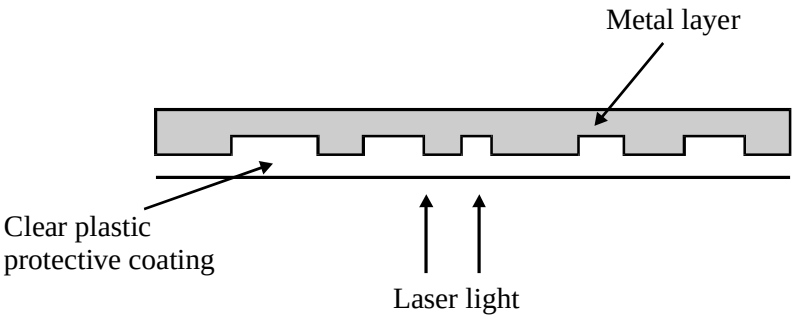
Unit 2 AS Physics Revision Pack

1. The diagram shows a cross-section through a compact disc.

The metal layer of a CD is the recording surface and contains narrow ridges, which form a spiral around the disc.



Red *monochromatic* laser light of wavelength 780 nm is used to view these ridges. When the light meets a ridge some of it scatters in all directions and some *interferes destructively* with light reflected from neighbouring valleys.

Explain the meaning of the words in *italics* in the passage above.

Monochromatic ……

……

Interferes destructively ……

……

(2)

Calculate the frequency of the red laser light.

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Frequency = ……………………………………

The refractive index of the plastic protective coating is 1.55. What is the speed of the laser light in the plastic coating?

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Speed = ……………………………………

Show that the wavelength of the laser light in the plastic coating is approximately 500 nm.

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Wavelength = ……………………………………

(4)

The height of the ridges on a CD is approximately 125 nm. Use your last answer to explain how destructive interference occurs.

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(3)

The infrared laser standard was fixed in 1980 because of the reliability and availability of relatively inexpensive lasers, which emit at 780 nm. However, blue light lasers are now being developed. These emit a wavelength about one half that of the red light lasers.

Will it be possible to play existing CDs using blue light laser CD players? Explain your answer.

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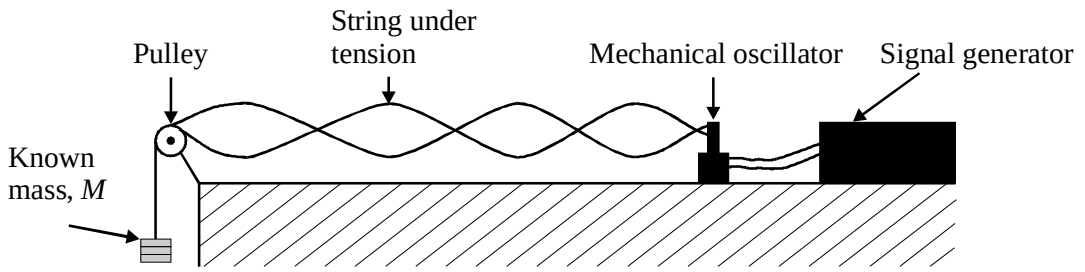
(2)
(Total 11 marks)

2. A student performs an experiment to investigate how the speed *v* of the waves on a stretched string is affected by the tension *T*. The tension *T* is equal to the weight of the mass hanging over a pulley as shown in the diagram.



For a particular mass, the student adjusts the frequency *f* of the signal generator until a standing wave is established. The frequency *f* and the wavelength λ are recorded. The procedure is repeated for a range of masses.

The student finds from an A level textbook that *v* is given by the expression

$$v = \sqrt{\frac{T}{\mu}}$$

Where μ is the mass per unit length of the string.

The student decides to see if the data supports this expression. She starts to process her data and plot it on to a graph.

Use the information in the table to add two more points to the graph. Record the results of your calculations in the table.

M/kg	*f*/Hz	λ/m			
0.16	30.6	0.37			
0.20	30.0	0.41			

(3)

Draw the line of best fit through the points on the graph.

(1)

Do the student's results support the relationship given above? Justify your answer.

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(2)

Use the graph to obtain a value for μ.

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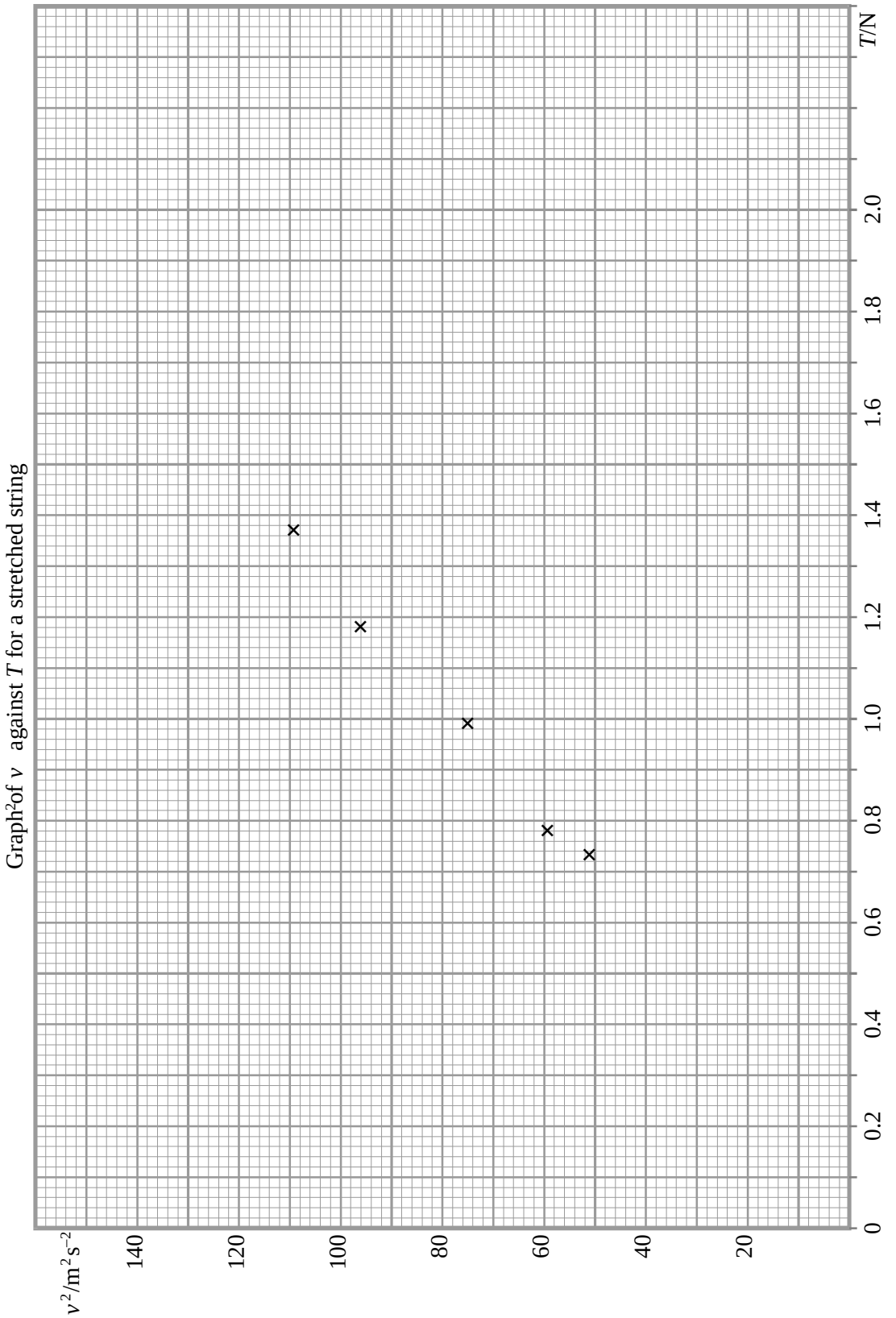
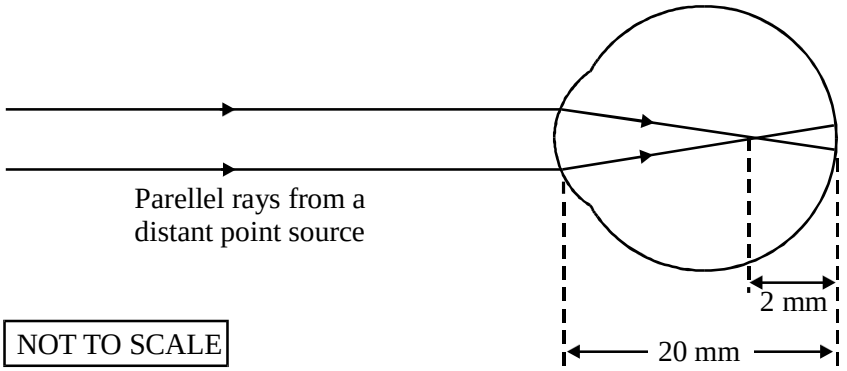


(3)
(Total 9 marks)

3. A simple model of the eye treats the focussing system of the eye as a single lens. For this question, assume the focussing system of the eye is a single lens situated at the front of the eye.

Short-sightedness is caused when rays from a distant point source are focussed in front of the retina as shown below.



Suppose that in the eyeball shown above the distance between the eye lens and the retina is 20 mm and that the image of a distant object is formed 2 mm in front of the retina as shown.

Calculate the power of the eye lens.

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Power = ……..……..……..……..……..……..

(2)

Short-sightedness can be most easily corrected by the use of a diverging lens. On the diagram above add a diverging spectacle lens just in front of the eye. Draw in the new path of rays.

(2)

Calculate the required power of spectacle and eye lens combination.

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Power = ..……..……..……..……..……..

(1)

When lenses are used in combination, the resulting power can be found by adding together the powers of the individual lenses. Calculate the focal length of the spectacle lens.

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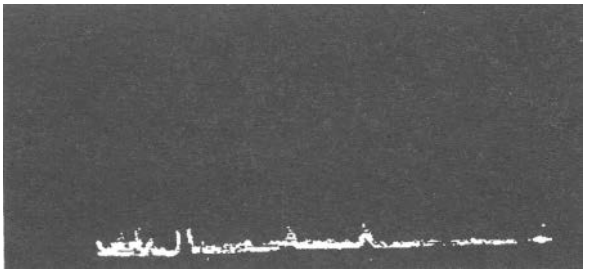
Focal length = ..……..……..……..……..……..

(3)

(Total 8 marks)

4. An ultrasound A-scan is a test that is commonly carried out to check that a fetus is developing correctly and growing at the expected rate. A typical use would be to monitor the growth of a baby's head.

The photograph on the left and the simplified diagram on the right show a scan of the baby's head.



Trace seen on monitor

Simplified diagram of trace

What quantity is represented by the horizontal axis of the trace?

…….……..……..……..……..……..……..……..……..……..……..……..……..……..……..……

(1)

Explain briefly how the two peaks of the trace are formed.

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(2)

Explain briefly how the trace could be used to obtain a measurement of the size of the baby's head.

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(3)

If ultrasound is used to image a moving object such as the heart, a Doppler shift is observed.

Explain what is meant by the term *Doppler shift*.

