horn is sounded as the car is moving at 30 m s^{-1} away from a stationary observer.

Calculate the frequency heard by the observer.

(ii) An observer on Earth notes that the frequency of light from a distant galaxy is Doppler shifted towards the red end of the spectrum.

State whether the galaxy is moving towards or away from Earth. **You must justify your answer**. **4**

(10)

3. A wave travelling along a horizontal string is represented by the equation

$$y = 25\sin 2\pi(55t - \frac{x}{16})$$

where x and y are in millimetres and t in seconds.

(*a*) State the amplitude of the wave. **1**

(*b*) Calculate the speed of the wave. **3**

(*c*) Two points on the string are separated by a horizontal distance of 24 mm. Calculate the phase difference between these points. **2**

(*d*) Another two points on the wave are described as being in phase.

State a possible value for the horizontal distance between these points. **1**

(7)

4. A transverse wave is described by the expression

$$y = 8{\cdot}0 \sin(12t - 0{\cdot}50x)$$

where t is in seconds and x and y are in metres.

(*a*) For this wave, calculate the:

(i) frequency;

(ii) wavelength. **2**

(*b*) (i) Calculate the phase difference, in radians, between the point at $x = 3{\cdot}0$ m and the point at $x = 4{\cdot}0$ m.

(ii) Calculate the time for the wave to travel between these two points. **4**

(*c*) The wave is reflected and loses some energy.

State a possible equation for the reflected wave. **2**

(8)

5. (*a*) According to modern particle theory, protons and neutrons are composed of combinations of up and down quarks. Up quarks have a charge of $+\frac{2}{3}e$ while down quarks have a charge of $-\frac{1}{3}e$.

(i) Name the force which holds the quarks together in protons and neutrons. **1**

(ii) State the combination of up and down quarks which make up:

(A) a proton;

(B) a neutron. **2**

(*b*) A neutron can decay into a proton, electron and antineutrino.

Name the force associated with this decay. **1**

(*c*) A thermal neutron has a velocity of $3{\cdot}5 \times 10^3\,\text{m s}^{-1}$.

Calculate the de Broglie wavelength of this neutron. **2**

(6)

6. (*a*) A travelling wave is represented by the expression

$$y = 2\cdot0 \times 10^{-4} \sin(1570t - 4\cdot6x)$$

where x and y are in metres and t is in seconds.

(i) Calculate the frequency of the wave. **2**

(ii) A wave with the same frequency and four times the intensity travels in the opposite direction.

Write down the equation which represents this wave. **2**

(*b*) A train emits a sound of frequency 800 Hz as it passes through a station. The sound is heard by a person on the station platform as shown in Figure 18.

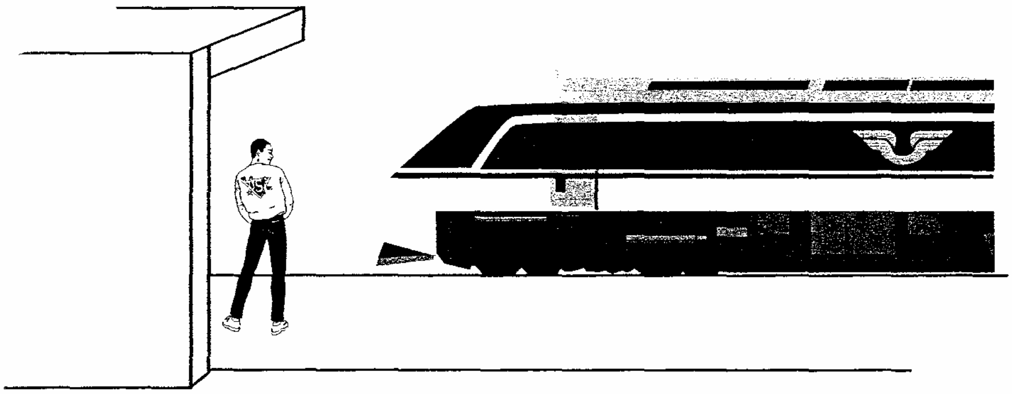

Figure 18

(i) Describe how the frequency of the sound, heard by the person, changes as the train passes through the station. **1**

(ii) Explain, in terms of wavefronts, why this frequency change occurs. You may wish to include a diagram as part of your answer. **2**

(iii) At one instant the person hears a sound of frequency 760 Hz. Calculate the speed of the train relative to the person on the platform at this time. **2**

(9)

7. (*a*) A water wave travels with a speed of 0·060 m s^{-1} in the positive x direction. Figure 14 represents the water wave at one instant in time.

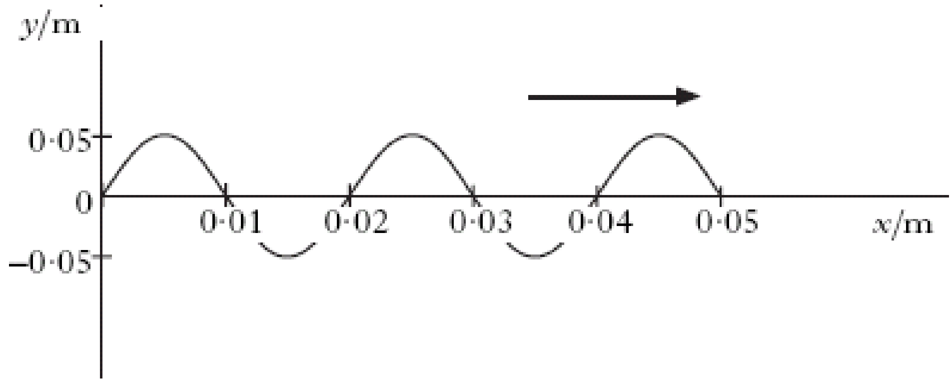

Figure 14

Write down an equation for the vertical displacement y of a point on the water surface in terms of the horizontal displacement x and time t.

Numerical values are required. **2**

(*b*) Write down an equation for an identical wave travelling in the opposite direction. **1**

(*c*) The amplitude of the wave gradually decreases.

Calculate the amplitude of the water wave when the intensity of the wave has decreased by 50%. **2**

(5)

8. (*a*) The driver of a sports car approaches a building where an alarm is sounding as shown in Figure 14.

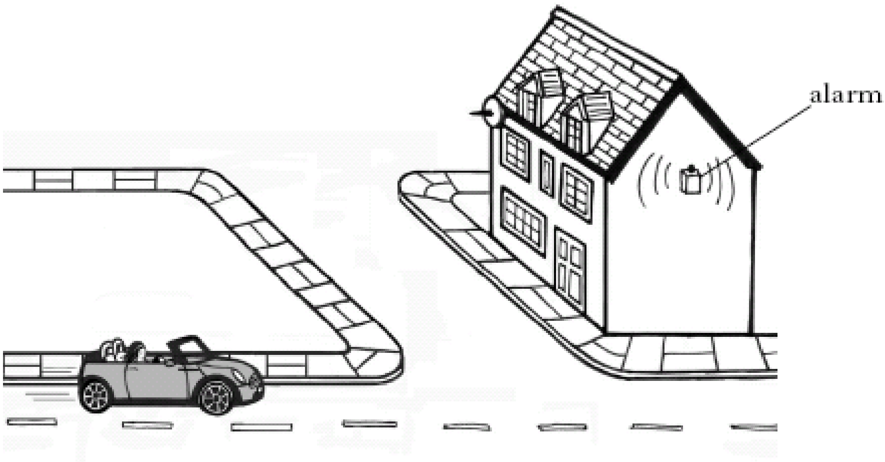

Figure 14

The speed of the car is $25{\cdot}0\,\mathrm{m\,s^{-1}}$ and the frequency of the sound emitted by the alarm is 1250 Hz.

