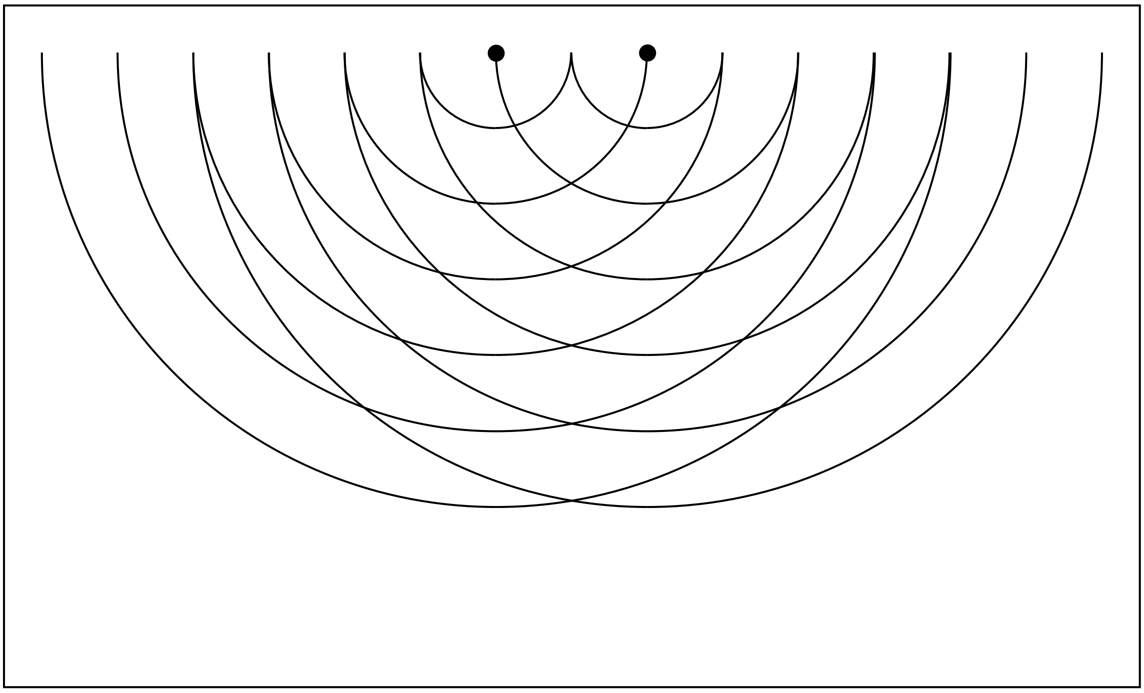
Wallace Hall Academy

CfE Higher Physics

Particles and Waves



Exam Questions Part 2

Contents

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^8\ m\ s^{-1}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\ J\ s$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\ C$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ kg$
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}\ m^3\ kg^{-1}\ s^{-2}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\ kg$
Gravitational acceleration on Earth	g	$9{\cdot}8\ m\ s^{-2}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\ kg$
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}\ s^{-1}$			

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	Water	1·33
Crown glass	1·50	Air	1·00

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

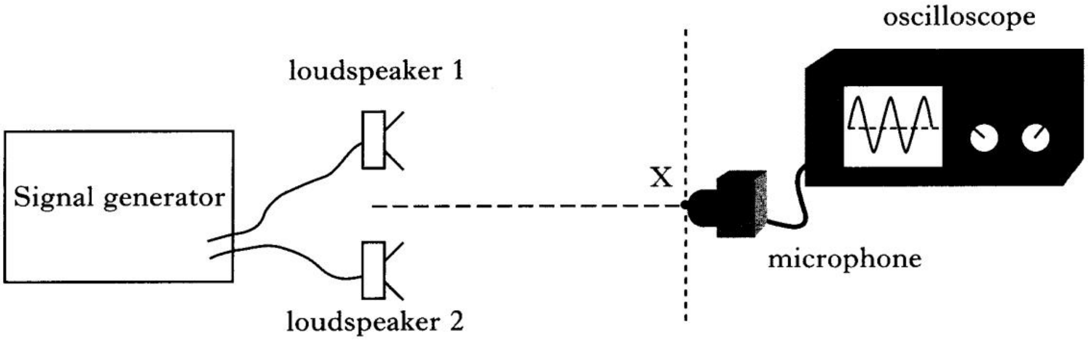
PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/kg m^{-3}	*Melting Point*/K	*Boiling Point*/K
Aluminium	$2{\cdot}70 \times 10^3$	933	2623
Copper	$8{\cdot}96 \times 10^3$	1357	2853
Ice	$9{\cdot}20 \times 10^2$	273	....
Sea Water	$1{\cdot}02 \times 10^3$	264	377
Water	$1{\cdot}00 \times 10^3$	273	373
Air	1·29	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

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

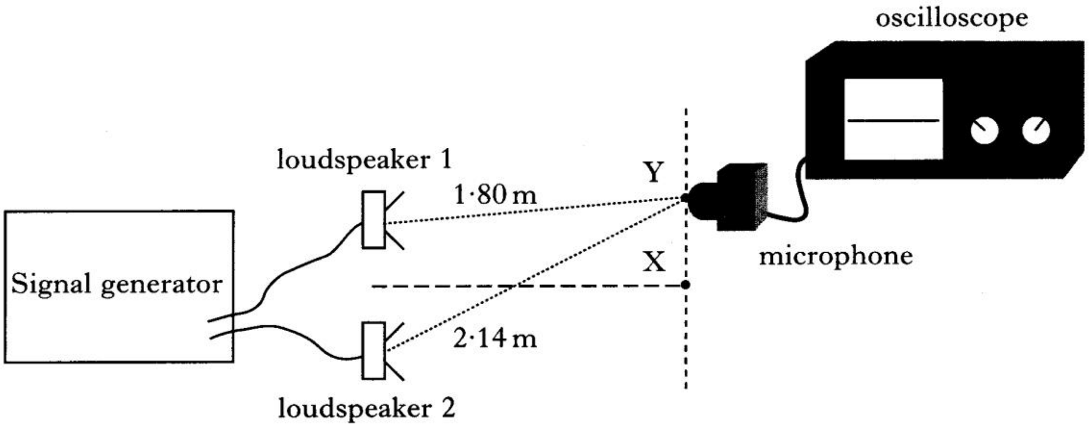
Section 5: Interference and Diffraction

1. A student is carrying out an experiment to investigate the interference of sound waves. She sets up the following apparatus.



The microphone is initially placed at point X which is the same distance from each loudspeaker. A maximum is detected at X.

(a) The microphone is now moved to the first minimum Y as shown.



Calculate the wavelength of the sound waves. 2

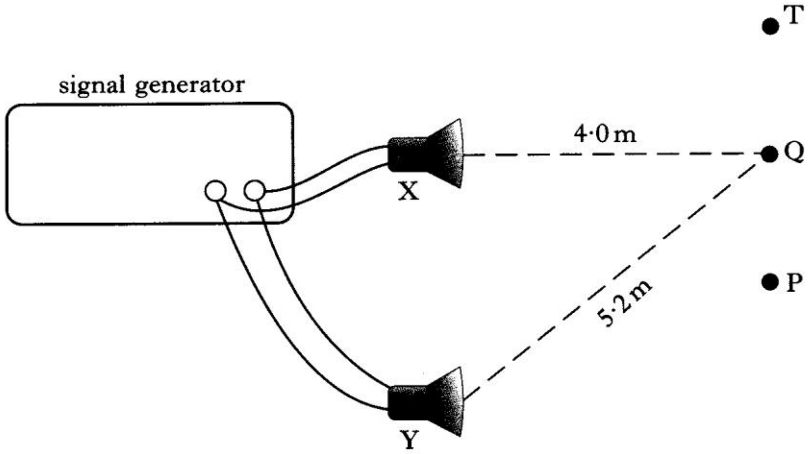
(b) Loudspeaker 1 is now disconnected.

What happens to the amplitude of the sound detected by the microphone at Y?

Explain your answer. 2

(4)

2. Two identical loudspeakers X and Y are set up in a room which has been designed to eliminate the reflection of sound. The loudspeakers are connected to the same signal generator as shown.



(a) (i) When a sound level meter is moved from P to T, maxima and minima of sound intensity are detected.

Explain, in terms of waves, why the maxima and minima are produced. 2

(ii) The sound level meter detects a maximum at P.

As the sound level meter is moved from P, it detects a minimum then a maximum then another minimum when it reaches Q.

Calculate the wavelength of the sound used. 2

(b) The sound level meter is now fixed at Q.

The frequency of the output from the signal generator is increased steadily from 200 Hz to 1000 Hz.