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(2)
(Total 8 marks)

5. When you look at the water on a sunny day you often see just the bright surface because of the glare of reflected light. Wearing Polaroid sunglasses can remove this glare and allow you to see the fish swimming beneath the water.

State the difference between polarised and non-polarised light.

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(1)

What do you see if you look at a light source through parallel polaroid filters which are placed so that their planes of polarisation are at 90° to each other (crossed polaroids)?

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(1)

The sunlight is partially polarised on being reflected from the water surface. How can the Polaroid sunglasses remove the glare, allowing the fish to be seen?

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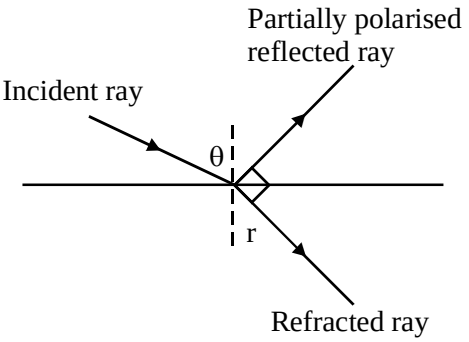
(1)

As the angle of incidence changes, the proportion of the light which is polarised also changes. There is one particular angle, θ, at which the polarisation of the reflected ray is complete. It is also found that at this angle the reflected ray and the refracted ray are at right angles.

($_a\mu_w$, refractive index from air to water = 1.33.)



Explain why the angle of refraction $r = 90 - \theta$.

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Show that θ is about 53°.

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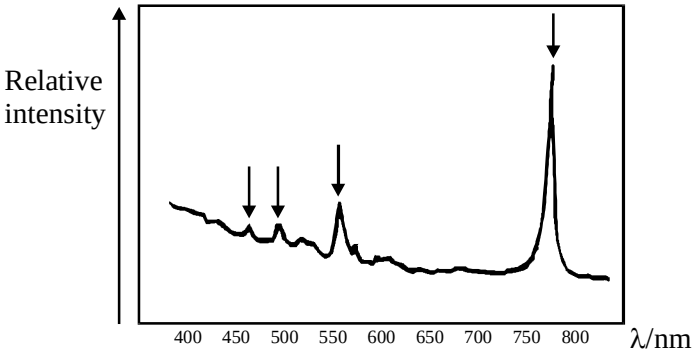
(3)
(Total 6 marks)

6. The diagram below shows the spectrum of light received from the quasar known as 3C273 (a quasar is an extremely luminous type of galaxy). The four peaks marked are hydrogen lines that have shifted in wavelength. In a laboratory, these lines have wavelengths 410 nm, 434 nm, 486 nm and 656 nm.



What is the name given to this shift in wavelength?

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(1)

Without doing any calculations, what does the spectrum of 3C273 allow you deduce about its motion?

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(1)

Using any *one* of the lines marked in the diagram, calculate the speed of 3C273 relative to the Earth.

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Speed = ..……..……..……..……..……..……..

(3)

What observations would you expect to make of light from a galaxy twice as distant as 3C273? State any assumption made.

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Distance = ..……..……..……..……..……..……..

(2)

(Total 7 marks)

7. The teacher of a class arranges a visit to the manufacturer of "bouncy castles". The class assume, naturally, that this will be a good excuse to jump up and down on a large rubber pillow of air. The teacher explains that there are some principles of physics associated with bouncy castles, such as energy changes and oscillations when children are bouncing on it.

The speed at which a child collides with the rubber pillows is typically about 2.5 m s^{-1}.
The time period of the oscillation is typically about 6 s.

Write an illustrated article explaining the relevance of the two topics above to bouncy castles. You should include estimates of quantities and use them in appropriate equations to confirm the estimates given above.

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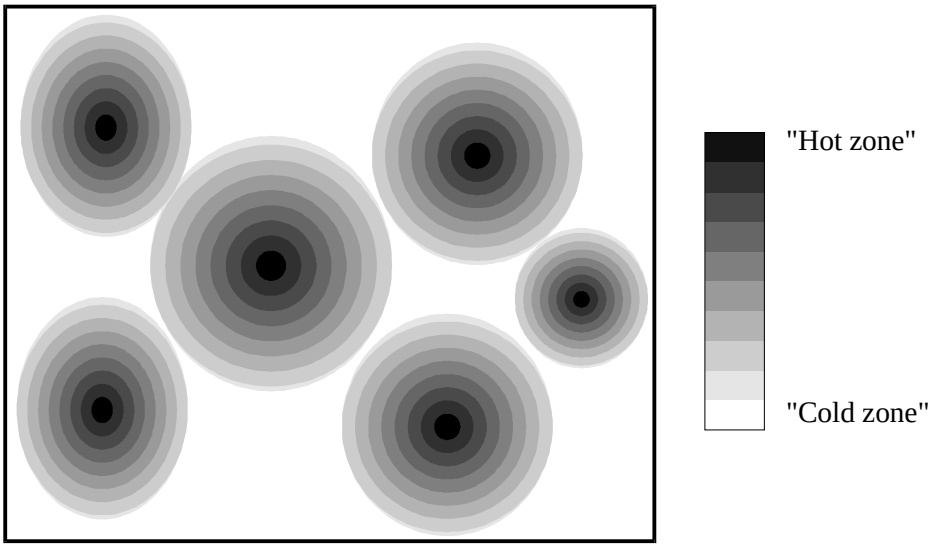
(Total 7 marks)

8. Babies' food sometimes carries the following warning: "Do not warm feeds in a microwave oven as this may cause uneven heating and could scald your baby's mouth".

An Internet site gives the following explanation:

> C*oherent* microwaves are emitted in all directions from a source within the oven. The waves reflect off the metal walls so that the microwave radiation reaching any particular point arrives from several different directions. The waves interfere and set up *standing* waves. This produces the pattern of hot and cold zones observed in food heated in a microwave oven.



Explain the meanings of the following words from the passage.

Coherent .....

.....

(1)

Standing wave ……

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.....

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(2)

On the diagram above, mark a possible position of *one* antinode, and label it **A.**

(1)

The frequency of the radiation used in a microwave oven is 2.45×10^9 Hz.

Show that the wavelength of the microwave radiation is about 12 cm.

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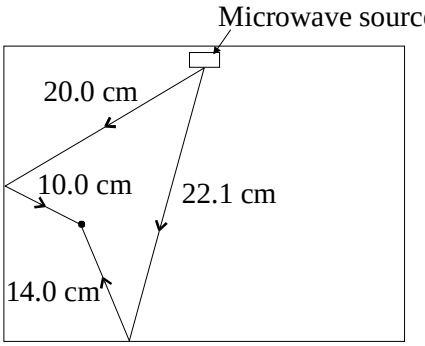
(1)

The diagram shows two different paths by which microwaves can reach the point X.



Not to scale

Find the path difference for waves reaching point X by the paths shown.

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Path difference = ……

(1)

Assuming waves do not reach point X along any other path, explain whether you would expect this point to be a microwave node or antinode.

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(3)

Some microwave ovens use two separate microwave frequencies to overcome the problem of uneven heating. Explain how this helps.

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(2)

(Total 11 marks)

9. An ocean can be considered to be made up of two layers: a layer of warm water and a layer of cold water. The interface between them is called a thermocline.

Why does the warm surface water float above the cold deep ocean water?

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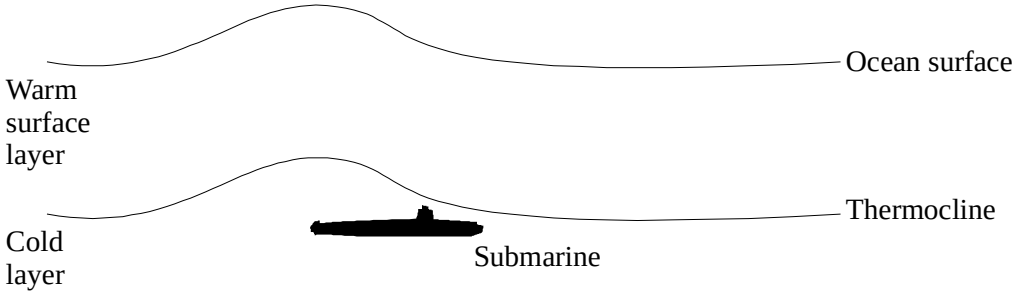
(1)



A surface ship uses sonar to detect submarines. Explain why the ultrasound waves travelling through the water partially reflect from the thermocline.

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(1)

Explain why a submarine travelling in the cold water just below the thermocline is very difficult to detect using surface sonar.

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(2)

Some scientists believe that the passage of a submarine could distort the thermocline and cause the surface of the ocean to bulge as shown. They think that they may be able to detect this bulge using radar from a satellite.

Explain why sonar cannot be used from a satellite.

……

……

(1)

A satellite is in orbit 6.0×10^7 m above the surface of the Earth and uses radar to measure the distance to the ocean surface. Calculate the time between the emission and detection of a radar pulse which strikes the surface of the ocean directly below the satellite.

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……

Time = ……..

(2)

The satellite's timing equipment is capable of measuring time to a precision of 1.0×10^{-9} s.

Calculate the minimum change in the height of the ocean which the satellite is capable of detecting.

……

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Minimum change = ……..

(2)

Suggest a possible problem in detecting submarines in this way.

……

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(1)

(Total 10 marks)

10. Farmers can choose the best time to harvest some fruits by measuring how much sugar their juice contains. The concentration of sugar in the juice alters its refractive index which can be measured with a refractometer. **Figure 1** shows a beam of light entering a refractometer. The juice is placed on top of the prism.

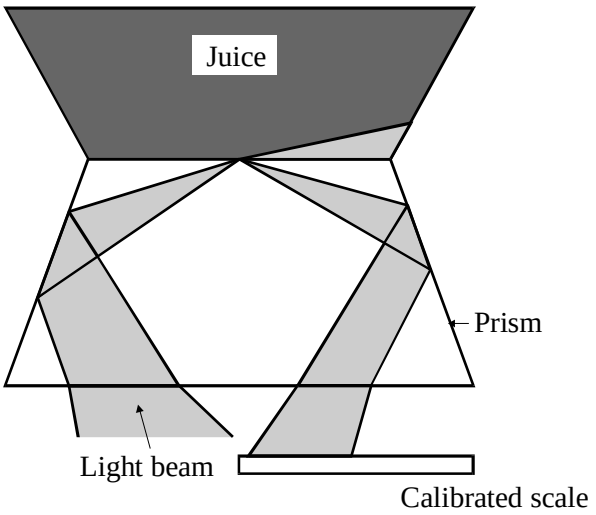

Figure 1

The light coming out of the prism hits the scale as shown in **figure 1**. Explain why part of the scale appears dark.

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(2)

A student uses a prism to investigate this effect in the school laboratory. A layer of juice is trapped between the prism and a microscope slide. **Figure 2** below shows a ray of light hitting the surface between the prism and the juice at the critical angle.