(i) Explain in terms of wavefronts why the sound heard by the driver does not have a frequency of 1250 Hz. You may wish to include a diagram to support your answer. **2**

(ii) Calculate the frequency of the sound from the alarm heard by the driver. **2**

(*b*) The spectrum of light from most stars contains lines corresponding to helium gas.

Figure 15(*a*) shows the helium spectrum from the Sun.

Figure 15(*b*) shows the helium spectrum from a distant star.

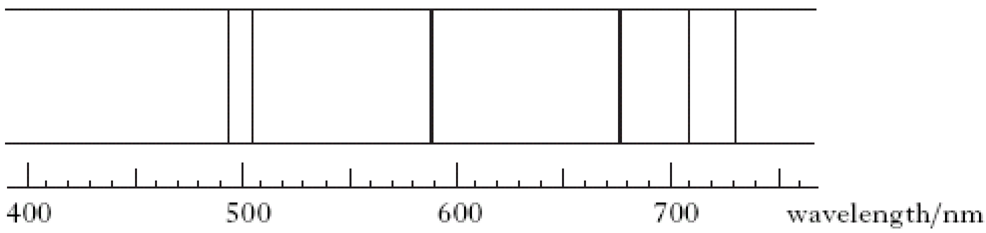

Figure 15(*a*)

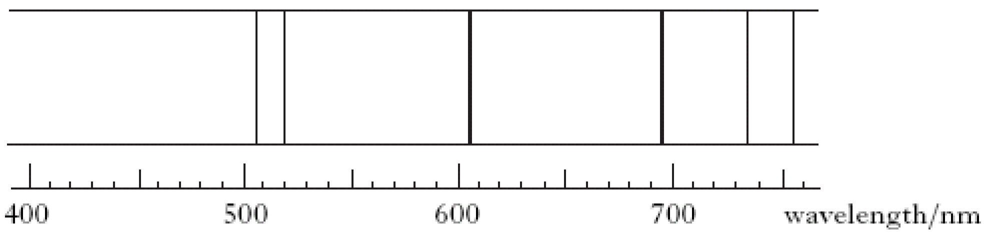

Figure 15(*b*)

By comparing these spectra, what conclusion can be made about the distant star? Justify your answer. **2**

(6)

9. A thin air wedge is formed between two flat glass plates which are in contact at one end and separated by a thin copper wire at the other end.

The experimental arrangement in Figure 16 shows how interference fringes can be observed using a travelling microscope.

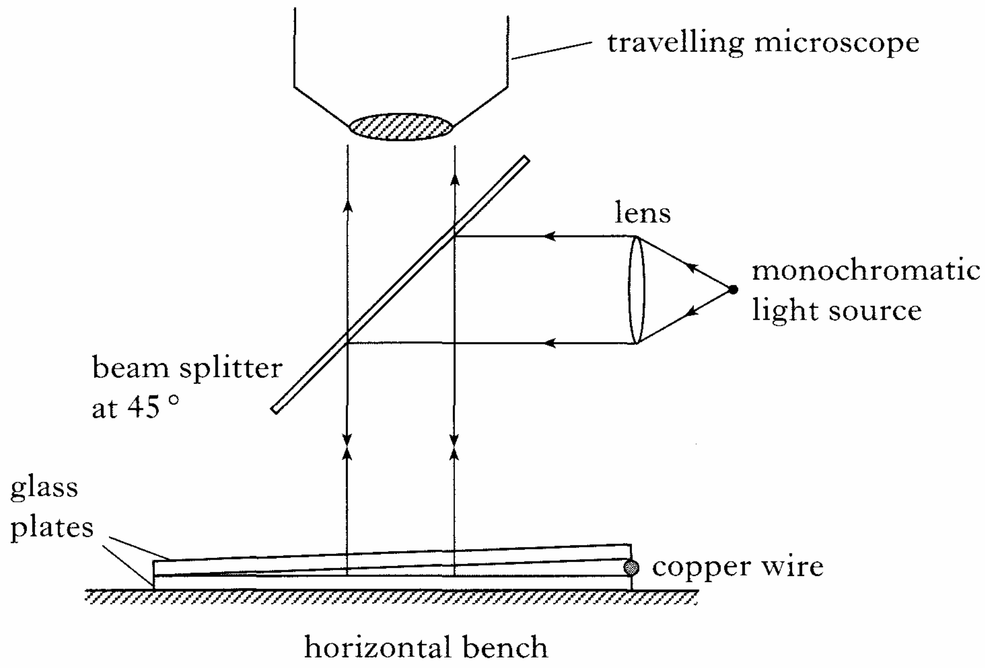

Figure 16

(*a*) In this arrangement, state whether the interference fringes are produced by division of amplitude or by division of wavefront. **1**

(*b*) Measurements are taken as follows:

separation of fringes	=	0·080 mm
length of each glass plate	=	75·0 mm
wavelength of monochromatic light	=	589 nm.

The separation of thin air wedge fringes is given by the expression

$$\Delta x = \frac{\lambda}{2\tan\theta}$$

where the symbols have their usual meanings.

Calculate the diameter of the copper wire. **2**

(*c*) Water enters the wedge and replaces all the air, as shown in Figure 17.

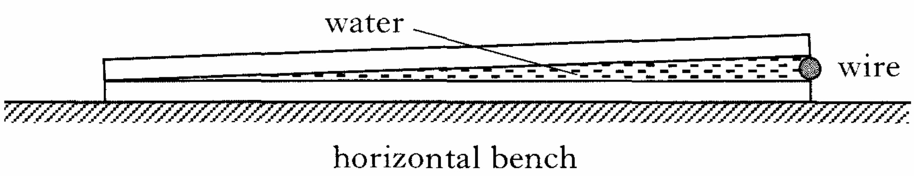

Figure 17

(i) Describe the change that occurs in the interference pattern.

(ii) Explain this change. **3**

10. (*a*) (i) Explain, **with the aid of a diagram**, how a thin coating on the surface of a camera lens can make it non-reflecting for monochromatic light at near normal incidence.

(ii) Calculate the thickness of a layer of magnesium fluoride required to make the surface of a lens non-reflecting for light of wavelength 500 nm.

(iii) When white light is incident upon a lens with this coating, a purple hue is observed in the reflected light. Explain how this colour effect is produced. **6**

(*b*) Light from a red laser is incident upon a double slit which has a slit separation of $5{\cdot}0 \times 10^{-5}$ m. A screen is placed 2·0 m beyond the double slit as shown in Figure 9.

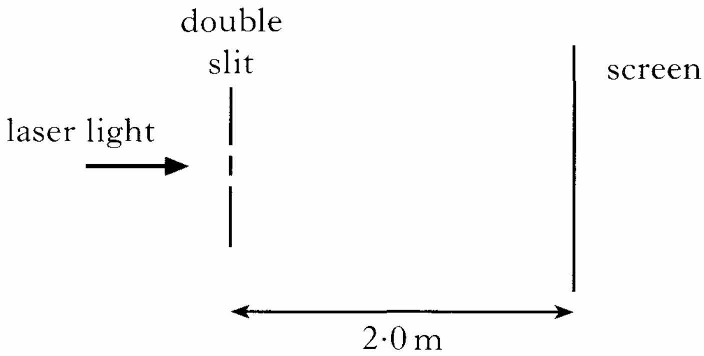

Figure 9

A pattern of light and dark fringes, as shown in Figure 10, is observed on the screen.