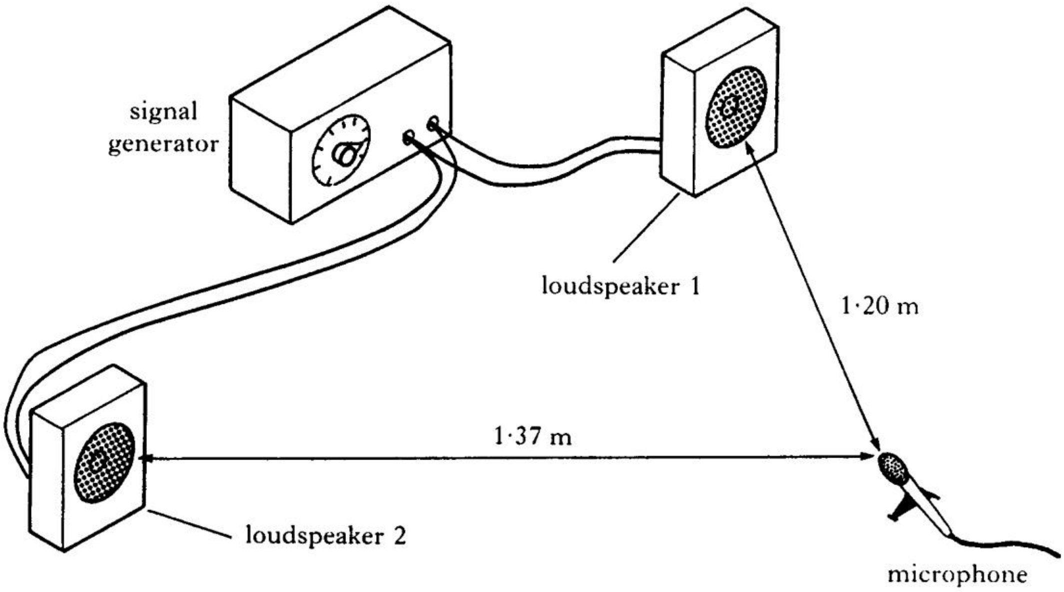
(i) What happens to the wavelength of the sound as the frequency of the output is increased? 1

(ii) Explain why the sound level meter detects a series of maxima and minima as the frequency of the output is increased. 2

(7)

3. Loudspeakers 1 and 2 are both connected to the same signal generator which is set to produce a 1·00 kHz signal.

Loudspeaker 1 is switched on but loudspeaker 2 is switched off.



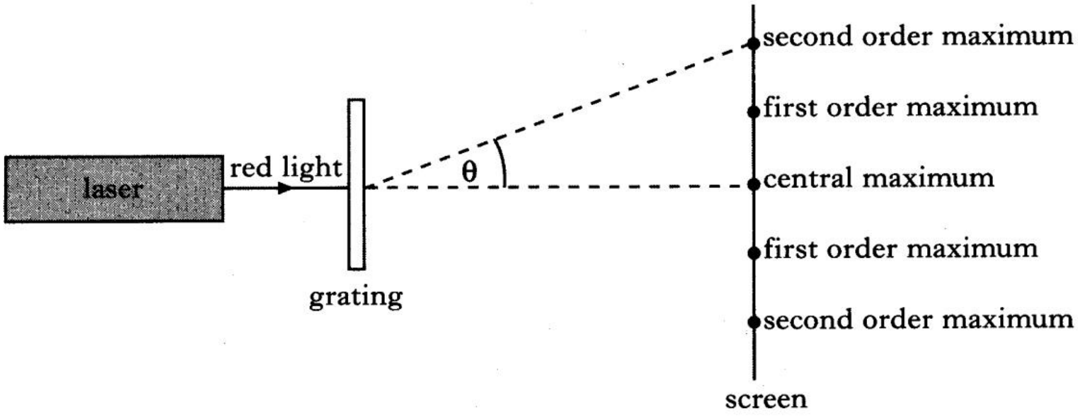
The speed of sound in air is 340 m s^{-1}.

State **and** explain, including an appropriate calculation, what happens to the amplitude of the signal picked up by the microphone when loudspeaker 2 is switched on. 3

(3)

4. A laser produces a narrow beam of monochromatic light.

(a) Red light from a laser passes through a grating as shown.



A series of maxima and minima are observed.

Explain in terms of waves how a minimum is produced. 1

(b) The laser is now replaced by a second laser, which emits blue light.

Explain why the observed maxima are now closer together. 1

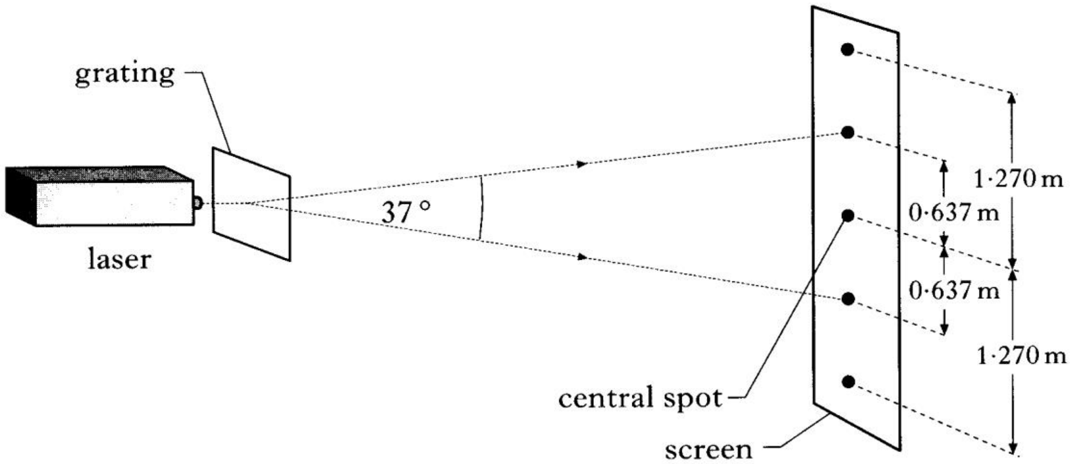
(c) The wavelength of the blue light from the second laser is $4{\cdot}73 \times 10^{-7}$ m.
The spacing between the lines on the grating is $2{\cdot}00 \times 10^{-6}$ m.

Calculate the angle between the central maximum and the second order maximum. 2

(4)

5. In an experiment, laser light of wavelength 633 nm is incident on a grating.

A series of bright spots are seen on a screen placed some distance from the grating. The distance between these spots and the central spot is shown.



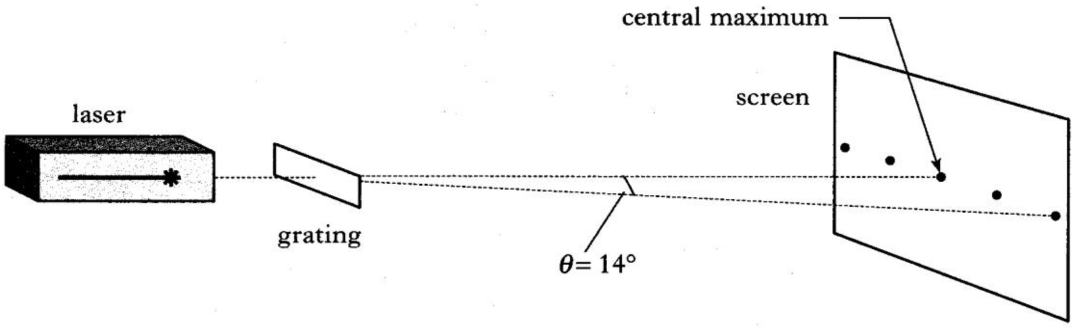
(a) Calculate the number of lines per metre on the grating. 3

(b) The laser is replaced with another laser and the experiment repeated. With this laser the bright spots are closer together.

How does the wavelength of the light from this laser compare with that from the original laser? You must justify your answer. 2

(5)

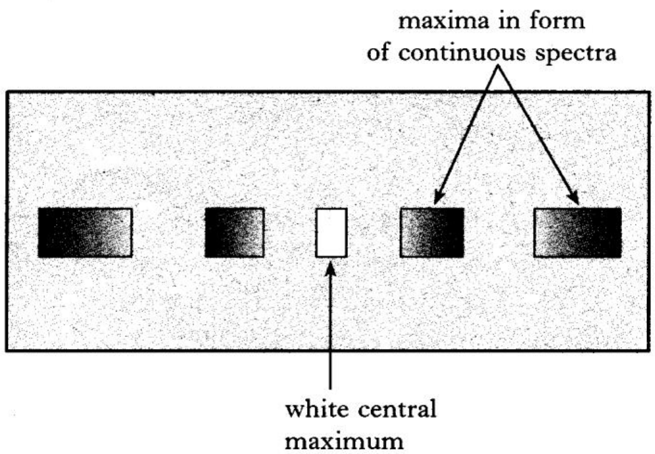
6. Light from a laser is shone onto a grating. The separation of the slits on the grating is $5{\cdot}0 \times 10^{-6}$ m. A pattern is produced on a screen as shown below.