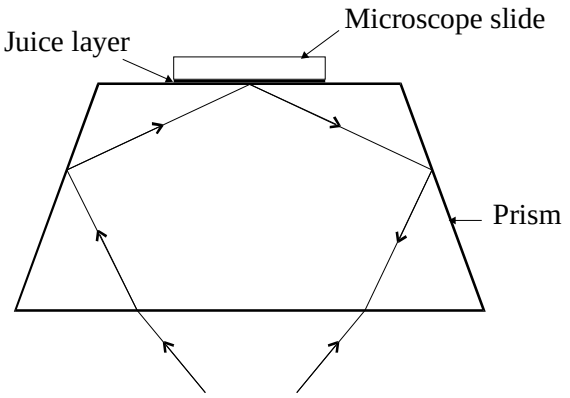

Figure 2

Mark the following angles on **figure 2** opposite:

the critical angle *C*
an incident angle *i*
a refracted angle *r*

(3)

Explain the term *critical angle.*

……

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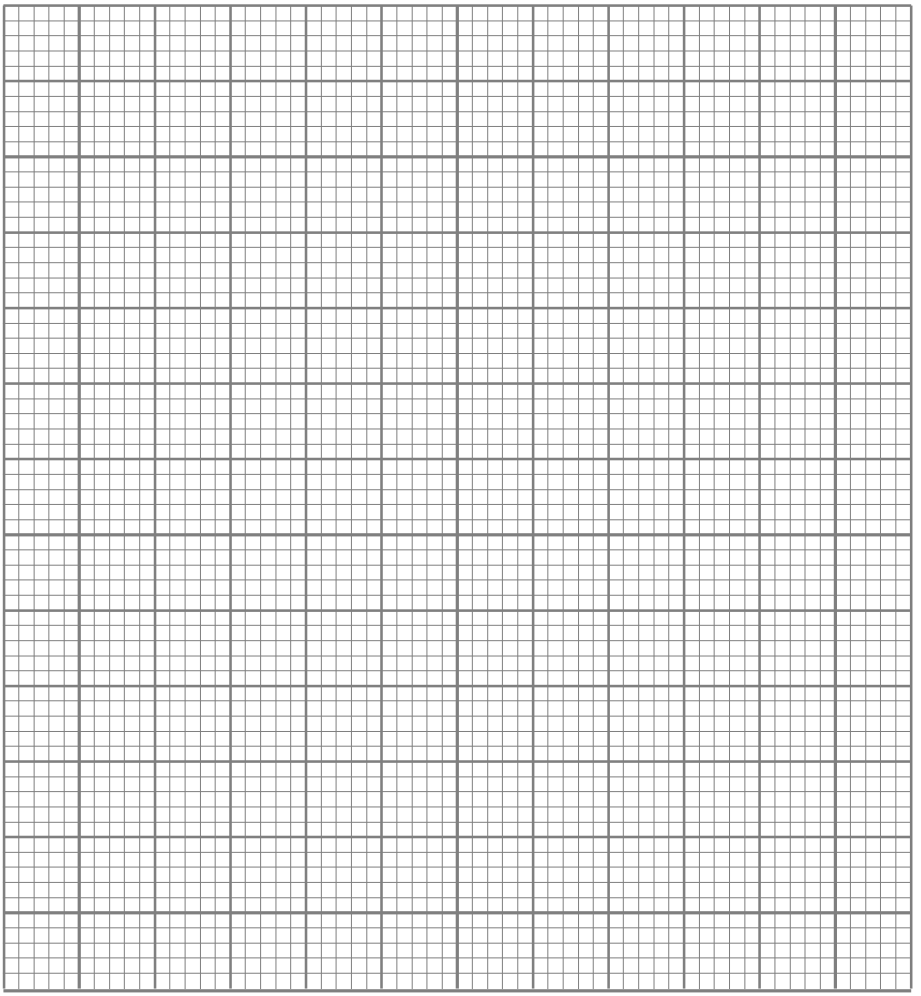
(2)

The student calculates these values of refractive index for different concentrations of sugar solution.

Concentration of sugar solution/%	Refractive index of sugar solution
0	1.333
15	1.356
30	1.381
45	1.410
60	1.442

Plot a graph of these results on the grid below.



(4)

From the graph, find the refractive index of a sugar solution of concentration 40%.

Refractive index: .....

(1)

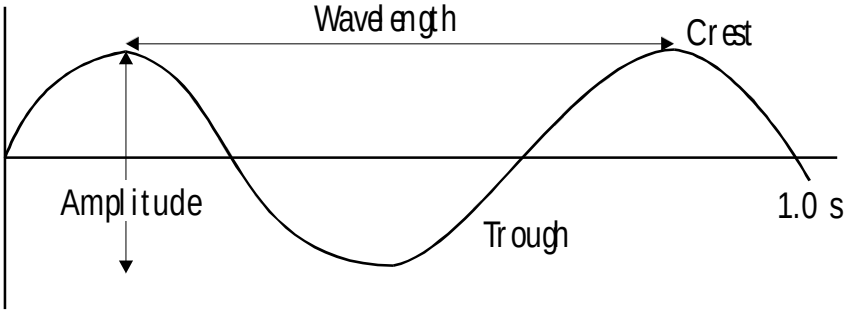
(Total 12 marks)

11. The following passage shows part of a student's revision notes which contain several errors.

Identify four of the errors in the student's notes and suggest corrections for the errors.

Waves

All waves require a medium to travel in. Waves carry the medium from place to place. The height of the crest of a wave, or the depth of the trough, is called the amplitude. The distance between two crests is the wavelength. The number of waves per second is the frequency.



e.g. Here there are 3 waves in one second, so the frequency is 3 kilohertz.

Error .....

Correction .....

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Error .....

Correction .....

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Error .....

Correction .....

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Error .....

Correction .....

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(Total 8 marks)

12. A musician who is also a physicist makes measurements on the strings of her harp. She chooses **three** of the nylon strings - the one at each end, and one near the middle. For each one she measures the length, the diameter and the frequency of the fundamental note produced when the string is plucked. She then constructs a spreadsheet to calculate the mass per unit length, the wave speed, and the tension in each string. Measured data is in **bold**; calculated values are in plain text. See below

	A	**B**	**C**	**D**	F	G	H	I
1	string number	**length /m**	**diam /mm**	**frequency /Hz**	volume of 1 metre length/m^3	mass per unit length/ kg m^{-1}	wave speed /m s^{-1}	tension /N
2								
3	1	**0.08**	**0.7**	**2048**	0.00000038	0.000437	328	47
4	22	**0.52**	**1.0**	**256**	0.00000079		266	64
5	36	**1.20**	**2.5**	**64**	0.00000491	0.005646	154	133
6								
7		**mass of a cubic metre of nylon/kg**						
8				**1150.00**				

Explain why the formula in cell H3 is

=2*B3*D3

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.....

(2)

Show how the value in cell F5 is calculated using the measurement in cell C5.

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.....

(2)

The value in cell G4 is not shown. Calculate what it should be.

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Value = ……..

(2)

Give an appropriate formula for cell I3 in terms of cells G3 and H3. Explain how you arrive at this formula.

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(2)

A friend says he has read that a harp is constructed so that all the strings are at about the same tension.

Comment on this idea

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(3)

(Total 11 marks)

13. *Read the following passage and answer the questions which follow.*

Diffraction

Light bends when it passes around an edge or through a slit. This effect is called diffraction. The angle through which the light bends is proportional to the wavelength of the light. Red light bends about 50% more than blue light.

The pattern of light and dark created when light passes through two slits shows that light has wave properties. The light waves that go through the slits spread out, overlap and add together to produce the pattern. In fact, the spacing between two adjacent dark bands in the pattern is inversely proportional to the slit separation.

Adapted from the website of the Exploratorium San Francisco

Use diagrams to explain how two waves overlap to produce a dark band.

(2)

Use the information in the passage to calculate an approximate wavelength for red light. Assume that the wavelength of blue light equals 460 nm.

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(2)

Blue light is shone through two slits separated by 0.10mm and adjacent dark bands in the pattern are 8.0 mm apart.

How far apart will the dark bands be if the slit separation is doubled?

.....

.....

(1)

The website also states that the diffraction pattern produced when sunlight passes through a feather consists of bands of light with coloured edges. Explain how this pattern occurs.

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.....

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(3)
(Total 8 marks)

14. A student is unable to focus on objects that are more than 2.0 m away unless he is wearing his glasses. His glasses enable him to see a distant object clearly by forming a virtual image of this object at 2.0 m from his eyes.

Explain whether the lenses are converging or diverging.

.....

.....

(1)

State the focal length of the lenses in his glasses.

.....

.....

Focal length = ……..

(1)

Hence, calculate the power of these lenses.

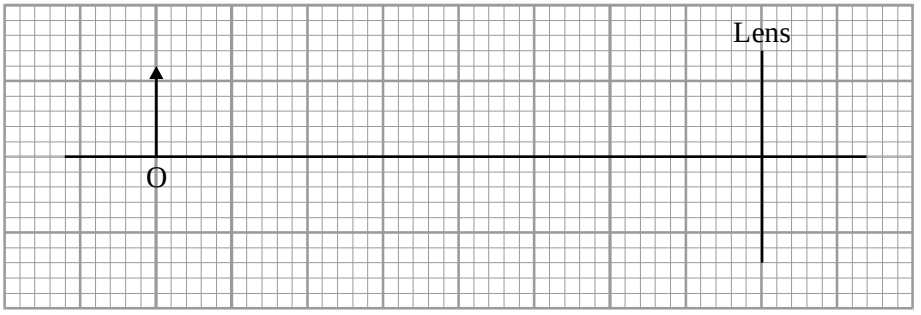
.....

.....

Power = ……..

(1)

Draw a ray diagram of one of these lenses forming an image of an object that is 4.0 m away from the lens. Label the image.



(3)

During his next sight test, the optician finds that the student's sight has changed. The student sees clearly when an additional lens of power +0.20 D is combined with his existing lenses.

Calculate the power of this new lens combination.

.....

(1)

Explain whether the student's sight when not wearing glasses has improved or worsened.

.....

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(1)
(Total 8)

15. A photographer uses a polarising filter over the camera lens. She notices that the intensity of the light received from the blue sky changes as she rotates the filter.

What does this suggest about light from the sky?

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.....

(1)

Explain the change in intensity as the filter is rotated.

.....

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(2)

The use of a polarising filter makes a blue sky appear darker, but the clouds remain bright.

Suggest why there is little change in the intensity of the light from the clouds.

.....

.....

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(1)

Astronomers notice the same effect with the radio waves emitted by some galaxies.
What does this suggest about these radio waves?

.....

.....

(1)

State why radio waves should behave in the same way as light.

.....

.....

(1)
(Total 6 marks)

16. Good suspension in a car helps prevent resonance in the various parts of the car such as the seats and mirrors. Each part has its own frequency of vibration.

What is this frequency called?

.....

(1)

Explain the term *resonance.*

.....

.....

.....

.....

(2)

Different frequencies of vibration can be applied to a system. Sketch a graph on the axes below to show the variation of amplitude with applied frequency for a vibrating system. Label your graph line A.

Mark the resonant frequency on the applied frequency axis.

Add a second line to show the effect of additional damping on this system. Label this line B.

(4)

How does *good suspension in a car help prevent resonance in the various parts of the car*?

.....

.....

.....