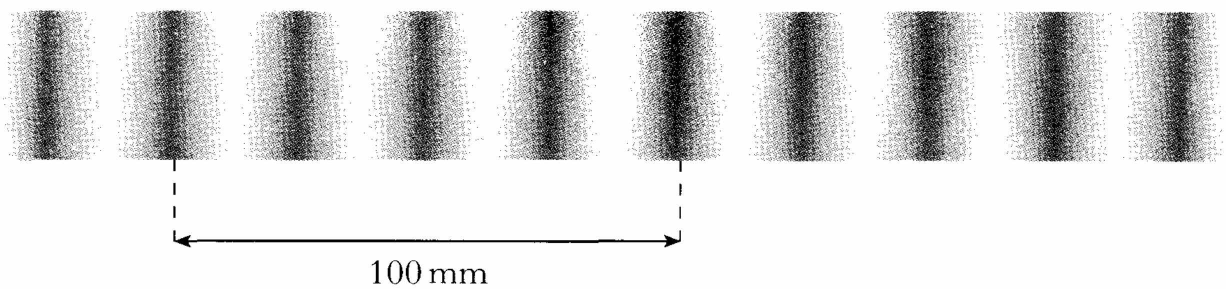

Figure 10

Calculate the wavelength of the laser light. **3**

(9)

11. (*a*) (i) State the condition for two light sources to be coherent.

(ii) Monochromatic light is directed towards a glass slide as shown in Figure 19. The glass has a refractive index of 1·4.

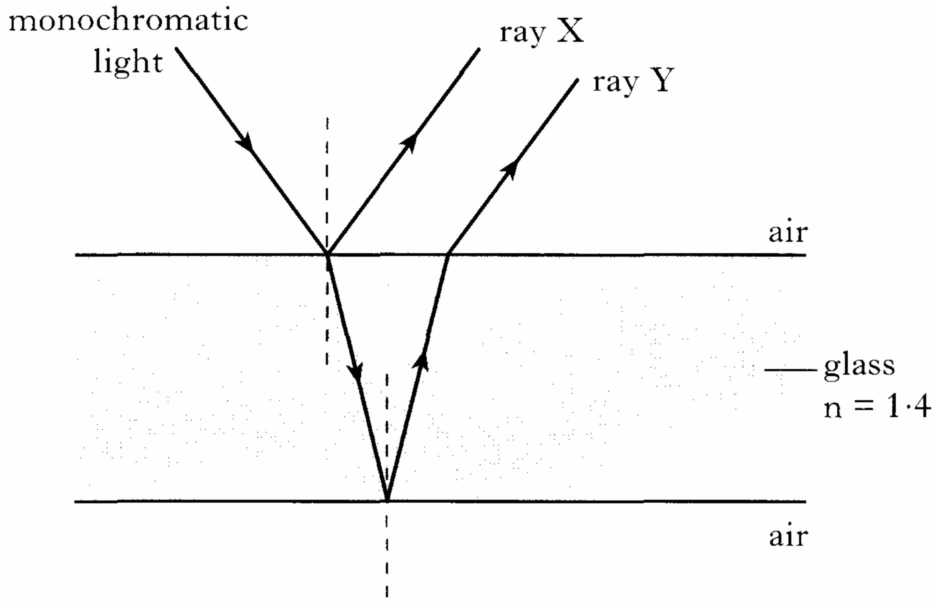

Figure 19

Ray Y has travelled further than ray X.

State the relationship between the path difference and the **optical** path difference between the rays.

(iii) In terms of optical path difference, state the conditions for:

(A) constructive interference of rays X and Y;

(B) destructive interference of rays X and Y.

(iv) A glass slide, set up as shown in Figure 19, is observed at near normal incidence. Constructive interference is observed.

The glass slide is now placed on the surface of a liquid of refractive index greater than 1·4. Destructive interference is now observed at near normal incidence.

Explain this observed change. **4**

(*b*) Good quality lenses reflect very little light.

A thin coating of magnesium fluoride on the surface of a lens reduces reflection.

(i) Explain briefly why this coating reduces reflection.

(ii) Calculate the thickness of magnesium fluoride that minimises reflection for light of wavelength 550 nm. **3**

(7)

12. A television aerial is shown in Figure 15.

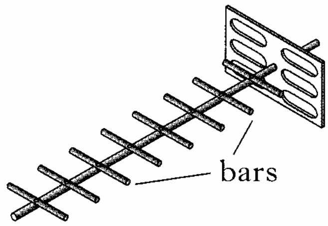

Figure 15

(*a*) Instructions for installing the aerial state

"*The television waves received are plane polarised. The aerial does not pick up a strong signal unless the plane of the bars is the same as the plane of polarisation of the television waves.*"

(i) Explain the term *plane polarised.*

(ii) The aerial is installed and connected to a television.

The television has a clear picture when the bars of the aerial are horizontal as shown in Figure 15.

The aerial is now slowly rotated until the bars are vertical as shown in Figure 16.

Describe what happens to the television picture during this rotation. **2**

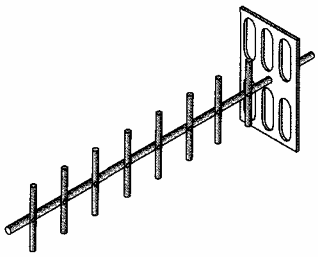

Figure 16

(*b*) Unpolarised light strikes the surface of a transparent material at the Brewster angle i_p, as shown in Figure 17. The reflected light is plane polarised.

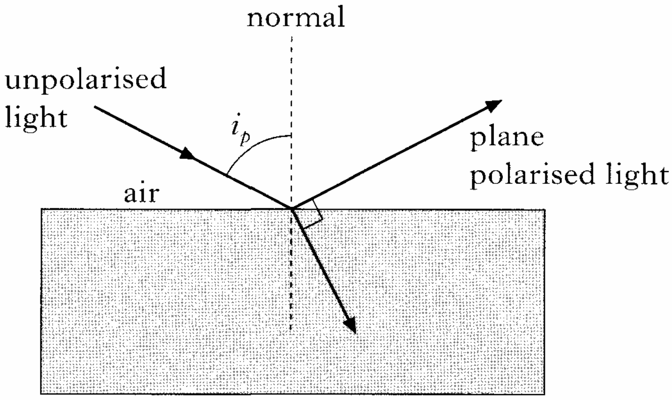

Figure 17

(i) Derive the expression

$$n = \tan i_p$$

where n is the refractive index of the transparent material.

(ii) Calculate the Brewster angle for perspex. **4**

(6)

13. A student sets up a Young's slits experiment in order to measure the wavelength of monochromatic light emitted by a laser. The light from the laser passes through a double slit before reaching a screen, where a pattern of light and dark fringes is seen, as shown in Figure 19.

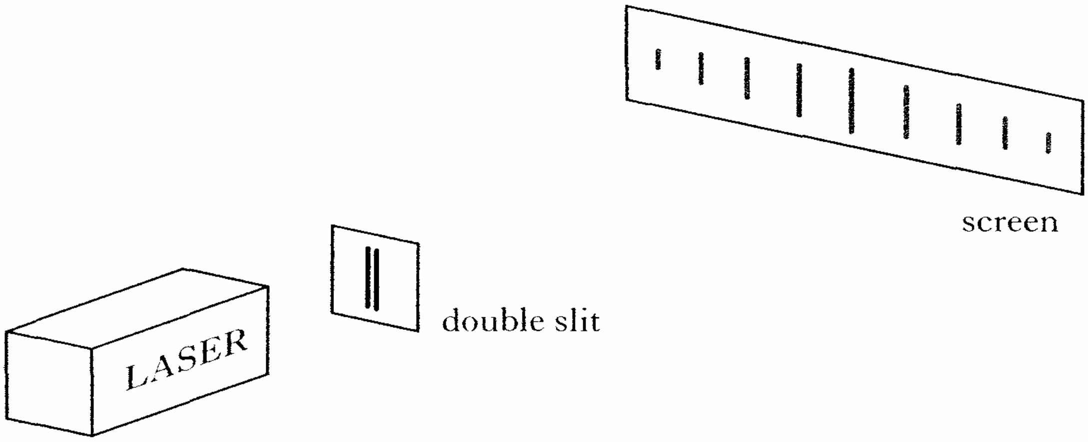

Figure 19

The student records the following measurements:

double slit separation	$= 0{\cdot}25 \pm 0{\cdot}01$ mm
distance between double slits and screen	$= 3{\cdot}91 \pm 0{\cdot}01$ m
distance between two adjacent bright fringes	$= 8{\cdot}0 \pm 0{\cdot}5$ mm.