(a) (i) The angle θ between the central maximum and the 2nd order maximum is 14°.
Calculate the wavelength of the light produced by the laser. 2

(ii) A pupil suggests that a more accurate value for the wavelength of the laser light can be found if a grating with a slit separation of $2{\cdot}0 \times 10^{-6}$ m is used.
Explain why this suggestion is correct. 2

(b) The laser is replaced by a source of white light and the pattern on the screen changes to a white central maximum with other maxima in the form of continuous spectra on each side of the central maximum.



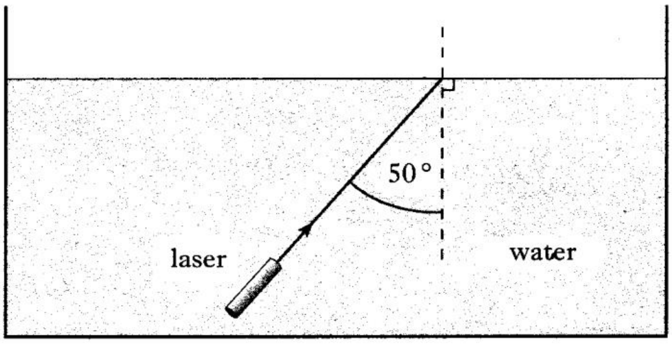
Explain:
(i) why the central maximum is white; 1
(ii) why the other maxima are in the form of continuous spectra. 2

(6)

Section 6: Refraction of Light

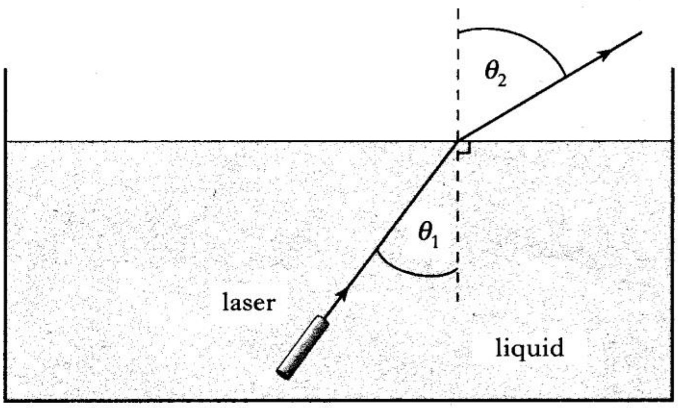
1. A laser beam is used to investigate the refraction of light from water into air.

   A waterproof laser is placed in within a tank of water and the laser beam is directed towards the water surface as shown below.

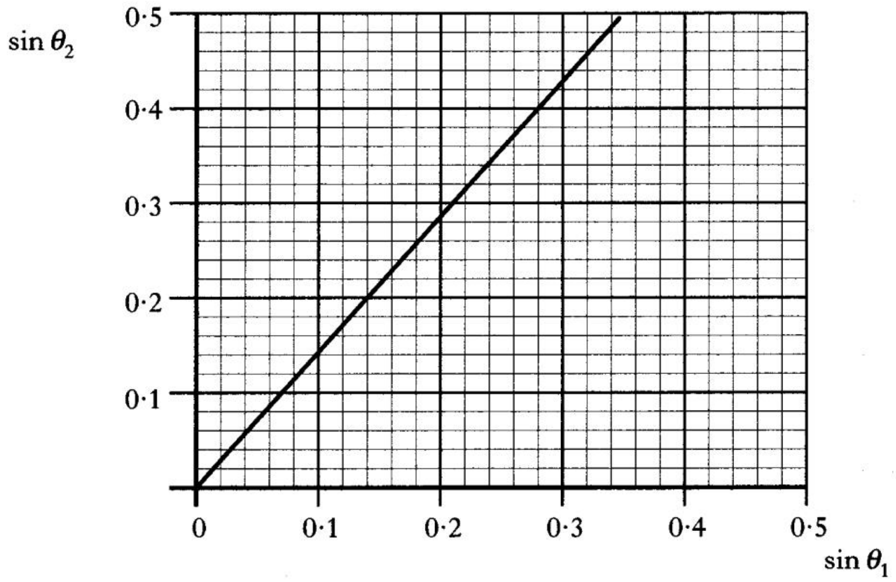


   (a) The water in the tank has a refractive index of 1·33. Describe what happens to the light at the water surface. You must justify your answer by calculation. 3

   (b) The water in the tank is replaced by another liquid. The position of the laser is altered so that the laser beam follows the path shown in the diagram below. The angle θ_1 and the angle θ_2, as shown in the diagram, are measured.



The measurements are repeated for different values of θ_1 and the corresponding values of θ_2. The values of sin θ_1 and sin θ_2 are used to plot the graph shown below.

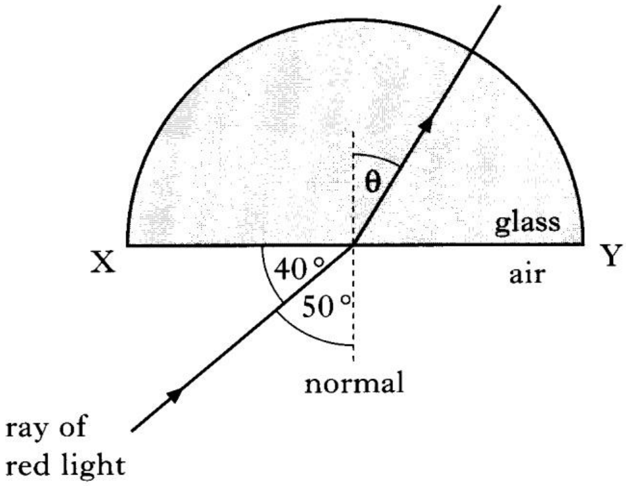


Use information from the graph to calculate the refractive index of the liquid. 2

(c) Light from the laser has a wavelength of 670×10^{-9} m. Calculate the wavelength of the laser light when passing through a liquid which has a refractive index of 1·47. 2

(7)

2. A ray of red light is incident on a semicircular block of glass at the midpoint of XY as shown.



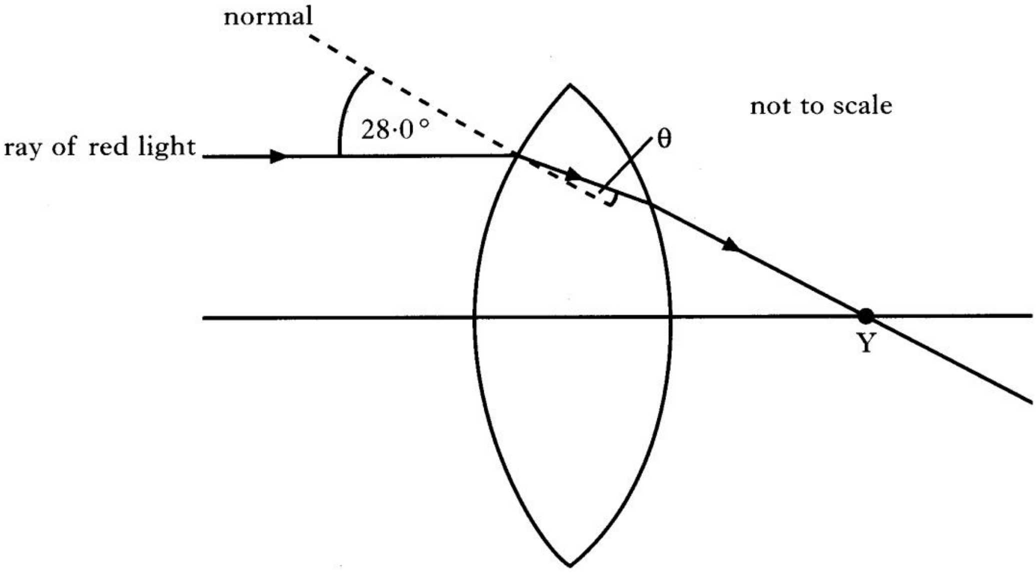
The refractive index of the block is 1·50 for this red light.