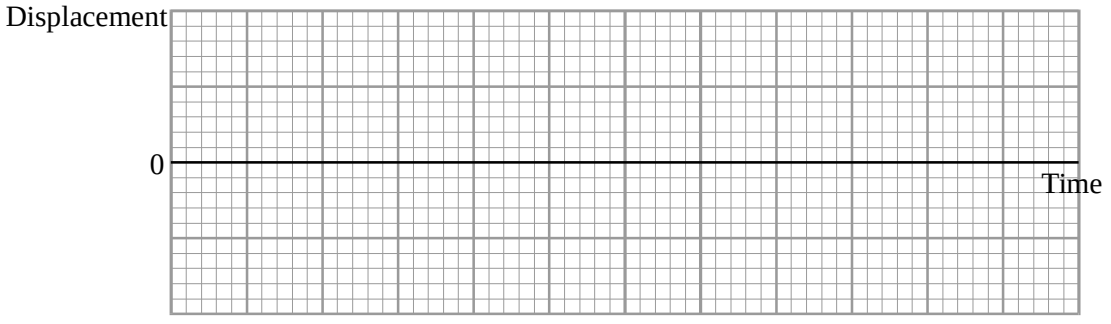
.....

(2)

(Total 9 marks)

17. A toy is suspended at the end of a long spring from the ceiling above a baby's cot. When it is pulled down slightly and then released it oscillates up and down with simple harmonic motion.

On the axes below, sketch a displacement-time graph for the first three oscillations of the toy. Assume that the effects of air resistance are negligible. Let zero displacement be at the mid-point of the oscillation.



(2)

Sketch velocity-time and acceleration-time graphs for the same three oscillations.

(2)

State two requirements for the toy to move with simple harmonic motion (SHM).

.....

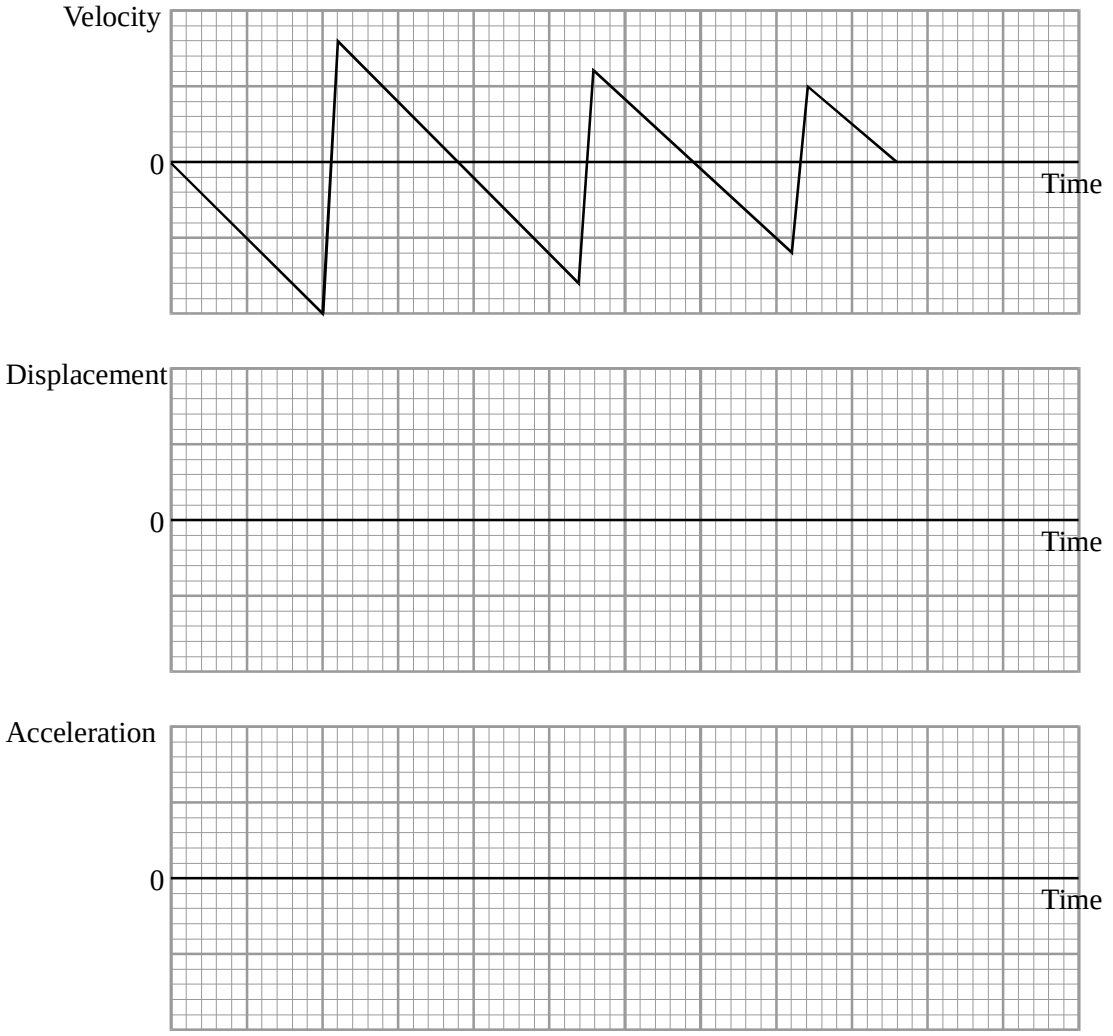
.....

.....

(2)

An older child bounces a rubber ball up and down on a hard floor. She releases the ball and allows it to bounce three times before catching it again. The velocity-time graph for this motion is shown below.

Draw displacement-time and acceleration-time graphs on the axes below for the same three bounces of this ball. Let zero displacement be floor level.



(4)

State and explain whether this ball is bouncing with simple harmonic motion,

.....

.....

.....

.....

(2)

(Total 12 marks)

18. (a) Briefly explain how scientists might investigate the order (or lack of it) in a liquid crystal.

.....

.....

(2)

(b) Calculate the speed of light along the director of the liquid crystal.

.....

.....

Speed =.....

(2)

(c) What is meant by **plane polarised** light?

.....

.....

(1)

(d) Describe an experiment that could be used to check whether the plane of polarisation had been rotated by a sugar solution.

.....

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(4)

(e) Calculate the thickness *d* of liquid crystal required for a 90° rotation of the plane of polarisation.

.....

.....

Thickness *d* =.....

(2)

(f) Calculate the electric field strength across the liquid crystal for a voltage of 1.5 V. State any assumption made.

.....

.....

.....

Electric field strength =.....

(3)

(g) Explain, with a suitable calculation, why, without multiplexing, only four parts of the display can be addressed within each scan.

.....

.....

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(4)

(h) The problem discussed in (g) can be reduced by the use of **multiplexing.** Explain the meaning of the word **multiplexing** and describe one way in which multiplexing might be achieved.

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(4)

(i) Liquid crystal displays only operate over narrow temperature ranges. Give two reasons why they will not operate outside this range.

.....

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.....

.....

(2)

(Total 24 marks)

19. In a stadium spectators sometimes stand up and sit down in turn producing a wave-like effect known as a "Mexican Wave" which travels around the stadium.

In this question we will consider a simple model for this wave travelling alone, a single line of people.

To start with, each person is sitting down. At time t = zero, person A starts the wave by standing up. He remains standing for 2.0 seconds, then sits down again. Person B follows A's movement exactly, but after a delay of 0.7 s caused by human reaction time. Each person along the line follows the movement of the person next to them, with the same delay of 0.7 s. The centre of each seat is 0.6 m from the next seat.

Complete the table to show the time at which each spectator stands and then sits.

	A	B	C	D	E	F
stands	0.0 s	0.7 s	1.4 s			
sits	2.0 s	2.7 s				

(2)

The diagrams below show which people are sitting and which are standing at various times.

Complete the diagram by drawing in the position of the six people A–F at time t = 3.0 s.

		A	B	C	D	E	F
Before the wave starts	standing						
	sitting	0	0	0	0	0	0
At t = 1 s	standing	0	0				
	sitting			0	0	0	0
At t = 3 s	standing						
	sitting						

(2)

State and explain which type of wave is demonstrated by this model.

.....

.....

.....

.....

(2)

Show that using this model the speed of the wave along the line of people is about 0.9 m s^{-1}.

.....

.....

(2)

The speed of a real Mexican wave is faster than that given by this model. Suggest a reason for this.

.....

.....

.....

(1)

(Total 9 marks)

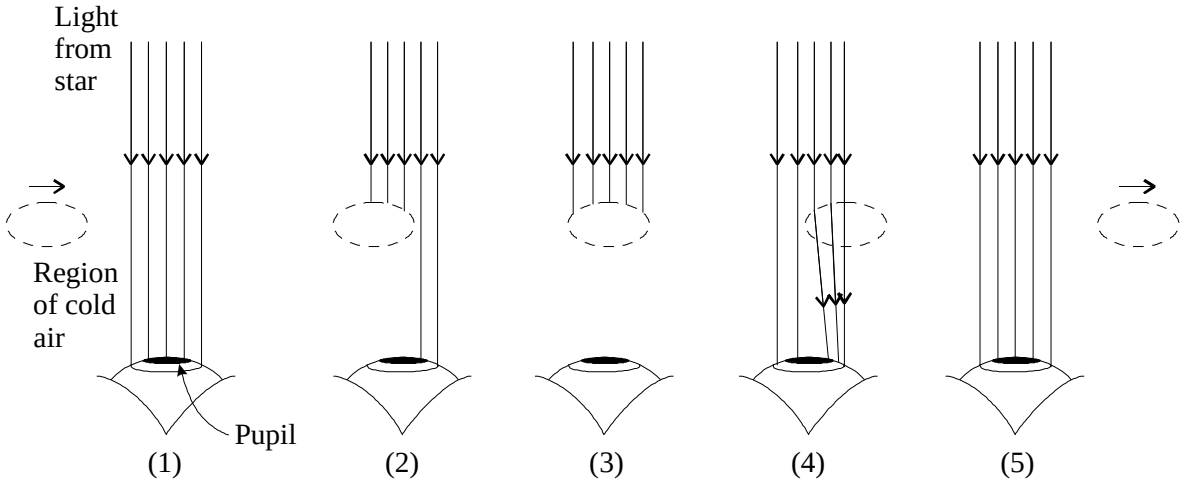
20. Explain what is meant by the focal length of a lens.

.....

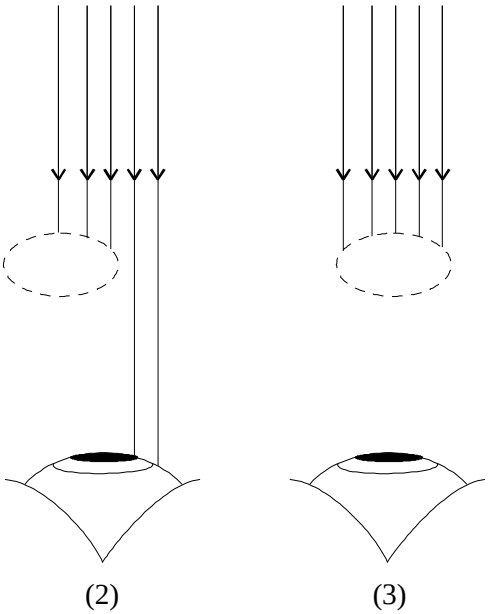
.....