(*a*) (i) Calculate the wavelength of the laser light. **2**

(ii) Show that the absolute uncertainty in the calculated wavelength is $\pm 4 \times 10^{-8}$ m. **2**

(iii) State why an answer of $\pm 3{\cdot}78 \times 10^{-8}$ m for part (*a*)(ii) would **not** be acceptable. **1**

(*b*) The student now measures the distance between 9 bright fringes (8 spaces). The result is

distance between 9 fringes (8 spaces) $= 64{\cdot}0 \pm 0{\cdot}5$ mm.

Calculate the new absolute uncertainty in wavelength, assuming the other measurements remain unchanged. **2**

(*c*) (i) The student then suggests that measuring the distance between 12 bright fringes would significantly reduce the absolute uncertainty in the wavelength. Explain why this is **not** correct. **1**

(ii) State which measurement must be made more accurately to reduce significantly the absolute uncertainty in the wavelength. **1**

(9)

14. In an experiment to measure the speed of sound in air, a loudspeaker, a signal generator and a reflector are set up as shown in Figure 14.

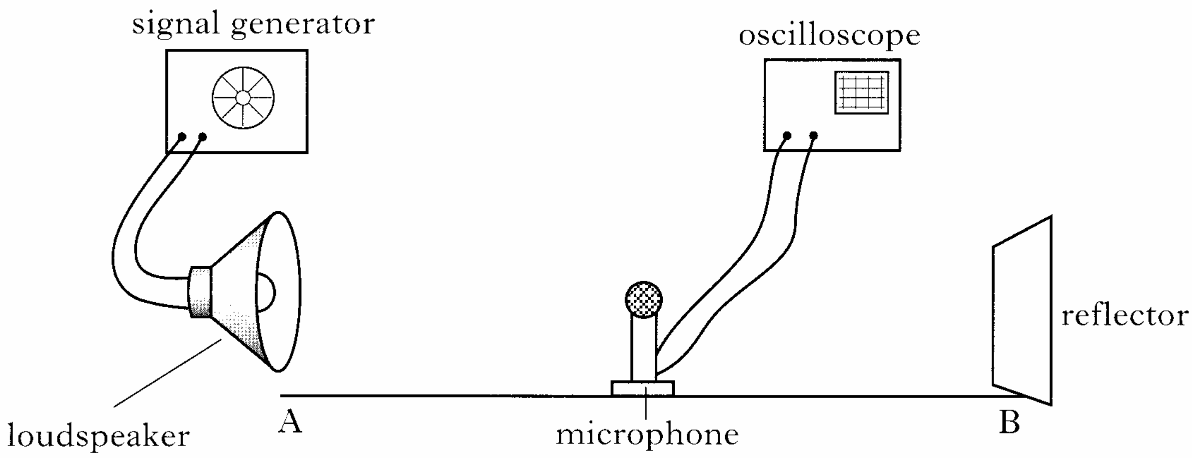

Figure 14

A stationary wave pattern is produced between the loudspeaker and the reflector. The intensity of the sound is monitored using a microphone connected to an oscilloscope. The microphone is moved steadily along line AB and the oscilloscope indicates alternate maximum and minimum values of sound intensity.

(*a*) What name is given to the points in the stationary wave pattern at which **minimum** values of sound intensity occur? **1**

(*b*) The signal generator is adjusted until the frequency of the sound produced is 2000 Hz. The distance between two successive points of minimum sound intensity is measured as 88 mm.

(i) Use this data to calculate the speed of sound in air. **3**

(ii) Suggest **one** improvement to the experiment which would result in a more accurate value for the speed of sound in air.

Justify your answer. **2**

(*c*) The microphone is placed at a position of minimum sound intensity. Without moving the microphone, the reflector is moved away from the loudspeaker until a minimum is again detected.

The intensity of sound at this minimum is found to be **greater** than the intensity of sound before the reflector was moved.

Explain this observation. **2**

(8)

15. (*a*) A thin coating of magnesium fluoride is applied to the surface of a camera lens.

Figure 15 shows an expanded view of this coating on the glass lens.

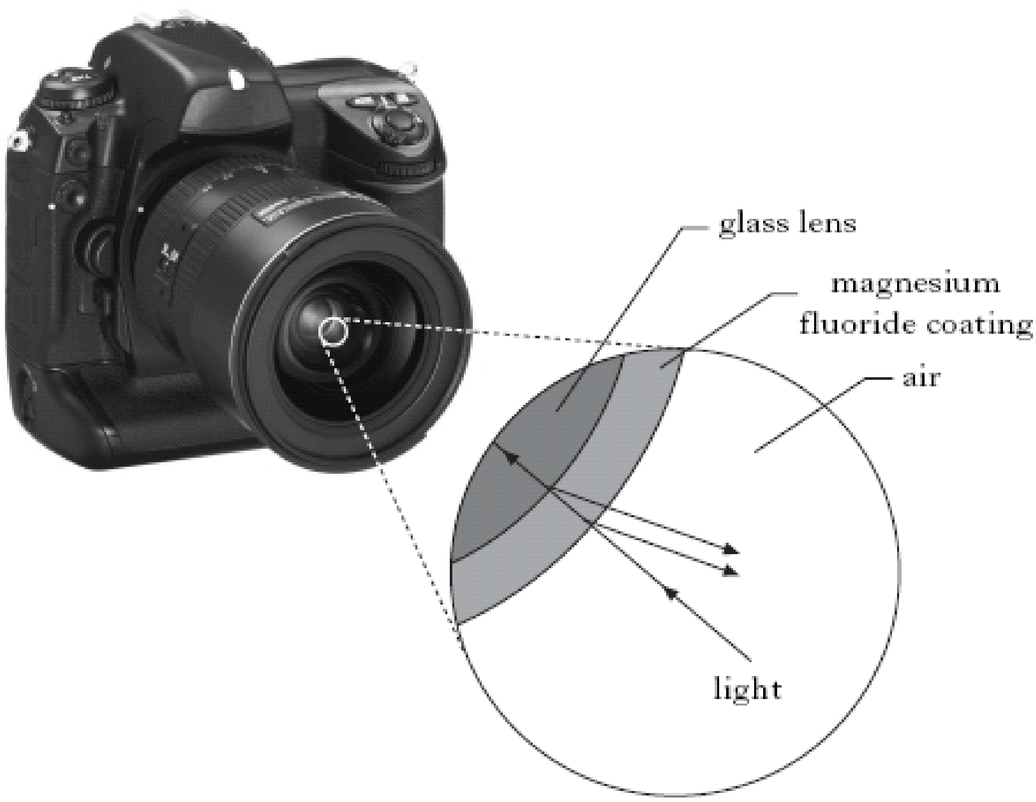

Figure 15

Monochromatic light is incident on the lens and some light reflects from the front and rear surfaces of the coating as shown in Figure 15.

(i) State the phase change undergone by the light reflected from:

(A) the front surface of the coating;

(B) the rear surface of the coating. **1**

(ii) Explain, in terms of optical path difference, why this coating can make the lens non-reflecting for a particular wavelength of light. **2**

(iii) Why is it desirable that camera lenses should reflect very little light? **1**

(iv) A particular lens has a magnesium fluoride coating of thickness $1 \cdot 05 \times 10^{-7}$ m.