(a) Calculate the angle θ shown on the diagram. 2

(b) The wavelength of the red light **in the glass** is 420 nm.
Calculate the wavelength of the light in air. 2

(c) The ray of red light is replaced by a ray of blue light incident at the same angle. The blue light enters the block at the same point.
Explain why the path taken by the blue light in the block is different to that taken by the red light. 1

3. (a) A ray of red light of frequency $4\cdot80 \times 10^{14}$ Hz is incident on a glass lens as shown.



The ray passes through point Y after leaving the lens.

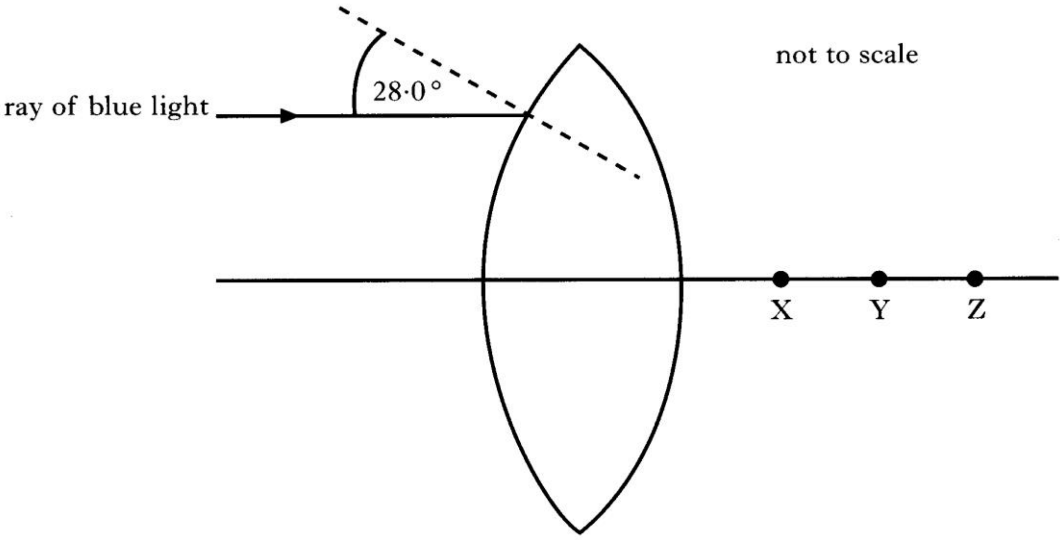
The refractive index of glass is 1·61 for this red light.

(i) Calculate the value of the angle θ shown in the diagram. 2

(ii) Calculate the wavelength of this light inside the lens. 3

(b) The ray of red light is now replaced by a ray of blue light.

The ray is incident on the lens at the same point as in part (a).

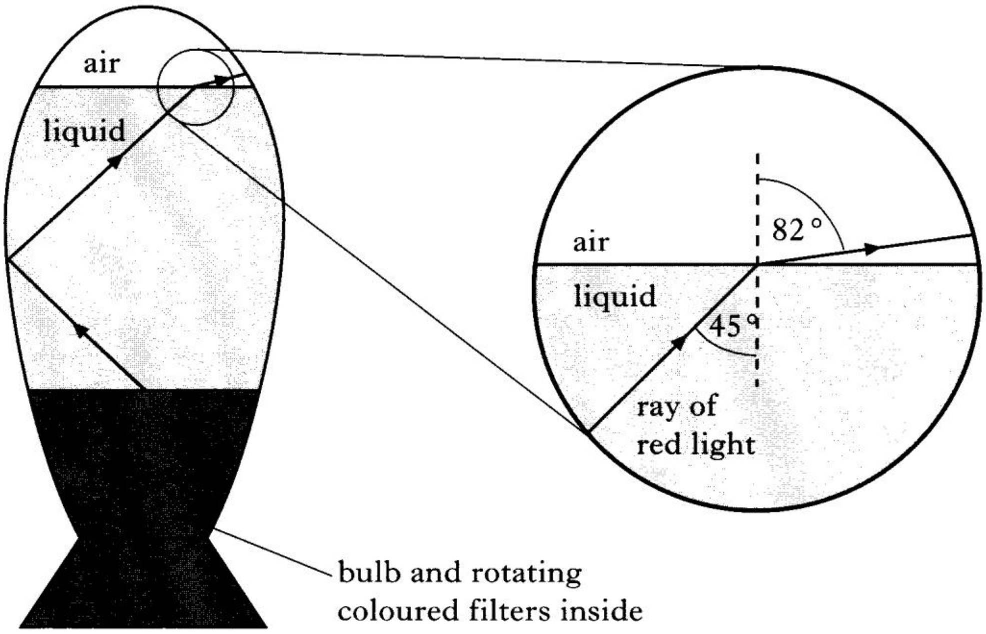


Through which point, X, Y or Z, will this ray pass after leaving the lens?
You must justify your answer. 1

(6)

4. A decorative lamp has a transparent liquid in the space above a bulb. Light from the bulb passes through rotating coloured filters giving red or blue light in the liquid.

(a) A ray of red light is incident on the liquid surface as shown.



(i) Calculate the refractive index of the liquid for the red light. 2

(ii) A ray of blue light is incident on the liquid surface at the same angle as the ray of red light.

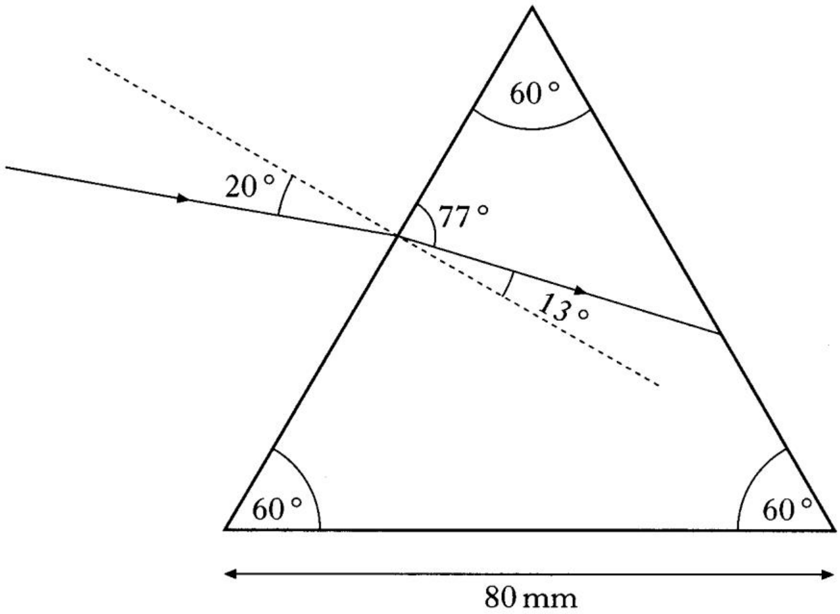
The refractive index of the liquid for blue light is greater than that for red light. Is the angle of refraction greater than, equal to or less than 82° for the blue light? You must justify your answer. 2

(b) A similar lamp contains a liquid which has a refractive index of 1·44 for red light. A ray of red light in the liquid is incident on the surface at an angle of 45° as before.

Sketch a diagram to show the path of this ray after it is incident on the liquid surface.
Mark on your diagram the value of all appropriate angles.
All relevant calculations must be shown. 3

(7)

5. A ray of red light is directed at a glass prism of side 80 mm as shown in the diagram below.



(a) Using information from this diagram, show that the refractive index of the glass for this red light is 1·52. 1

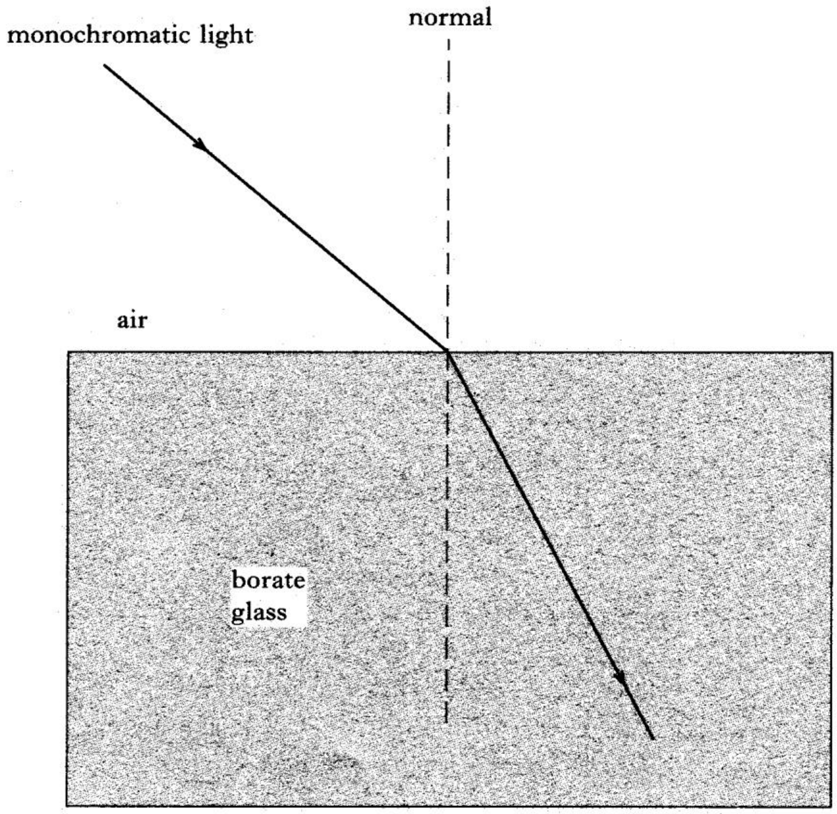
(b) What is meant by the term *critical angle*? 1