(2)

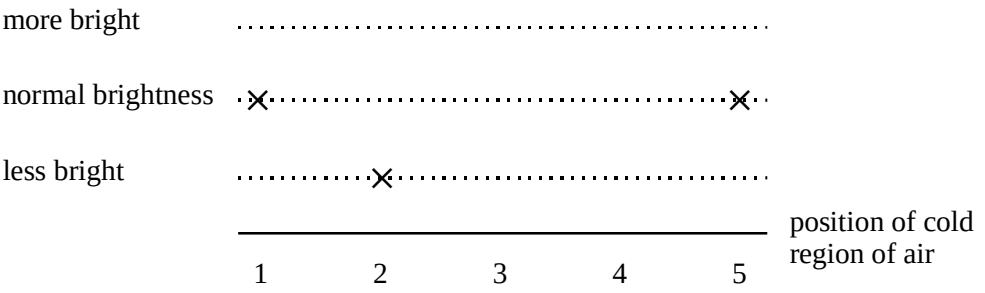
Stars appear to twinkle because their light is refracted as it passes through regions of different densities in the Earth's atmosphere. In a simple model of this situation, a convex region of air that is colder than its surroundings acts like a converging lens. The sequence of diagrams below represents such a region of colder air moving across in front of a person who is watching a particular star. Diagrams 1, 4 and 5 have been completed to show the path of light from the star. The diagrams are not drawn to scale.



Diagrams 2 and 3 are reproduced below. Complete these ray diagrams.



The diagram below shows the variation in brightness of the star as it appears to the observer for diagrams 1, 2 and 5.



Complete this diagram to show the observed brightness when the cold region is in the position shown on diagrams **3** and **4.**

(2)

Explain the variation in observed brightness as the cold air region moves from the position shown in diagram **1** to that shown in diagram **3**.

.....

.....

.....

.....

(3)

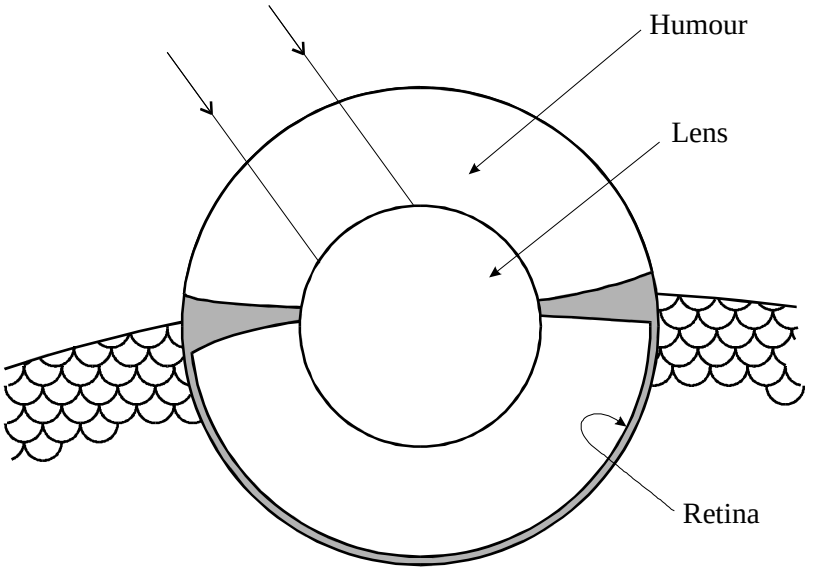
Give one reason why the Sun does not appear to twinkle in the same way.

.....

.....

(1)
(Total 11 marks)

21. In the eye of a fish, a transparent crystalline sphere is supported at the centre of a ball of liquid, called humour. The crystalline sphere acts as a lens and forms sharp images on the retina.



Fish eye

The light rays pass without bending from water into the humour. State the value for the refractive index for light travelling from water into the humour, $_{w}\mu_{h}$.

$_{w}\mu_{h}$ = ...

(1)

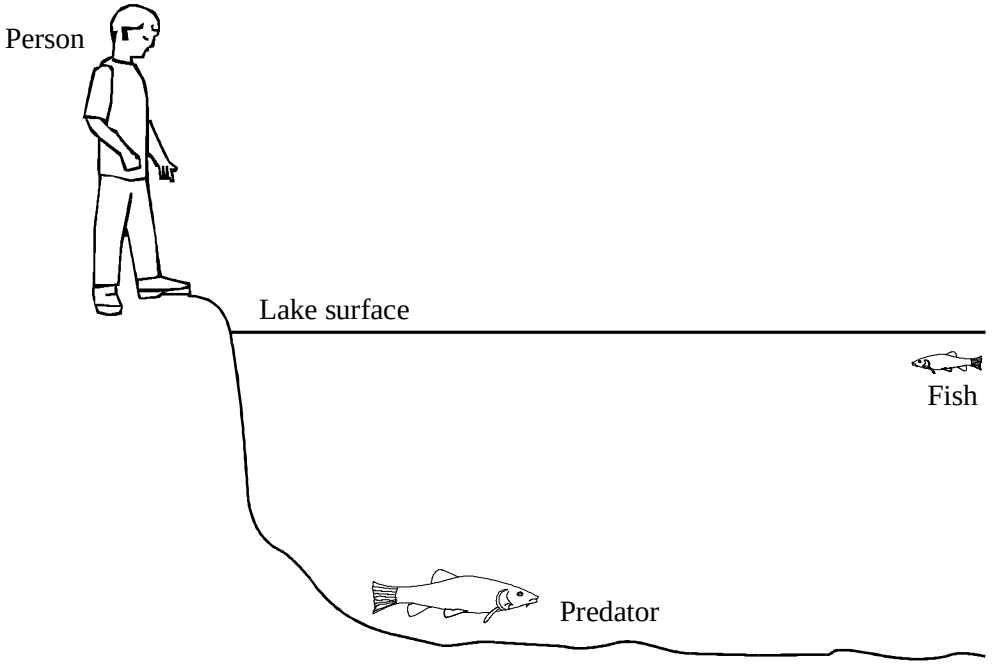
Extend the two rays shown in the diagram to show how they form a sharp image of a distant object on the retina.

(2)

The fish focuses on objects that are at different distances by moving the lens relative to the retina. The fish looks at a distant object then a close one. Use diagrams to explain how the lens must be moved to keep the image in focus.

(3)

Looking **upward** when the surface of the lake is smooth, the fish can see people on the bank and predators near the bottom of the lake.



On the diagram draw one ray of light reaching the fish

(i) from the person's head,

(ii) from the predator.

(3)

Calculate the critical angle for light passing from water to air. The refractive index for light travelling from air into water is 1.33.

.....

.....

.....

Critical angle = ...

(2)

(Total 11 marks)

22. **Quantum Balls**

BUCKYBALLS - spherical molecules made up of 60 carbon atoms - can behave like waves, blurring the boundary between the everyday world and the realm of quantum mechanics.

Markus Arndt and his colleagues at the University of Vienna sent buckyballs through a diffraction grating. A detector beyond the grating showed a clear interference pattern, where waves superimpose, indicating wavelike behaviour. “The interference pattern can only be explained if, in effect, each molecule goes through at least two of the openings” says Anton Zeilincer, who supervised the research.

Zeilinger predicts similar results with objects as large as viruses. He suggests that people think that quantum physics deals with small particles and classical physics deals with large things but that really the quantum world has no boundary.

Based on New Scientist Magazine, vol. 164, issue 2208.

Explain the words below.

Diffraction

.....

.....

.....

Superposition

.....

.....

.....

Quantum

.....

.....

.....

(4)

State one other particle you have met in your course which exhibits similar wavelike behaviour.

.....

(1)

What does this passage tell us about classical and quantum physics?

.....

.....

.....

.....

(2)
(Total 7 marks)

23. In a railway system the rails are exposed to high stresses which can lead to the development of small cracks. For safety the regular testing and monitoring of rails in service is a vital requirement. Ultrasonics can be used as a method of quick, non-destructive testing without removing the rails.

Give one reason why it is important to have a quick, non-destructive method of testing rails without removing them.

.....

.....

(1)

Ultrasonics involves the use of sound waves with frequencies above 20 kHz, the maximum frequency usually audible to human beings.

Describe sound waves passing through a steel rail in terms of the displacement of the particles in the steel.

.....

.....

.....

.....

.....

.....

(3)

The speed of sound in steel is 5900 m s^{-1} and the frequency used is 4.0 × 106 Hz.

Show that the wavelength of the ultrasonic waves is about 1.5×10^{-3}m.

.....

.....

(2)

What is meant by

frequency? .....

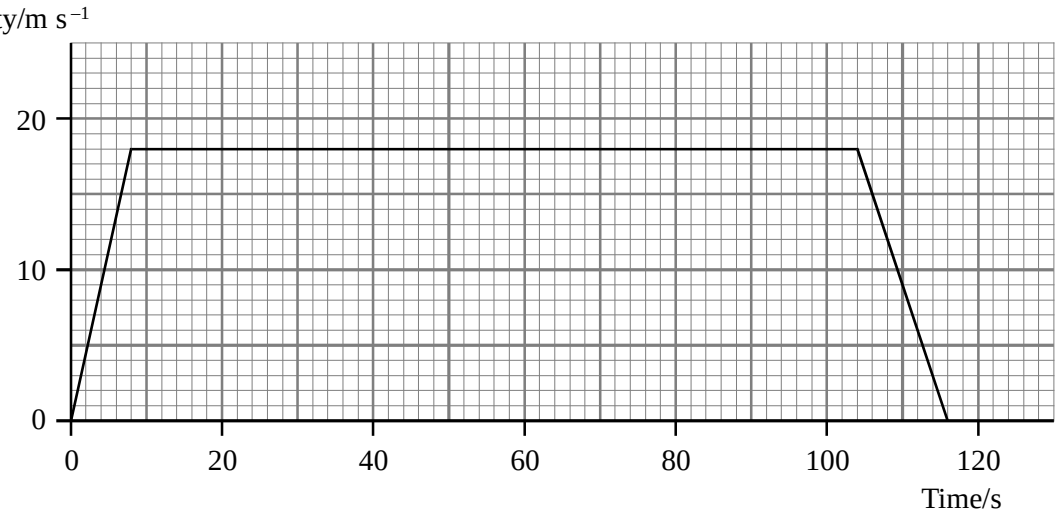
.....

wave1ength? .....

.....

(3)

Ultrasonic fault detectors are mounted on a special coach which can carry out testing at high speeds. The velocity-time graph below records the motion of the coach while testing a length of track.



Use the graph to find the length of track tested.

.....

.....

.....

.....

Length = ...

(3)

(Total 12 marks)

24. Extract from "The Last Word", New Scientist magazine.

> Question: While listening to the radio tuned to a frequency of 94.6 MHz (1 MHz= 1×10^6 Hz), I realised that I could either make the radio signal loud or reduce it almost to nothing by moving about the room or simply by leaning backwards or forwards. What caused this problem?
>
> Answer: The reason for your problem is that radio signals, of wavelength about 3 metres, are being reflected off the walls, floor and ceiling of the room - and, of course, off you. The signals therefore reach the radio by at least two different paths. This leads to an effect called superposition. By trial and error you can place your body in a position to cause this cancellation effect and then by moving by about *75* cm you can hear the signal clearly.