Calculate the wavelength of light for which this lens is non-reflecting. **2**

15. (continued)

(*b*) A thin air wedge is formed between two glass plates which are in contact at one end and separated by a thin metal wire at the other end.

Figure 16 shows sodium light being reflected down onto the air wedge. A travelling microscope is used to view the resulting interference pattern.

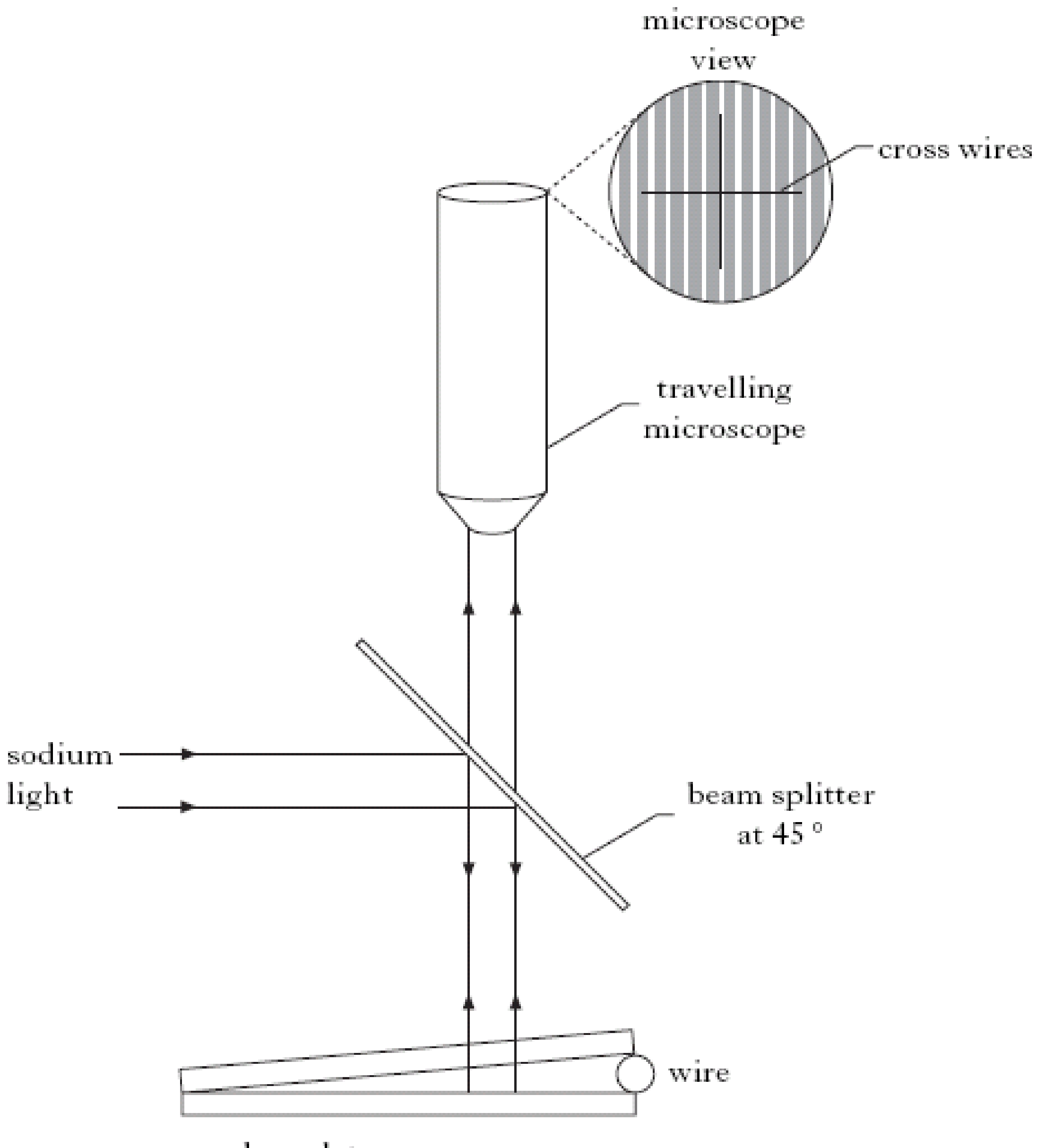

Figure 16

Explain how the diameter of the wire is determined using measurements obtained with this apparatus.

Assume the sodium light is monochromatic.

Your answer should include:

- the measurements required
- any data required
- the equation used. **2**

(8)

16. (*a*) (i) State what is meant by the term *plane polarised light*. **1**

(ii) Figure 16 shows the refraction of red light at a water-air interface.

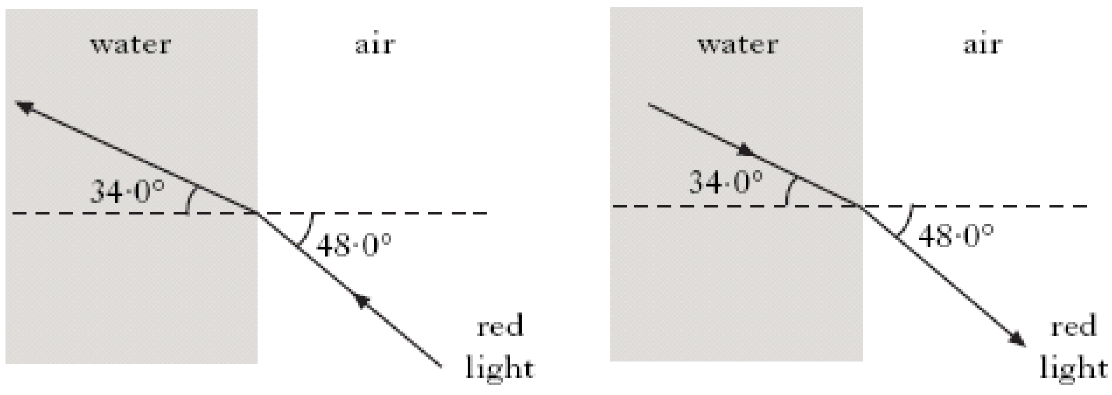

Figure 16

The refractive index n for red light travelling from air to water is 1·33. Show that the refractive index μ for red light travelling from **water** to **air** is 0·752. **1**

(iii) Figure 17 shows a ray of unpolarised red light incident on a water-air interface.

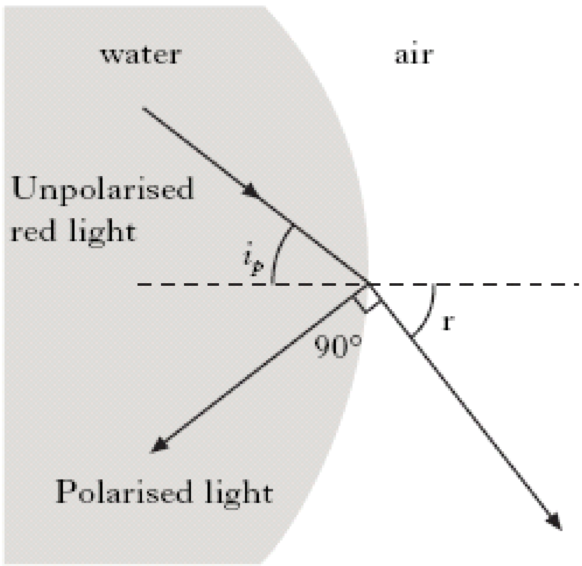

Figure 17

For light travelling from water to air,

$$\mu = \tan i_p$$

where i_p is the Brewster angle.