(c) Calculate the critical angle for the red light in the prism. 2

(d) Sketch a diagram showing the path of the ray of red light until it leaves the prism. Mark on your diagram the values of all relevant angles. 3

(7)

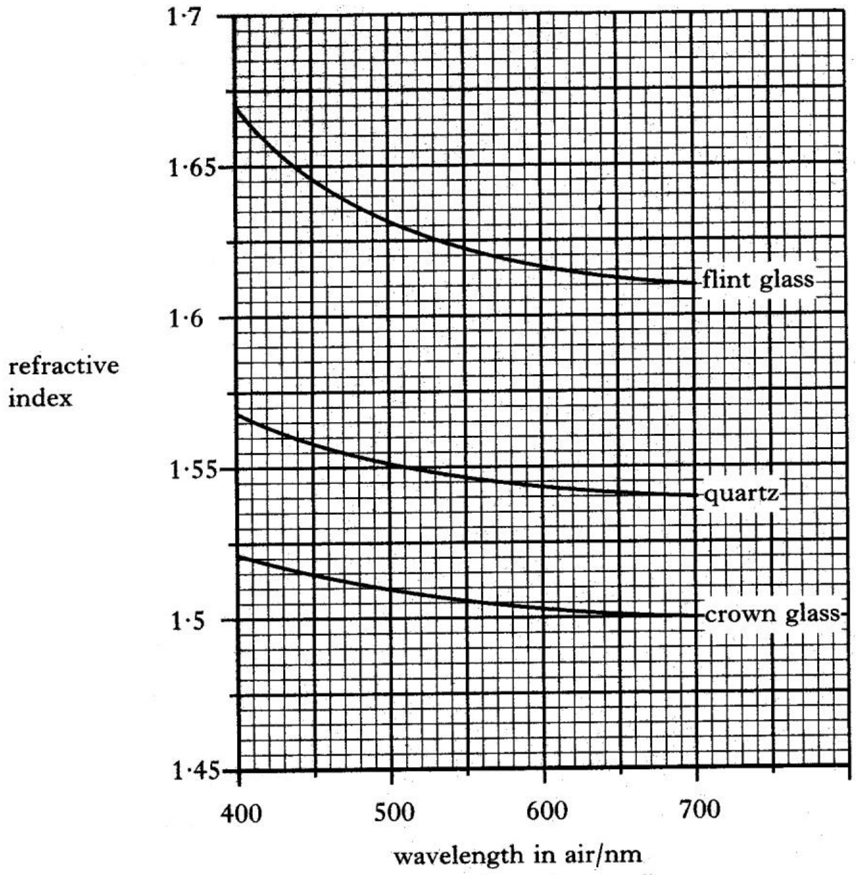
6. (a) The following diagram shows a ray of monochromatic light passing from air into a block of borate glass. The diagram is drawn to scale.



(i) Use measurements taken from the above diagram to calculate the refractive index of borate glass for this light. You will need to use a protractor. 2

(ii) Calculate the value of the critical angle for this light in the borate glass. 2

(b) The following graph shows how refractive index depends on the type of material and the wavelength in air of the light used.

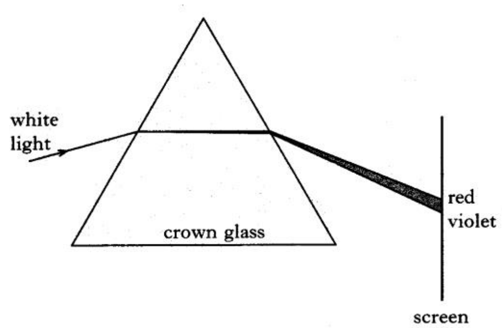


A ray of light of wavelength 510 nm in air passes into a block of quartz.

(i) Calculate the wavelength of this light in the quartz. 2

(ii) Explain what happens to the value of the critical angle in quartz as the wavelength of visible light increases. 2

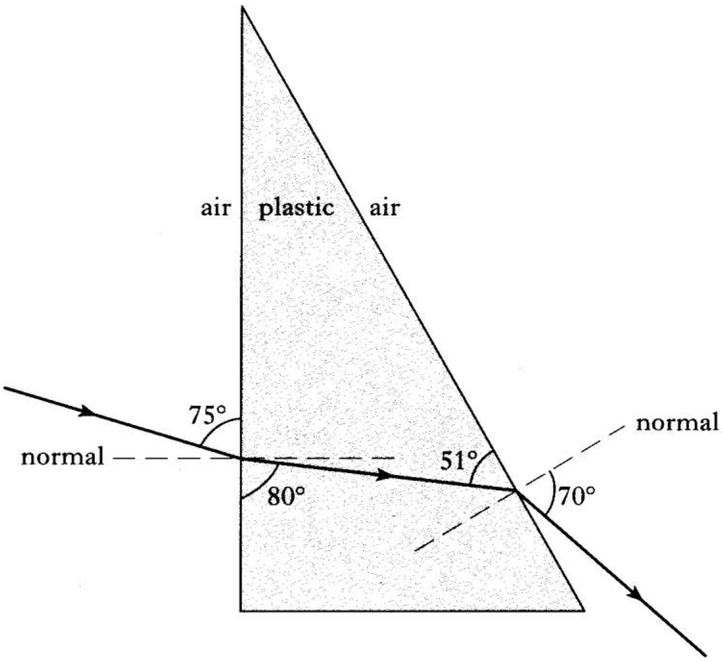
(iii) A ray of white light enters a triangular prism made of crown glass, producing a visible spectrum on a screen, as shown below.



The crown glass prism is now replaced by a similar prism made from flint glass.
Describe how the visible spectrum on the screen is different from before. 1

(9)

7. (a) The diagram below shows the refraction of a ray of red light as it passes through a plastic prism.

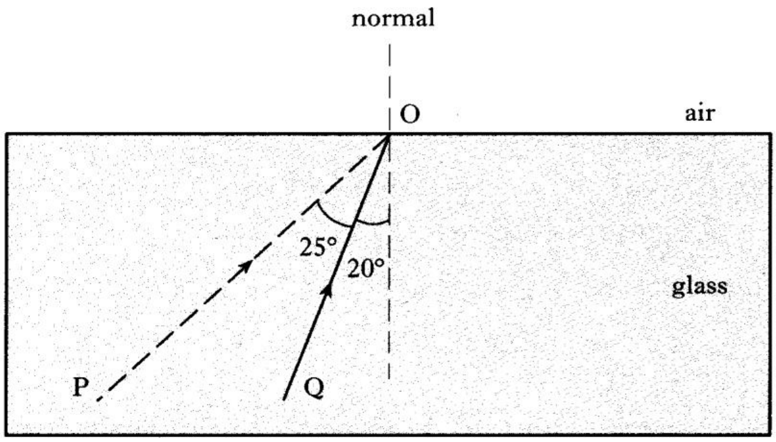


Calculate the refractive index of the plastic for this red light. 2

(b) The refractive index of a glass block is found to be 1·44 when red light is used.