What is meant by superposition?

.....

.....

(2)

Explain why the body in one particular place can cause a cancellation effect.

.....

.....

.....

.....

.....

.....

(3)

Explain why stepping forwards by 75 cm could be enough to change the effect from cancellation to a loud signal.

.....

.....

.....

(3)

(Total 8 marks)

25. A lens of focal length 50 mm is used as a magnifying glass to view an insect.

What type of lens is needed?

.....

(1)

Calculate the power of the lens.

.....

.....

Power = ...

(2)

The lens is placed 30 mm from the insect. Calculate the distance of the image from the lens.

.....

.....

.....

.....

.....

Distance = ...

(3)

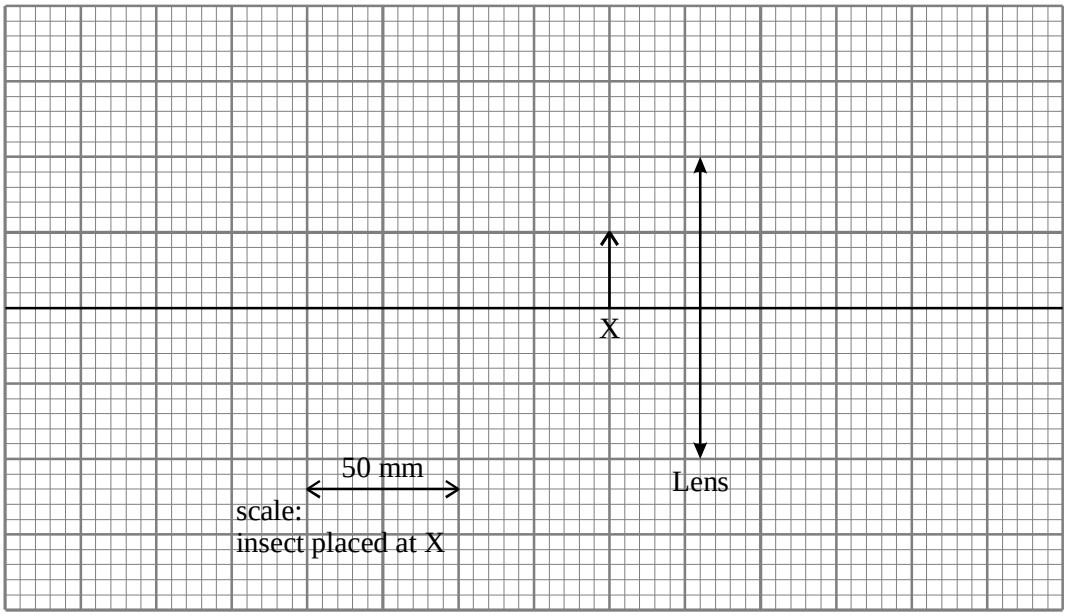
Explain whether the image is real or virtual.

.....

.....

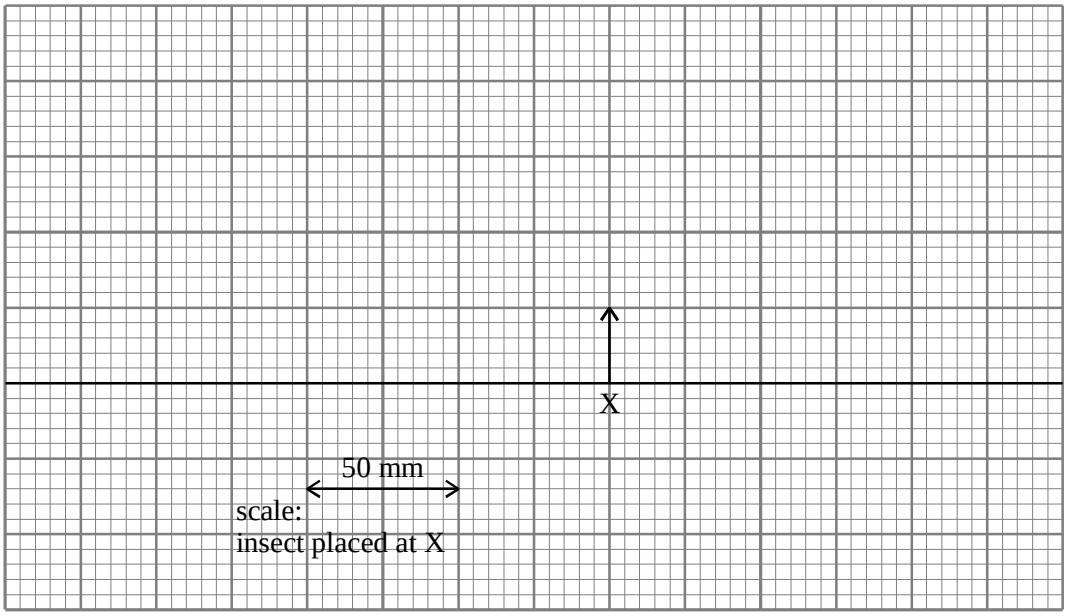
(1)

Complete the ray diagram below to show where the image is formed. Draw the eye of the observer on your diagram.



(3)

Use the grid below to show how the image can be made larger with the same lens.



(2)
(Total 12 marks)

26. A food packaging factory is moving soup through a 0.075 m diameter pipe when an obstruction occurs in the pipe. An ultrasound probe, connected to an oscilloscope, is moved along the pipe to find the obstruction (figure 1). The oscilloscope trace is shown below (figure 2).

Figure 1

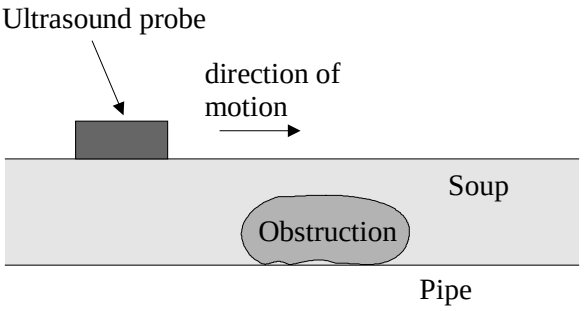
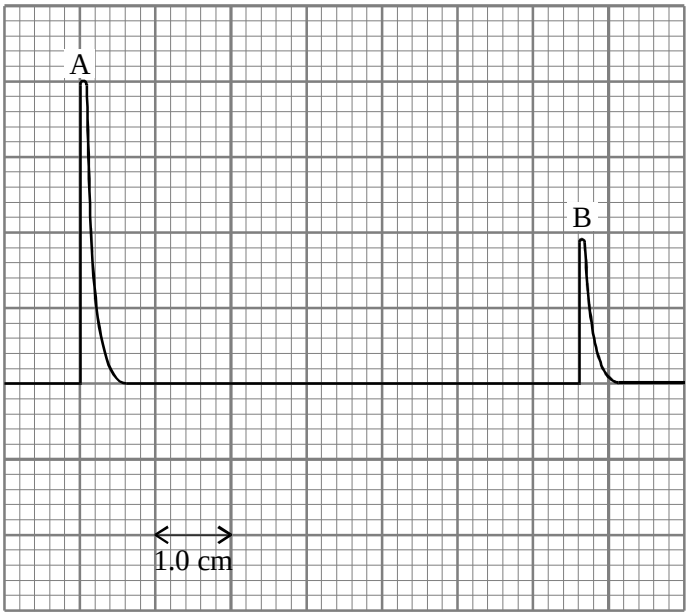


Figure 2



Oscilloscope time base = 20×10^{-6} s cm^{-1}.

On figure 2, pulse A is the outgoing signal from the probe and pulse B is the reflected signal from the other side of the pipe

Calculate the speed of the ultrasound in the liquid in the pipe.

.....

.....

.....

Speed = ...

(2)

State one way in which the oscilloscope trace will change when the ultrasound probe is above the obstruction.

.....

.....

.....

(1)

After the obstruction has been cleared, a "Doppler" ultrasound probe is used to measure the speed of the soup in the pipe. Describe the principle of this method.

.....

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(3)

What must be measured to determine the speed of the soup?

.....

.....

(1)

Someone says that this would be easier if the soup contained lumps like vegetables. Comment on this suggestion.

.....

.....

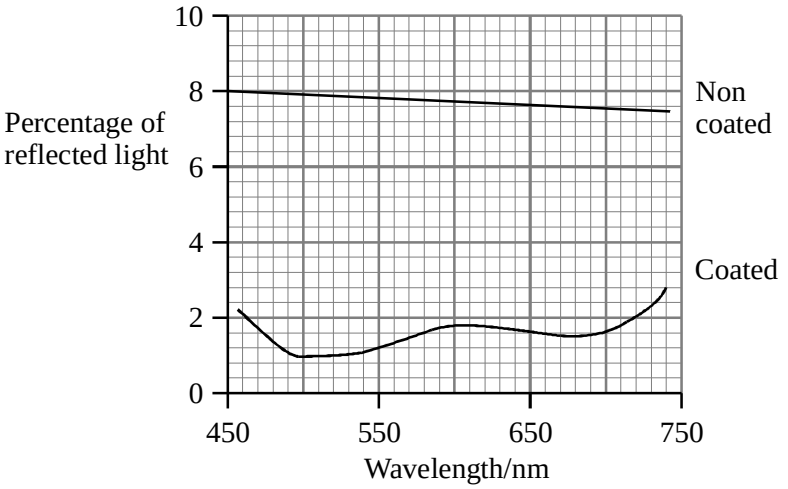
.....

(1)

(Total 8 marks)

27. One of the main features of glass is that it is transparent. However, most glass surfaces reflect some of the incident light so that only some of the light is transmitted. This is a particular problem if the glass is to be used for spectacle lenses which may be worn in low light conditions such as when driving at night. The problem can be reduced by the use of a special coating which reduces the amount of reflected light.

The graph below shows the relationship between the percentage of reflected light and the wavelength for two glass surfaces, one of which has been treated with a special non- reflective coating.

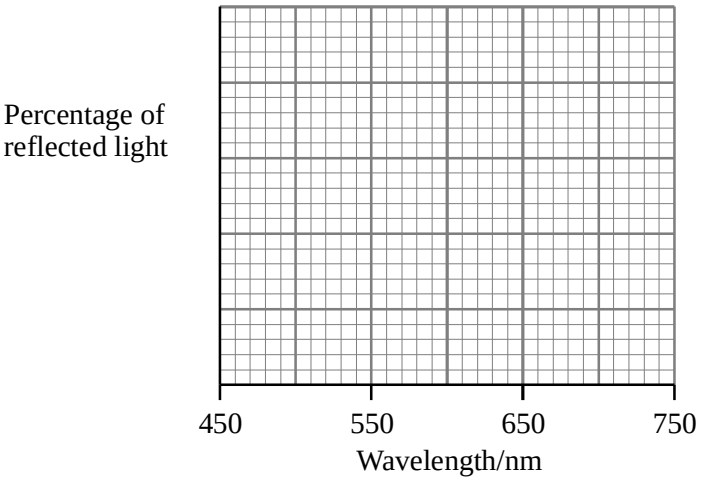


State the wavelength range for which the coated glass reflects less than 2% of the incident light.