Calculate the Brewster angle for red light at this water-air interface. **1**

16. **(continued)**

(*b*) A rainbow is produced when light follows the path in a raindrop as shown in Figure 18.

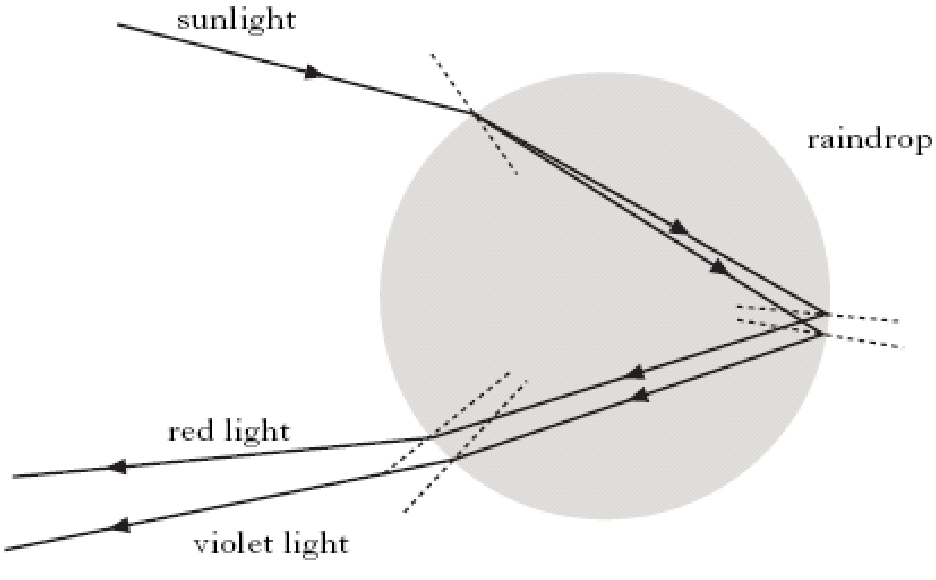

Figure 18

The light emerging from the raindrop is polarised.

The refractive index, μ, at a water to air interface is 0·752 for red light and 0·745 for violet light.

Calculate the difference in Brewster's angle for these two colours. **2**

(*c*) Rainbows produce light that is 96% polarised. A photographer plans to take a photograph of a rainbow. Her camera has a polarising filter in front of the lens as shown in Figure 19.

Figure 19

She directs her camera at the rainbow and slowly rotates the filter to see which is the best image to take.

Describe what happens to the image of the rainbow as she slowly rotates her filter through 180 °. **2**

(7)

17. (*a*) State the difference between polarised and unpolarised light. **1**

(*b*) Unpolarised monochromatic light is incident on a glass block of refractive index n at an angle i_p, as shown in Figure 18.

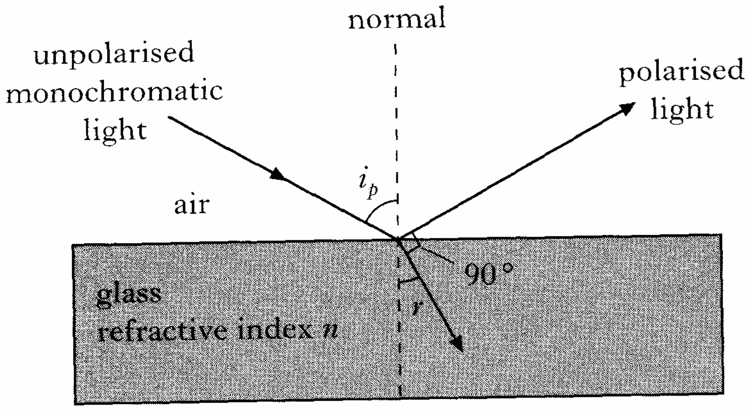

Figure 18

Light is refracted by the glass at angle r and polarised light is reflected by the glass.

Derive the expression

$n = \tan i_p$ where i_p is known as Brewster's angle. **2**

(*c*) Sunlight is reflected from the surface of a loch as shown in Figure 19.

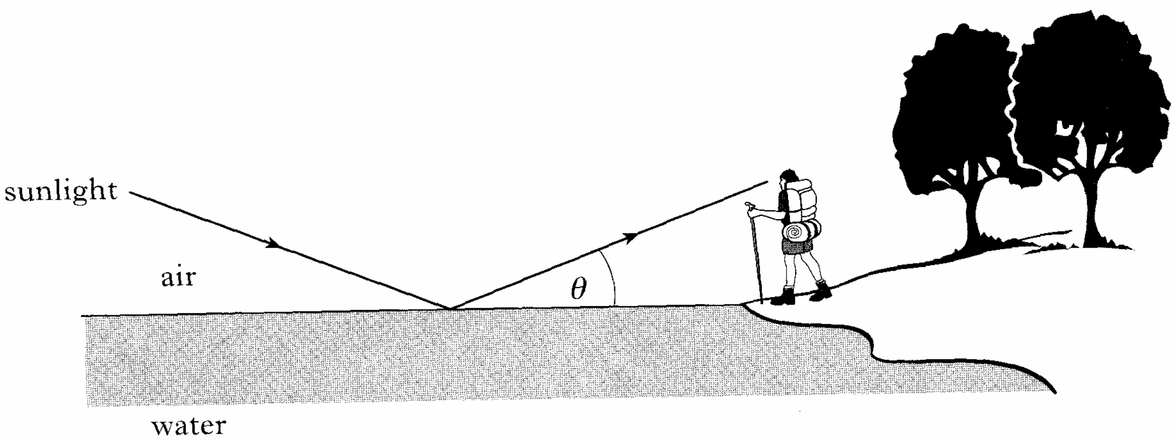

Figure 19

Calculate the angle θ at which the water reflects plane polarised light to the observer on the shore. **2**

(5)

18. (*a*) State the difference between plane polarised light and unpolarised light. **1**

(*b*) Figure 20 shows two polarising filters.

The first filter is called the polariser and the second the analyser.

The direction of the transmission axis is shown for each filter.

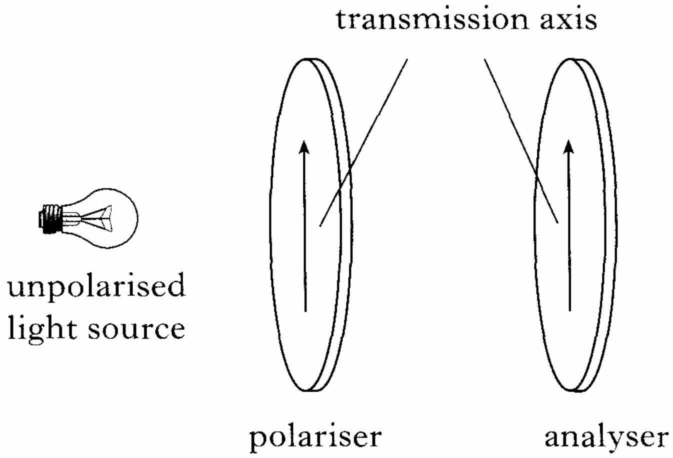

Figure 20

Unpolarised light is passed through the two filters.

The transmission axis of the analyser is now turned to different positions as shown in Figure 21.

Analyser setting	*Position of analyser's transmission axis*	*Intensity of transmitted light*/W m^{-2}
A	↑	5·0
B	↗	
C	→	
D	↘	
E	↓	

Figure 21

The intensity of transmitted light when the analyser is at setting A is 5·0 W m^{-2}.

State possible values for the intensity of the transmitted light when the transmission axis of the analyser is at settings B, C, D and E. **2**

18. (continued)

(*c*) Light can be polarised by reflection from a sheet of glass.

For a particular angle of incidence i_p, the reflected ray is totally plane polarised. This situation is represented in Figure 22.