(i) Calculate the value of the critical angle for this red light in the glass. 2

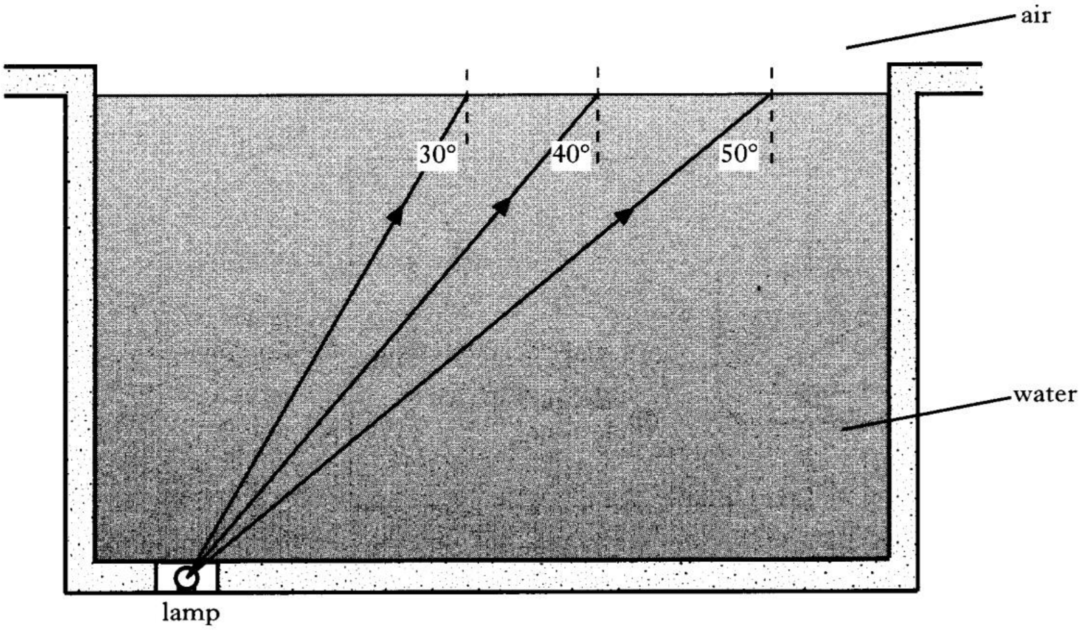
(ii) The diagram shows the paths of two rays of this red light, PO and QO, in the glass block.



When rays PO and QO strike the glass-air boundary, **three** further rays of light are observed.
Copy and complete the diagram to show **all five** rays.
Clearly indicate which of the three rays came from P and which came from Q. The values of all angles should be shown on the diagram. 4

(8)

8. A swimming pool is illuminated by a lamp built into the bottom of the pool.



Three rays of light from the same point in the lamp are incident on the water-air boundary with angles of incidence of 30°, 40° and 50°, as shown above.
The refractive index of the water in the pool is 1·33.

(a) Draw a diagram to show clearly what happens to each ray at the boundary. Indicate on your diagram the sizes of appropriate angles.
All necessary calculations must be shown. 5

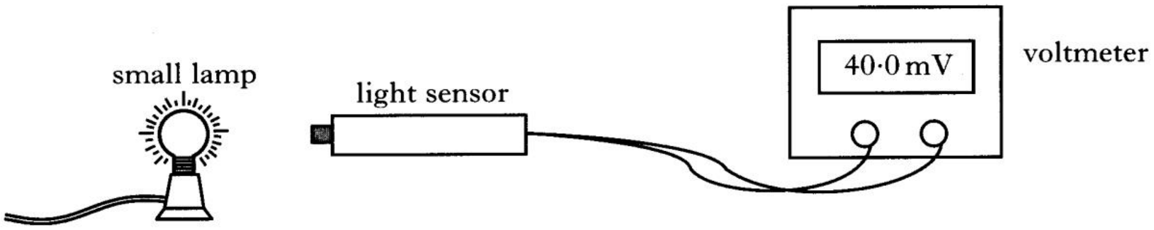
(b) An observer stands at the side of the pool and looks into the water. Explain, with the aid of a diagram, why the image of the lamp appears to be at a shallower depth than the actual depth of the bottom of the pool. 2

(7)

Section 7: Spectra

1. The diagram shows a light sensor connected to a voltmeter.

   A small lamp is placed in front of the sensor.



The reading on the voltmeter is 20 mV for each 1·0 mW of power incident on the sensor.

(a) The reading on the voltmeter is 40 mV.
The area of the light sensor is $8 \cdot 0 \times 10^{-5}$ m^2.
Calculate the irradiance of light on the sensor. 3

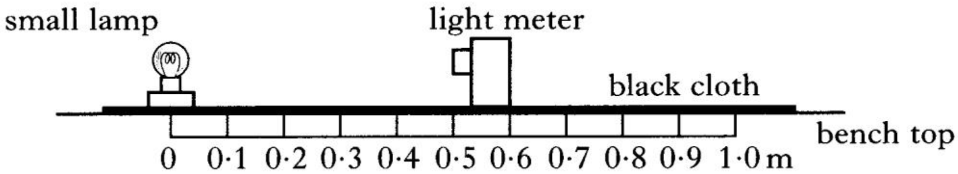
(b) The small lamp is replaced by a different source of light.
Using this new source, a student investigates how irradiance varies with distance.
The results are shown.

Distance/m	0·5	0·7	0·9
Irradiance/W m^2	1·1	0·8	0·6

Can this new source be considered to be a point source of light?
Use **all** the data to justify your answer. 2

(5)

2. A student carries out an experiment to investigate how irradiance on a surface varies with distance from a small lamp.
Irradiance is measured with a light meter.
The distance between the small lamp and the light meter is measured with a metre stick.
The apparatus is set up as shown in a darkened laboratory.



The following results are obtained.

Distance from source/m	0·20	0·30	0·40	0·50
Irradiance/units	675	302	170	108

(a) What is meant by the term *irradiance*? 1

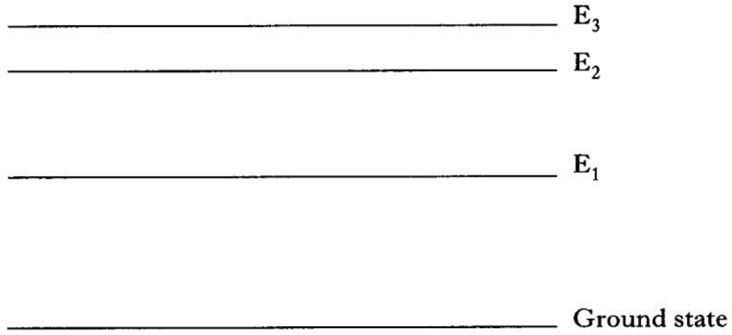
(b) Use **all** the data to find the relationship between irradiance *I* and the distance *d* from the source. 2

(c) What is the purpose of the black cloth on top of the bench. 1

(d) The small lamp is replaced by a laser. Light from the laser is shone on the light meter.
A reading is taken from the light meter when the distance between it and the laser is 0·50 m.
The distance is now increased to 1·00 m.
State how the new reading on the light meter compared with the one taken at 0·50 m. Justify your answer. 2

(6)

3. A particular atom has energy levels as shown below.



Transitions are possible between all these levels to produce emission lines in the electromagnetic spectrum.

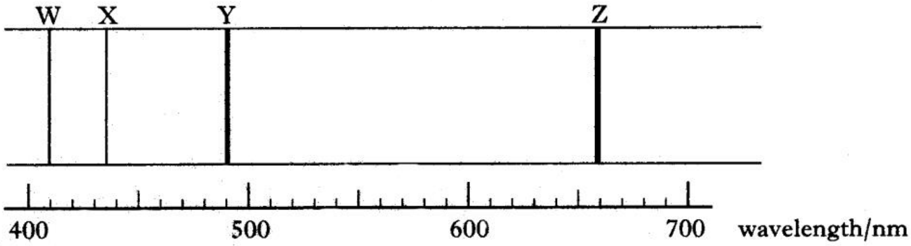
(a) How many lines are in the spectrum of this atom? 1

(b) Between which two energy levels does an electron transition lead to the emission of radiation of the lowest frequency? 1