.....

(1)

Sketch a graph of the percentage of light **transmitted** by the coated glass surface against wavelength. Add a suitable scale to the y axis.



(2)

The smallest amount of light is reflected when the wavelength in the coating is about 360 nm. Calculate the wavelength in air. (The refractive index of the coating is 1.38.)

.....

.....

Wavelength = ...

(1)

Explain why the thickness of the coating should be 90 nm to obtain the minimum amount of reflection.

.....

.....

.....

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.....

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(3)

Light reflected from the glass surface may be plane polarised. Explain the difference between unpolarised and plane polarised light.

.....

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.....

.....

.....

.....

(2)

(Total 9 marks)

28. Debbie complains on the internet:

> I have the loudest neighbours you've ever heard and they seem to be able to stay up ALL night. Their dog barks all the time, but their three main weapons are the guitar, the stereo and SURPRISE! They also have an alarm clock that's so loud that it sounds as if it's attached to the stereo.

James replies:

> Noise can be blocked out nowadays, with electronics and good soundproofing. The electronic device is just some sort of microphone that can pick up and analyse a sound. The device can produce the opposite frequencies and/or wavelengths of these sounds to balance them out.

Consider the phrase **good soundproofing**.

(1)

What type of material is best for soundproofing?

.....

(1)

Explain what makes this type of material good for soundproofing.

.....

.....

.....

(1)

James' reply shows some confusion about how electronic soundproofing works. Rewrite a short reply correctly explaining the physics of electronic sound reduction.

.....

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(4)

The noise level that Debbie hears may be made worse by resonance occurring in the building structure.

Explain what is meant by the term **resonance** in the context of high noise levels in buildings.

.....

.....

.....

.....

(2)

Name the process that reduces the amount of sound transmitted in this way.

.....

(1)
(Total 9 marks)

29. An earthquake produces waves which travel away from the epicentre (the source) through the body of the Earth. The particles of the Earth oscillate with simple harmonic motion as the waves pass carrying energy away from the source.

State the conditions which must occur for the motion of the particles to be simple harmonic.

.....

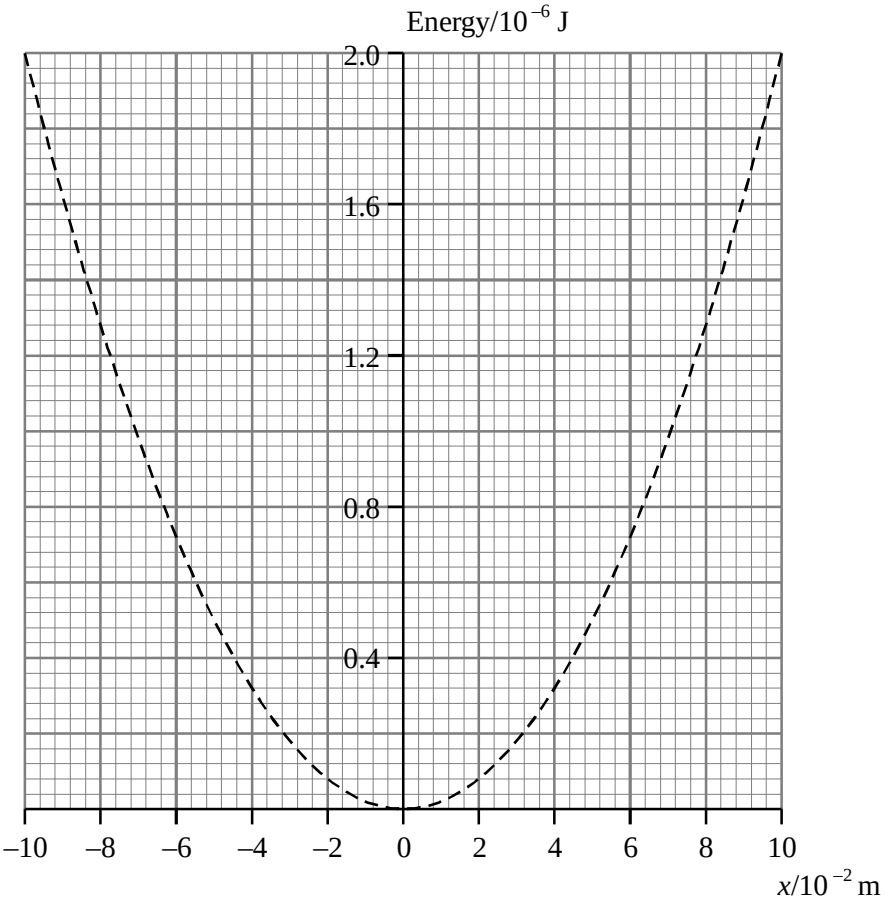
.....

.....

.....

(2)

The graph below shows the variation of potential energy E_p with displacement x of a particle 100 km from the epicentre.



Add to the graph labelled lines which show the variation with displacement of

(i) the kinetic energy E_k of the particle,

(ii) the total energy T of the particle.

(2)

Calculate the constant k where k is the stiffness of the "bonds" between particles oscillating within the Earth.

.....

.....

.....

.....

Stiffness = ...

(2)

The radiant energy flux of light is given by:

$$F = \frac{L}{4\pi d^2}$$

Assume the intensity of the waves produced by this earthquake decreases with distance from the epicentre in a similar way.

Draw a line on the previous graph to show the variation in potential energy of a similar particle 150 km from the epicentre.

.....

.....

.....

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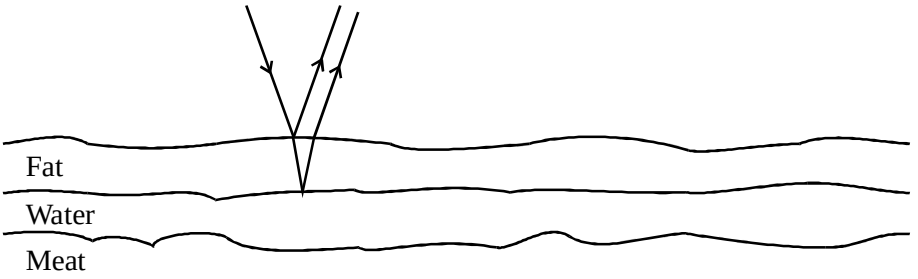
(3)
(Total 9 marks)

30. Sometimes shiny colours maybe seen on the surface of cold meats, with different colours appearing at different parts of the surface. It has been suggested that this is caused because the fat and water on the surface of the meat separate into two layers. The colours are caused by *superposition* of light reflected from the upper and lower surfaces of the fat layer.



What is meant by **superposition?**

.....

.....

.....

(2)

At one point on the surface where light strikes the top of the fat layer at right angles, the path difference between reflecting from the top and bottom surfaces of the fat layer is 8×10^{-7} m.

Calculate the thickness of the fat layer here.

.....

.....

Thickness = ...

(1)

In fat, green light has wavelengths between about 3.7×10^{-7} m and 4.1×10^{-7} m.

Explain why some green light will undergo constructive superposition at this place on the meat.

.....

.....

.....

.....

(2)

The whole visible spectrum has wavelengths between about 3.0×10^{-7} m and 5.2×10^{-7} m in fat.

Explain what happens to wavelengths other than green light at this place in the meat.

.....

.....

.....

.....

(2)

Explain why shiny colours other than green may be seen at different places on the surface of the meat.

.....

.....

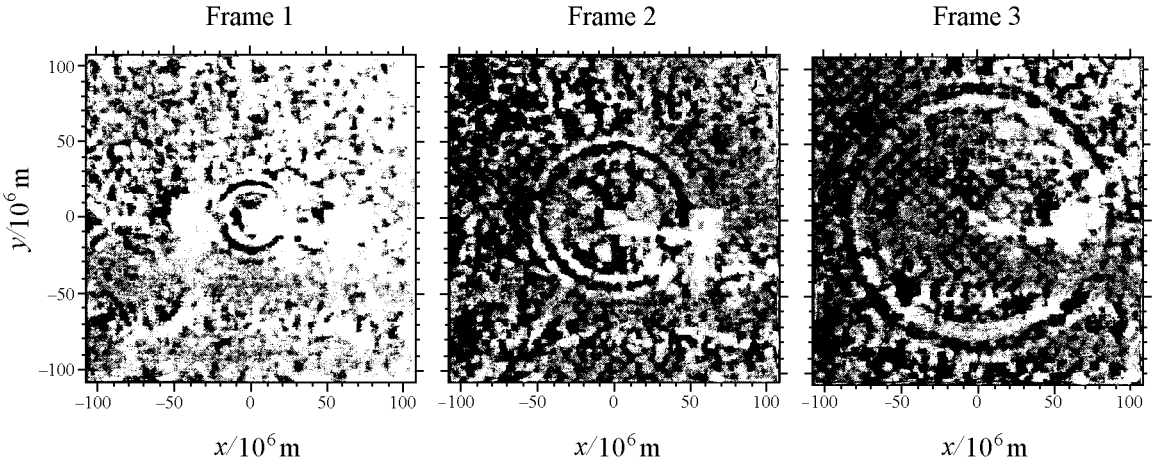
.....

.....

(2)

(Total 9 marks)

31. The photograph sequence shows a ripple spreading out over the surface of the sun, following an event similar to an earthquake somewhere within it. The interval between each successive frame is 10 minutes. A distance scale is marked beside each frame.



Measure the diameter of the dark ring of the ripple in frames 1 and 2 in mm.

Diameter of dark ring in frame 1 = ... mm

Diameter of dark ring in frame 2 = ... mm

(1)

Show that in the time interval between frames 1 and 2, the ripple travels about 25×10^6 m.

.....

.....

.....

.....

(2)

Hence calculate a speed in m s^{-1} for the ripple from frame 1 to frame 2.

.....

.....

Speed = ... m s^{-1}

(3)

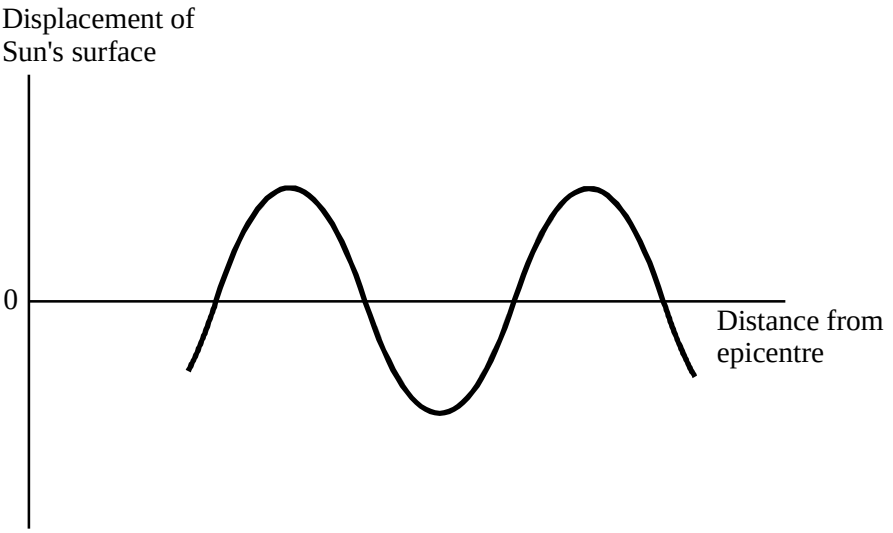
How could a physicist check whether the speed of the ripple was constant?