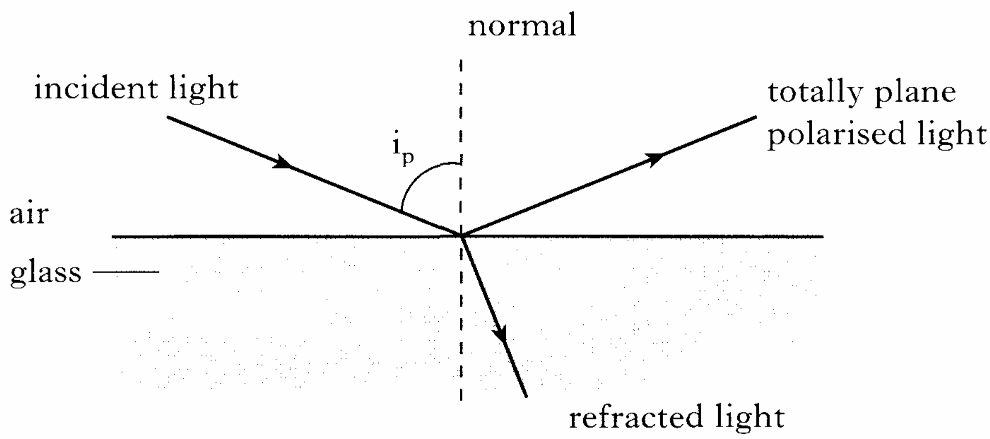

Figure 22

Show that,

$$\tan i_p = n$$

where n is the refractive index of the glass. **2**

(5)

19. A student sets up a "Young's double slit" experiment, as shown in Figure 18, to measure the wavelength of laser light.

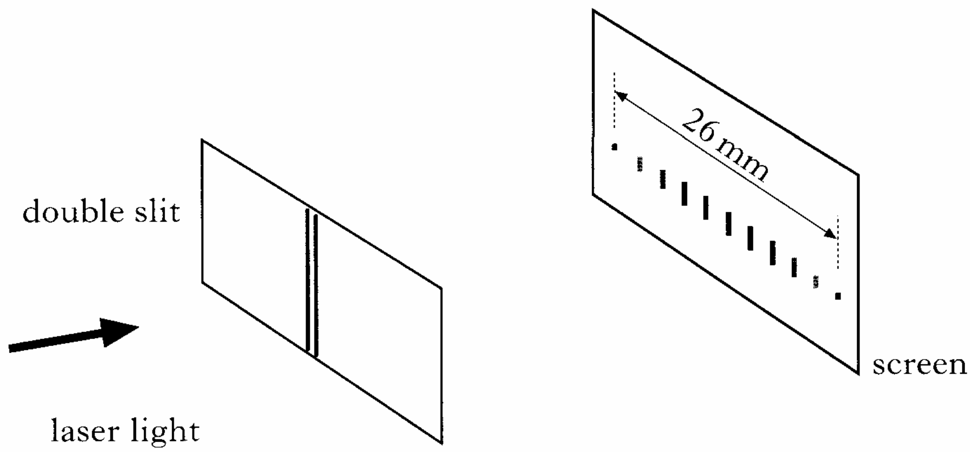

Figure 18

The student obtains the following results.

Separation of 11 fringes	26 (±2) mm
Distance to screen from slits	2·00 (±0·01) m
Separation of slits	0·52 (±0·02) mm

(*a*) Calculate the wavelength of the laser light. **2**

(*b*) Calculate the percentage uncertainty in this wavelength. **3**

(*c*) Suggest an improvement to the experiment that would reduce the uncertainty in the calculated value of the wavelength.
Justify your answer. **2**

(*d*) Which principle does this experiment illustrate, interference by division of wavefront or by division of amplitude? **1**

(8)

20. (*a*) State the difference between plane polarised light and unpolarised light. **1**

(*b*) The digital display on a calculator consists of many small segments of liquid crystal material.

A "0" changes to an "8" when the middle segment switches from light to dark as shown in Figure 20.

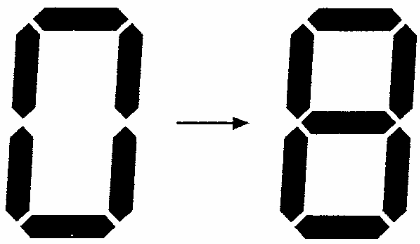

Figure 20

To make one segment of a 7-segment display, a slice of liquid crystal is placed between a piece of polarising material and a mirror. Figure 21 shows this arrangement for the **middle segment only**.

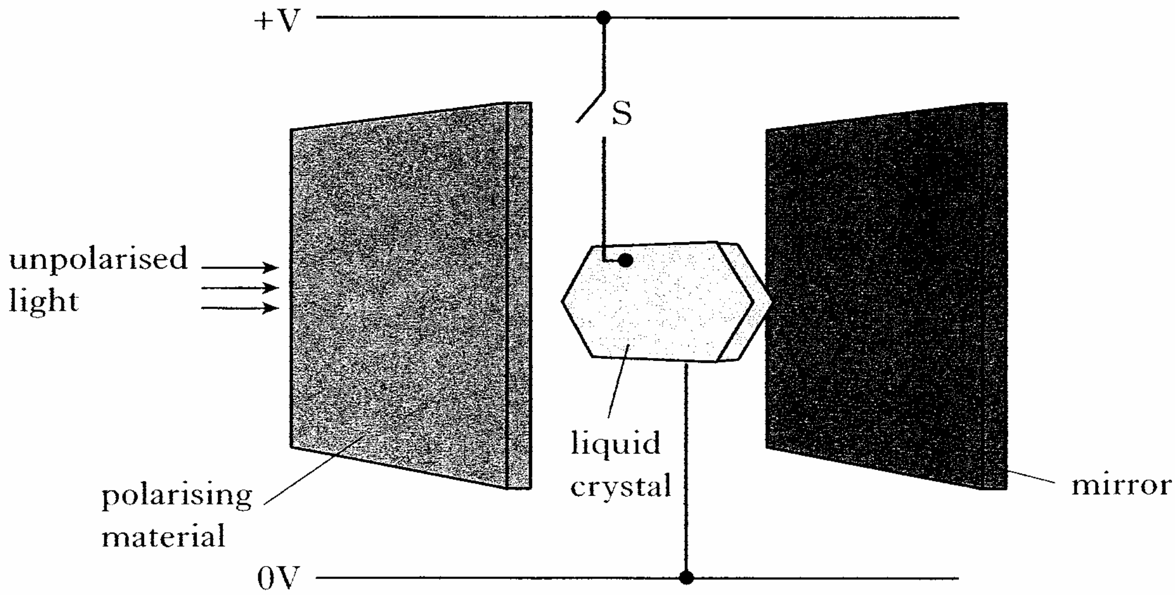

Figure 21

The following table summarises the effect of switch S.

Switch S	*Response of liquid crystal*
open	transmits polarised light
closed	does not transmit polarised light

(i) Explain why the liquid crystal appears dark when switch S is closed. **2**

(ii) State what happens to the switch when an "8" is changed to a "0". **1**

20. (continued)

(*c*) A student sees a row of numbers displayed on a calculator through a separate piece of polarising material as shown in Figure 22.