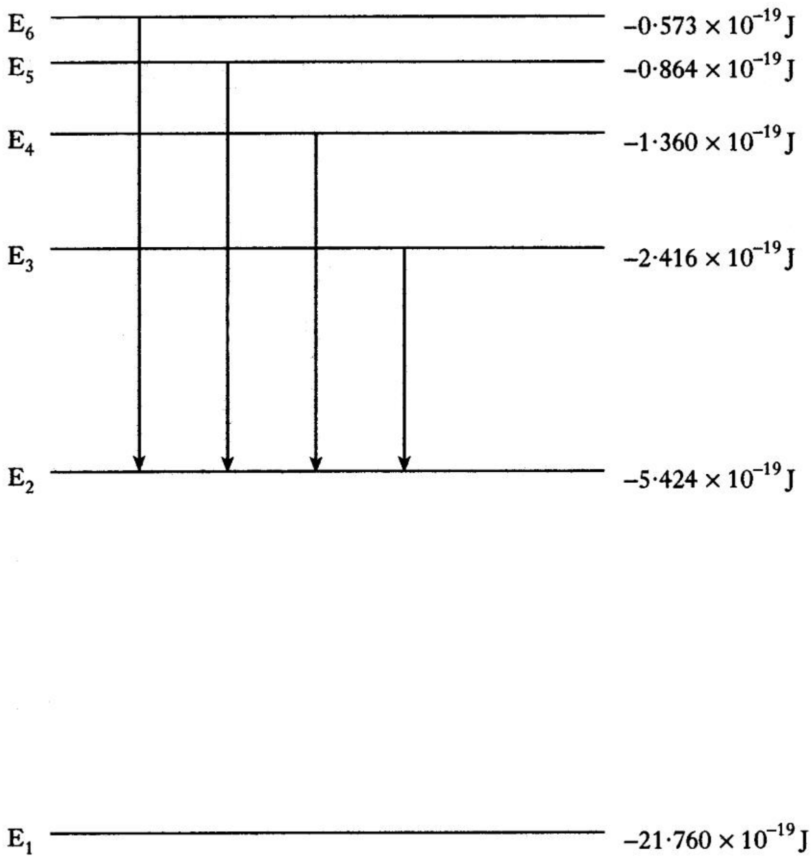
(c) Explain why some lines in the spectrum are more intense than other. 1

(3)

4. The line emission spectrum of hydrogen has four lines in the visible spectrum as shown in the following diagram.



These four lines are caused by electron transitions in a hydrogen atom from high energy levels to a low energy level E_2 as shown below.



(a) From the information above, state which spectral line W, X, Y or Z is produced by an electron transition from E_3 to E_2. 1

(b) Explain why lines Y and Z in the line emission spectrum are brighter than the other two lines. 1

(c) Infrared radiation of frequency $7{\cdot}48 \times 10^{13}$ Hz is emitted from a hydrogen atom.

(i) Calculate the energy of one photon of this radiation. 2

(ii) Show by calculation which electron transition produces this radiation. 2

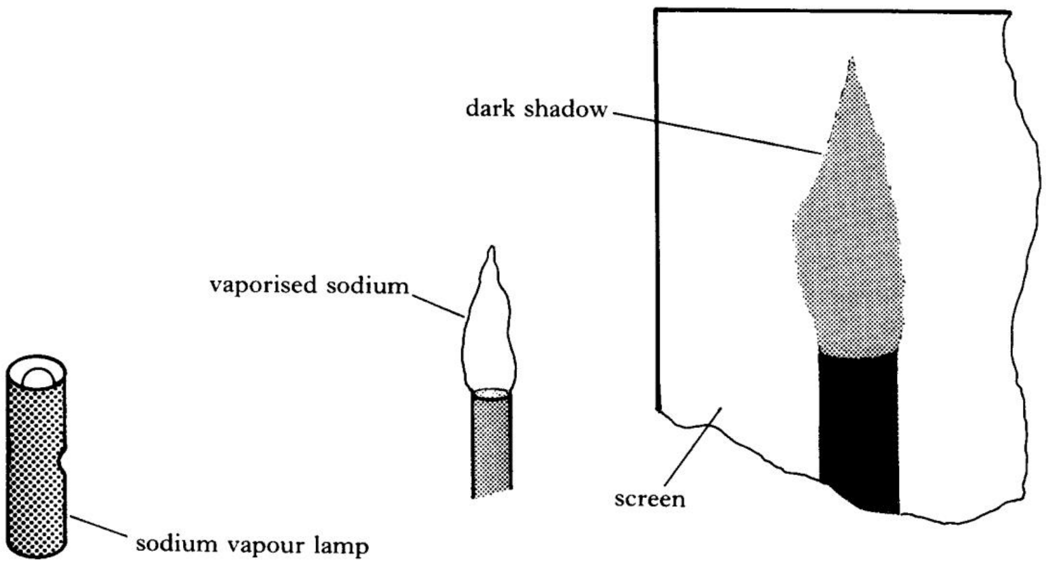
(6)

5. (a) A sodium vapour lamp emits bright yellow light when electrons make transitions from one energy level to another within the sodium atom.

(i) State whether electrons are moving to a higher or lower energy level when the light is emitted. 1

(ii) Using information provided in the data sheet, calculate the energy difference between these two electron energy levels in the sodium atom. 3

(b) A Bunsen flame contains vaporised sodium is placed between a sodium vapour lamp and a screen as shown.



(i) Explain why a dark shadow of the flame is seen on the screen. 1

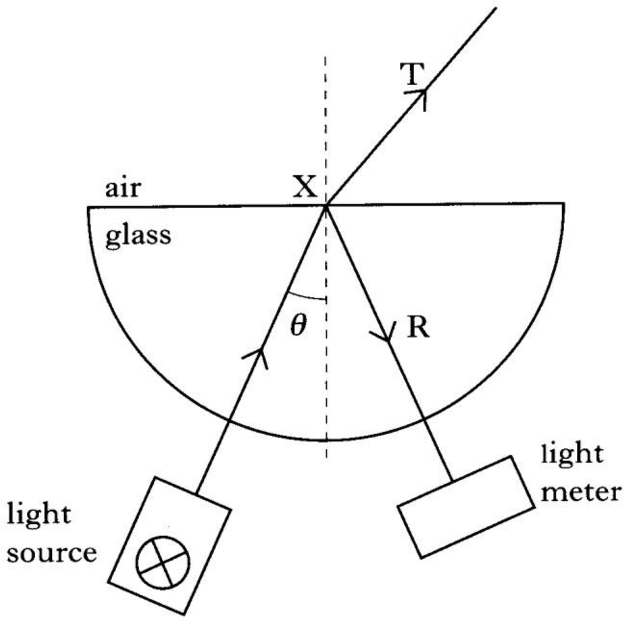
(ii) The sodium vapour lamp is replaced with a cadmium vapour lamp. Explain why there is now no dark shadow of the flame on the screen. 1

(6)

Section 8: Uncertainties and Experiments in Waves

1. A student is investigating the effect that a semicircular block has on a ray of monochromatic light.

   She observes that at point X the incident ray splits into two rays:
   T – a transmitted ray;
   R – a reflected ray.

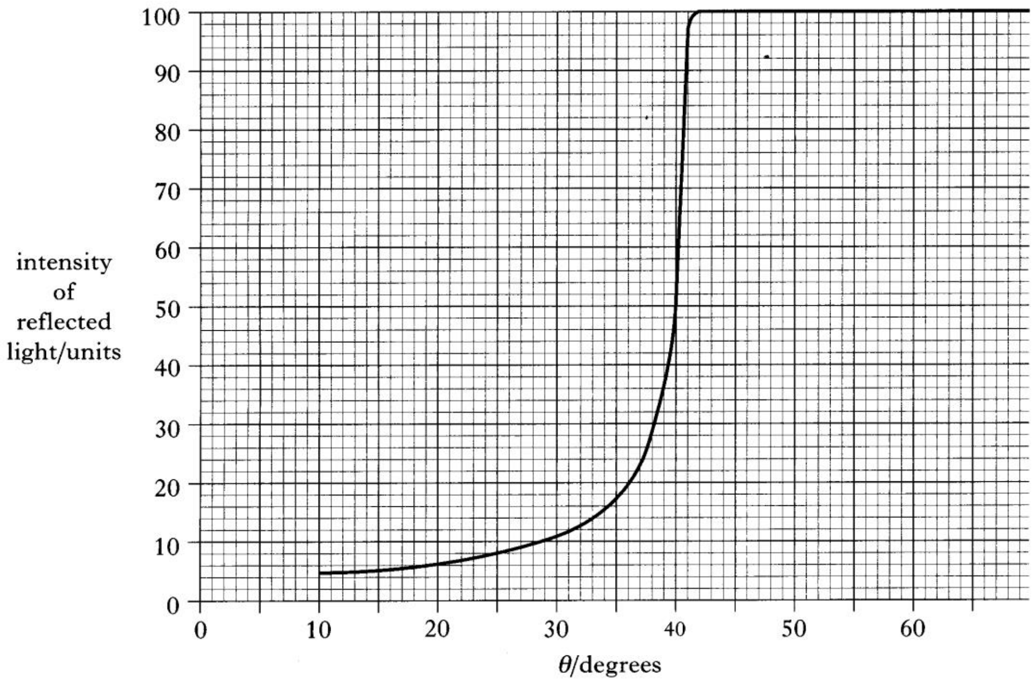


   The student uses a light meter to measure the irradiance of ray R as angle θ is changed.