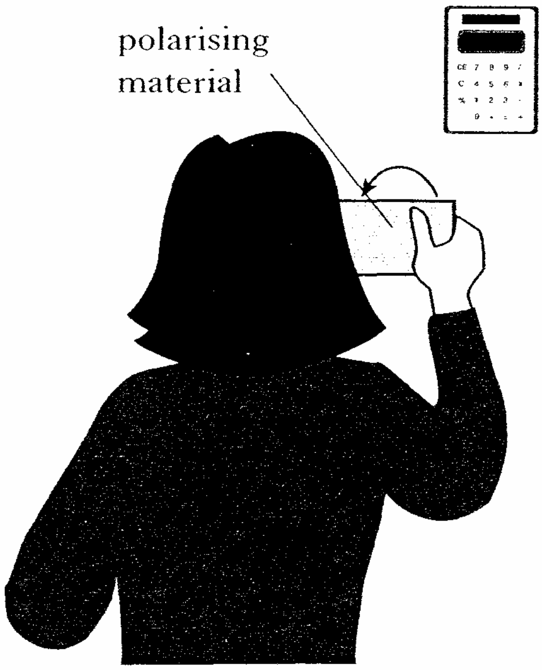

Figure 22

The student rotates the piece of polarising material through 180°. Explain what is seen as the polarising material is rotated. **2**

(6)

21. (*a*) An air wedge is formed between two flat glass plates of length l, which are in contact at one end. They are separated by a human hair of diameter d at the other end, as shown in Figure 15.

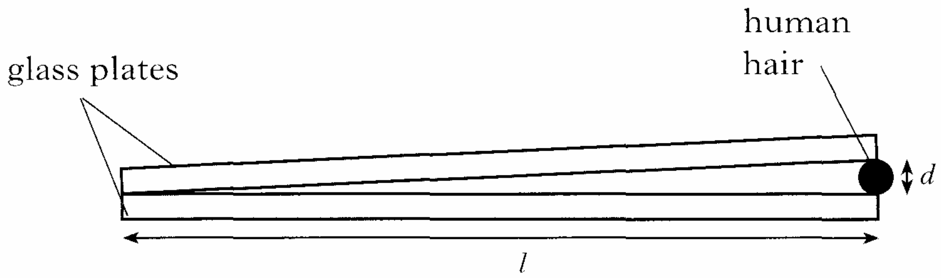

Figure 15

The air wedge is illuminated from above by a monochromatic light source of wavelength λ. When viewed from above a series of interference fringes of separation Δx is observed.

(i) Use this information to derive an expression for the diameter of the human hair. **2**

(ii) The wavelength of the monochromatic light is 589 nm, the length of the glass plates is 75 mm and the separation between two adjacent dark fringes is $3{\cdot}4 \times 10^{-4}$ m.

Calculate the diameter of the hair. **1**

(*b*) A camera lens can be made non-reflecting by coating it with a thin layer of magnesium fluoride.

(i) Calculate the thickness of magnesium fluoride required to make the lens non-reflecting for light of wavelength 548 nm. **2**

(ii) The lens has a thin film of transparent liquid placed on its surface as shown in Figure 16. The refractive index of the liquid is 1·45.

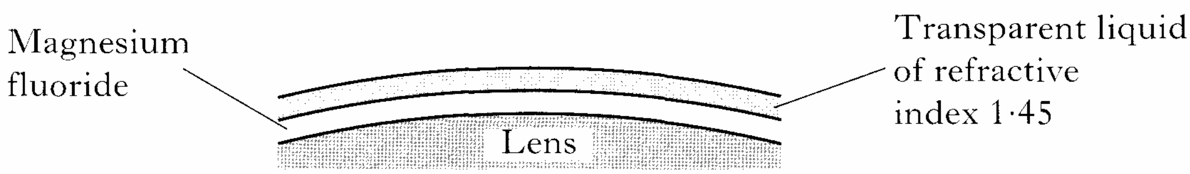

Figure 16

Explain why the coating is no longer non-reflective. **2**

(*c*) Explain why coloured fringes can be observed when a thin film of oil forms on a puddle of water. **1**

(8)

22. The apparatus shown in Figure 17 is set up to measure the speed of transverse waves on a stretched string.

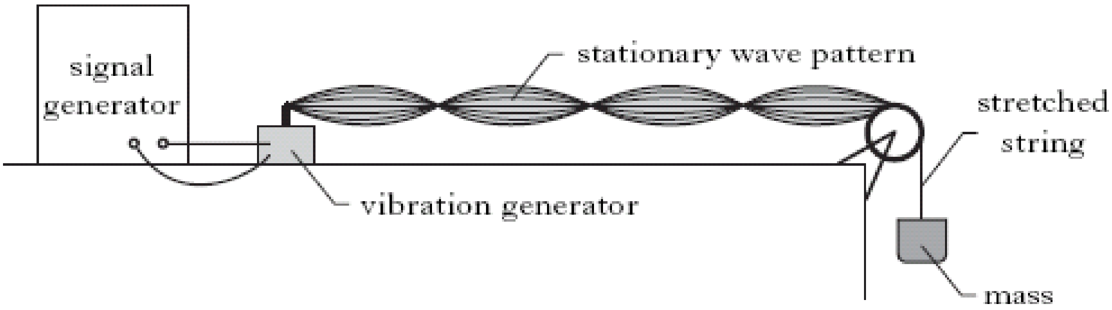

Figure 17

The following data are obtained.

Distance between adjacent nodes = $(0{\cdot}150 \pm 0{\cdot}005)$ m
Frequency of signal generator = (250 ± 10) Hz

(*a*) Show that the wave speed is $75\,\text{m}\,\text{s}^{-1}$. **2**

(*b*) Calculate the absolute uncertainty in this value for the wave speed. Express your answer in the form $(75 \pm \quad)\,\text{m}\,\text{s}^{-1}$. **3**

(*c*) (i) In an attempt to reduce the absolute uncertainty, the frequency of the signal generator is increased to (500 ± 10) Hz. Explain why this will **not** result in a reduced absolute uncertainty. **1**

(ii) State how the absolute uncertainty in wave speed could be reduced. **1**

(7)

23. Light from a helium-neon laser is incident on a double slit. A pattern of light and dark fringes is observed on a screen 3·50 m beyond the slits as shown in Figure 20.

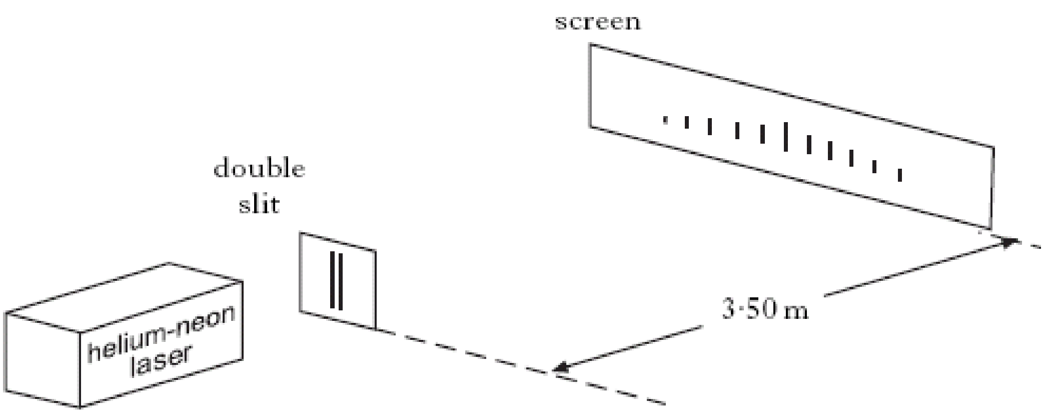

Figure 20

(*a*) State whether these fringes are caused by division of amplitude or division of wavefront. **1**

(*b*) The distance between two adjacent bright fringes on the screen is 7·20 mm. Calculate the separation of the two slits. **2**

(*c*) The distance between the double slit and screen is increased to 5·50 m. The distance between the fringes is remeasured and the calculation of the slit separation is repeated.

(i) Explain **one** advantage of moving the screen further away from the double slit. **2**

(ii) State **one** disadvantage of moving the screen further away from the double slit. **1**

(6)