   (a) State what is meant by the *irradiance* of a radiation. 1

   (b) Explain why, as angle q is changed, it is important to keep the light meter at a constant distance from point X for each measurement of irradiance. 1

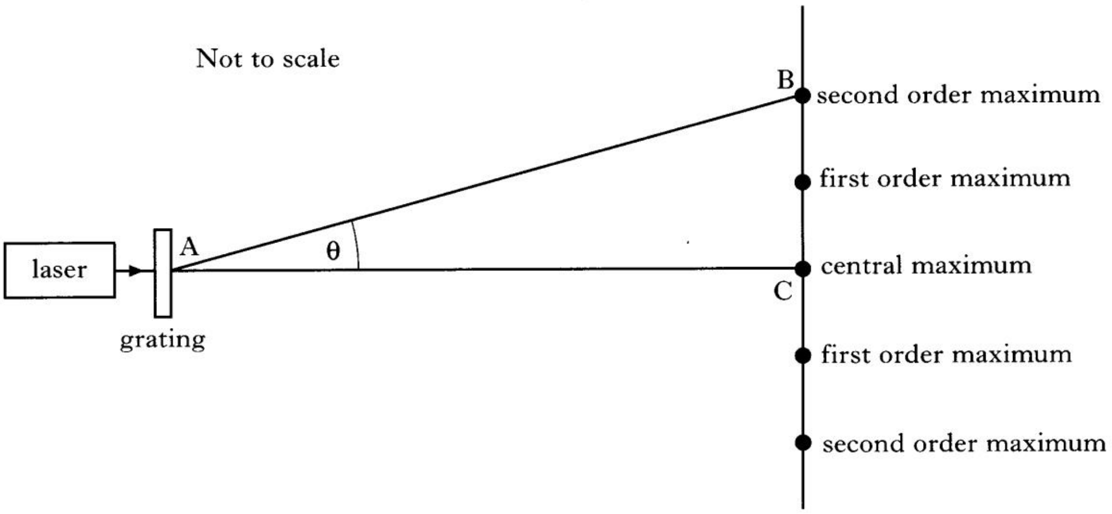
(c) The graph below is obtained from the student's results.



(i)	What is the value of the critical angle in the glass for this light?	1
(ii)	Calculate the refractive index of the glass for this light.	2
(iii)	As the angle θ is increased, what happens to the irradiance of ray T?	1

(6)

2. An experiment to determine the wavelength of light from a laser is shown.



A **second** order maximum is observed at B.

(a) Explain in terms of waves how a maximum is formed. 1

(b) Distance AB is measured six times. The results are shown:

1·11 m 1·08 m 1·10 m 1·13 m 1·11 m 1·07 m

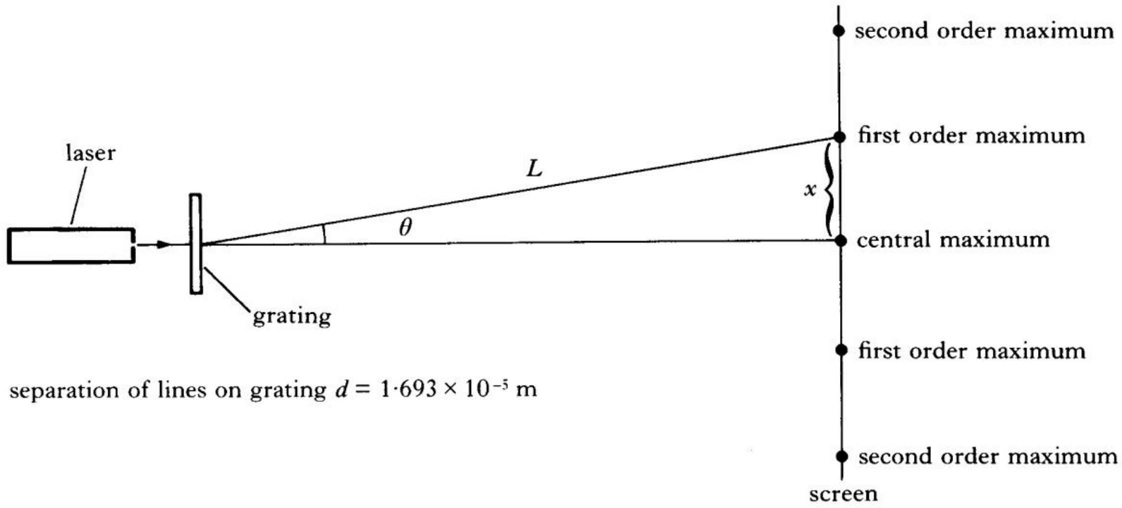
(i) Calculate:
(A) the mean value for distance AB; 1
(B) the approximate random uncertainty in this value. 1

(ii) Distance BC is measured as (270 ± 10) mm.
Show whether AB or BC has the largest percentage uncertainty. 2

(iii) The spacing between the lines on the gating is $4{\cdot}00 \times 10^{-6}$ m.
Calculate the wavelength of the light from the laser.
Express your answer in the form
wavelength ± **absolute** uncertainty. 3

(8)

3. The apparatus shown below is set up to determine the wavelength of light from a laser.



The wavelength of the light is calculated using the equations:

$\lambda = d \sin \theta$ and $\sin \theta = \dfrac{x}{L}$

where angle θ and distances x and L are shown in the diagram.

(a) Seven students measure the distance L with a tape measure.

Their results are as follows.

2·402 m 2·399 m 2·412 m 2·408 m 2·388 m 2·383 m 2·415 m

Calculate the mean value for L **and** the approximate random uncertainty in the mean. 2

(b) The best estimate of the distance x is (91 ± 1) mm.
Show by calculation whether L or x has the largest percentage uncertainty. 2

(c) Calculate the wavelength, in nanometres, of the laser light.
You must give your answer in the form
final value ± absolute uncertainty. 3

(d) Suggest an improvement which could be made so that a more accurate estimate of the wavelength could be made.
You must use only the same equipment and make the same number of measurements. 1

(8)

Section 9: Open-ended Questions

1. Monochromatic light is shone onto a diffraction grating to produce an interference pattern on a screen.

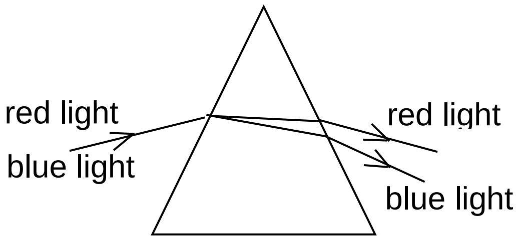
   Describe the significance of 'diffraction' on the production of an interference pattern. 3

2. A ray of light of wavelength $5{\cdot}0 \times 10^{-7}$ m is shone onto a diffraction grating. The spacing between the lines of the grating is $5{\cdot}8 \times 10^{-7}$ m. An interference pattern is observed on a screen.

   A student observing the pattern states that there is *no limit* to the number of maxima of intensity produced on the screen.

   Use your knowledge of physics to comment on this statement about the number of maxima. 3

3. In an experiment a ray of red light and a ray of blue light pass through a triangular glass prism as shown.



   A student viewing this experiment makes the following statement about the refractive index of the glass and the frequency of the light.

   '*The refractive index of the glass depends on the frequency of light.'*

   Use your knowledge of physics to comment on this statement. 3

4. A beam of blue light and a beam of red light are shone onto a screen.

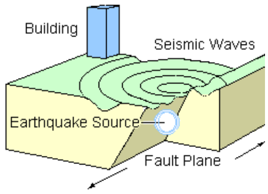
   A student states that a beam of blue light will *always* produce a greater irradiance on the screen than the beam of red light.

   Use your knowledge of physics to comment on this statement. 3

5. An extract from a student's investigation diary is shown.

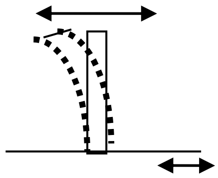
9th November

Investigation – Preventing damage from earthquakes.



We found on the web that most of the energy of seismic waves from earthquakes is from waves close to a certain frequency.

We carried out an experiment to find how the amplitude of vibration of the top of a building depended on the frequency of vibration of the ground.



We used a flexible model of a building which was stuck to a horizontal plate that we vibrated at different frequencies.

Here are the results.

Vibration frequency / Hz	Amplitude of vibration / mm
0.5	18
1.0	32
1.5	48
2.0	49
2.5	34
3.0	10

The student has taken six sets of readings and used the results to reach a conclusion.

(a) Sketch a graph of the results. 2

(b) Using the information from your sketch graph write a conclusion for the experiment. 2

(c) Suggest two improvements that the student could have made to the collection of data for this investigation. 2

(d) Suggest any changes or extensions to the experiment that would make it more useful in determining the effect of earthquakes on buildings. 2

(8)