.....

.....

(1)

The diagram shows a cross-section of part of the ripple for the first photograph.



On the diagram above, mark and label the wavelength and amplitude.

(2)

The wavelength is 1.4×10^7 m.

Calculate the frequency of the waves.

.....

.....

Frequency = ...

(2)

These images were stored in digital form. What does digital mean?

.....

.....

(1)

(Total 12 marks)

32. There are concerns among fishermen that dwindling fish stocks in the world's oceans are result a of modern fishing, techniques. Fishing trawlers can detect shoals of fish using ultrasound.

Describe the movement of water molecules when an ultrasound wave passes.

.....

.....

.....

.....

(2)

Ultrasound pulses can be transmitted into the sea and the reflected waves can be detected and used to find the position of a shoal of fish.

Explain why **pulses** of ultrasound are used.

.....

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(1)

A shoal of fish is at a depth of 300 m. Calculate the time interval between transmitting the pulse and receiving its echo.

(The speed of ultrasound in water = 1500 m s^{-1}.)

.....

.....

.....

.....

Time interval = ...

(2)

A **continuous** ultrasound signal can be used to determine the speed of the shoal of fish.

Name the effect used in this method.

.....

Briefly explain the physics principles of this effect.

.....

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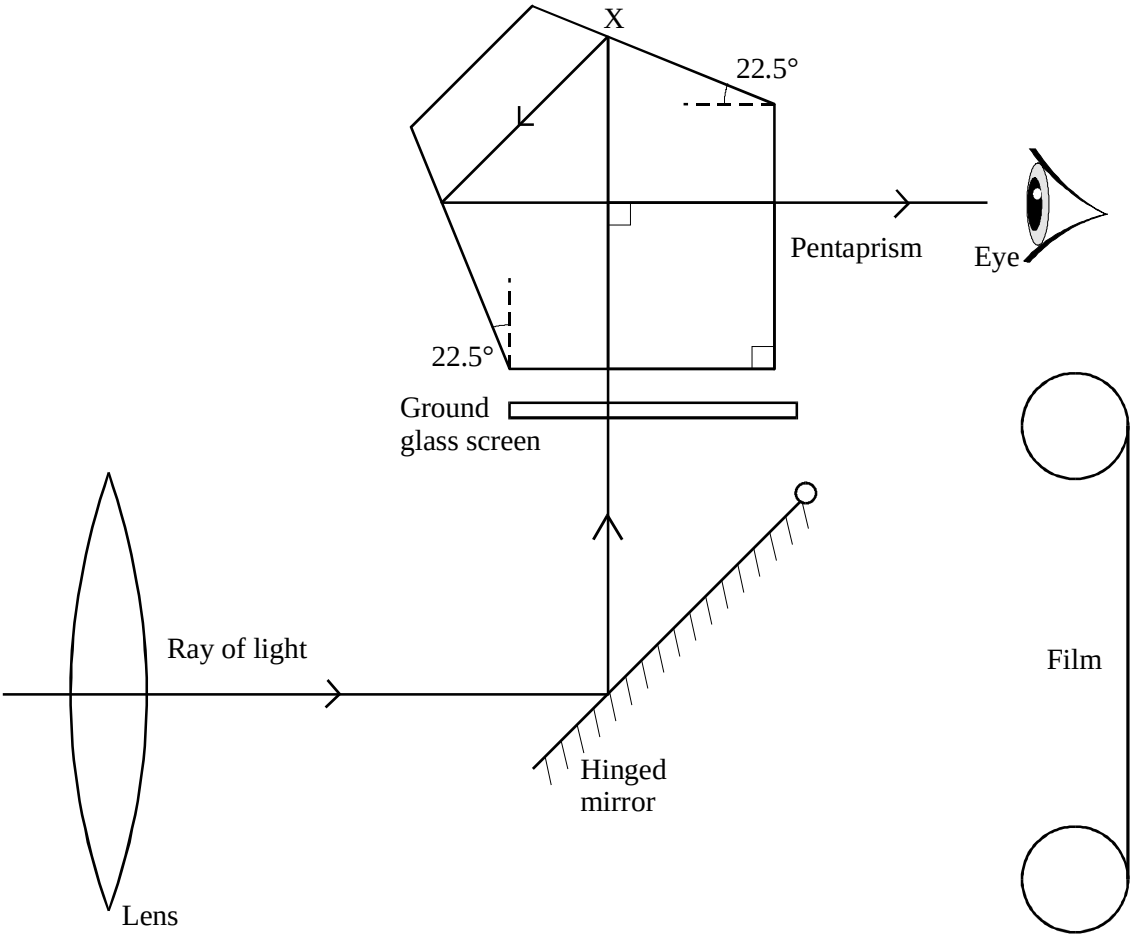
.....

.....

(3)

(Total 8 marks)

33. The simplified diagram shows the path of a ray of light through a single lens reflex (SLR) camera. SLR cameras have the advantage that the photographer is able to view the image through the main lens rather than through a separate viewfinder.



The light passing through the lens is reflected by the hinged mirror to form an image on a ground glass screen. This image is then viewed through the pentaprism which reflects the light so that the viewfinder shows exactly the same scene as the lens.

Show that the critical angle for light in the glass pentaprism is about 42°.
(Refractive index for light passing from air to glass = 1.5)

.....

.....

(2)

Draw in the normal at X.
Calculate the angle of incidence for the light at X.

.....

.....

Angle of incidence = ...

(1)

Hence explain why the face of the pentaprism around X must be silvered to behave like a mirror.

.....

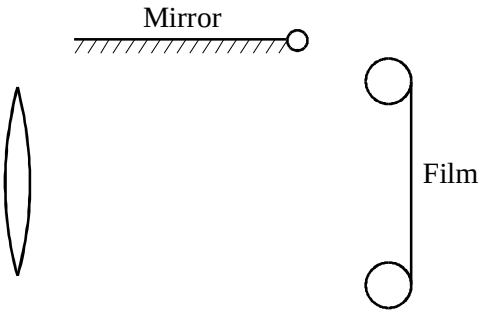
.....

.....

.....

(2)

The mirror swings up before the picture is taken.



The power of the lens is +20 D.
Calculate its focal length.

.....

.....

Focal length = ...

(1)

The distance of the lens from the film is adjusted in order to obtain a focused image of objects at different distances. Calculate the image distance required to take a photograph of a person 2.0 m away.

.....

.....

.....

Image distance = ...

(2)

Describe the nature of the image.

.....

.....

(2)

(Total 10 marks)

34. Deaf musicians detect sounds by sensing vibrations which travel through the floor. Some people say that these musicians keep in time better than others, because sound travels faster through a wooden floor than through the air.

Calculate the speed of sound in wood.

Young modulus of wood = 16 GPa
Density of wood = 600 kg m^{-3}

.....

.....

.....

Speed of sound = ...

(2)

For musicians 10 m apart, is there a noticeable time difference between sounds which travel through the wooden floor and through the air? Justify your answer with relevant calculations.

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

.....

.....

.....

.....

(2)

The amplitude of the sound vibrations which arrive through the floor is three times larger than that through the air. How do the intensities of these sounds compare?

.....

.....

.....

.....

(2)

State how the amplitude of echoes is reduced in a concert hall.

.....

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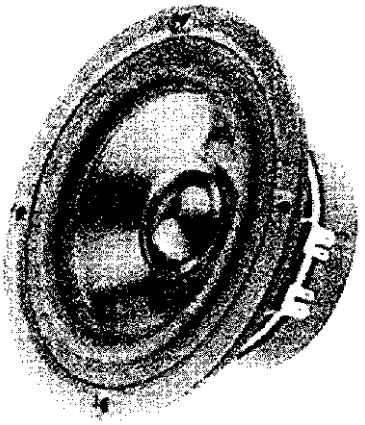
.....

(1)

(Total 7 marks)

35. The speaker shown below is used to produce the bass notes in a music system.



The cone moves with simple harmonic motion and it emits a single-frequency sound of 100 Hz. When it is producing a loud sound, the cone moves through a maximum distance of 2.0 mm.

The equation that mathematically describes the displacement of the cone is
$x = 1.0 \times 10^{-3} \cos 628\, t$.

Show that the data for this speaker lead to the numbers in the equation above.

.....

.....

.....

.....

(2)

Calculate

(i) the maximum acceleration of the cone

.....

.....

Maximum acceleration = ...

(ii) the maximum speed of the cone

.....

.....

Maximum speed = ...

(3)

On the grid below sketch the acceleration-time graph for two cycles of vibration of this speaker cone used under these conditions. Add suitable numerical scales to the two axes.

(3)

Explain why designers ensure that bass speakers have a natural frequency of oscillation much greater than 100 Hz.

.....

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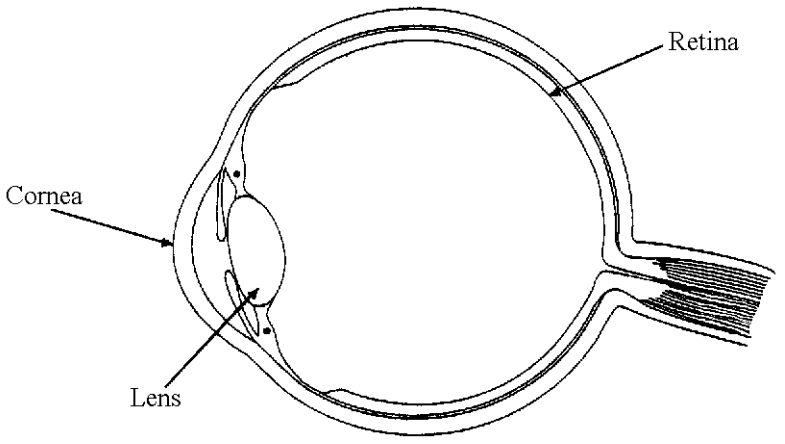
.....

(2)
(Total 10 marks)

36. The diagram shows a cross-section through a human eye.



Light from an object being viewed is focused on the retina by the cornea and the lens. The cornea does most of the focusing, with the thickness of the lens being adjusted to allow clear images to be formed of objects at different distances.

The following table gives typical data for a 10-year-old.

Maximum power of lens /	Maximum total power of lens + cornea /	Power of cornea / .....
14.0	56.0	

The unit for the power of the lens has been left out of the table. Fill it in.

(1)

The focusing, effect of the cornea and lens may be combined to consider them as a single lens. This is done by adding the power of each to find the power of the combination.

Complete the table by filling in the power of the cornea.

(1)

Explain what is meant by focal length.

.....

.....

.....

.....

(2)

Use the information in the table to show that the effective focal length for the eye of the 10-year-old at maximum power is about 0.02 m.

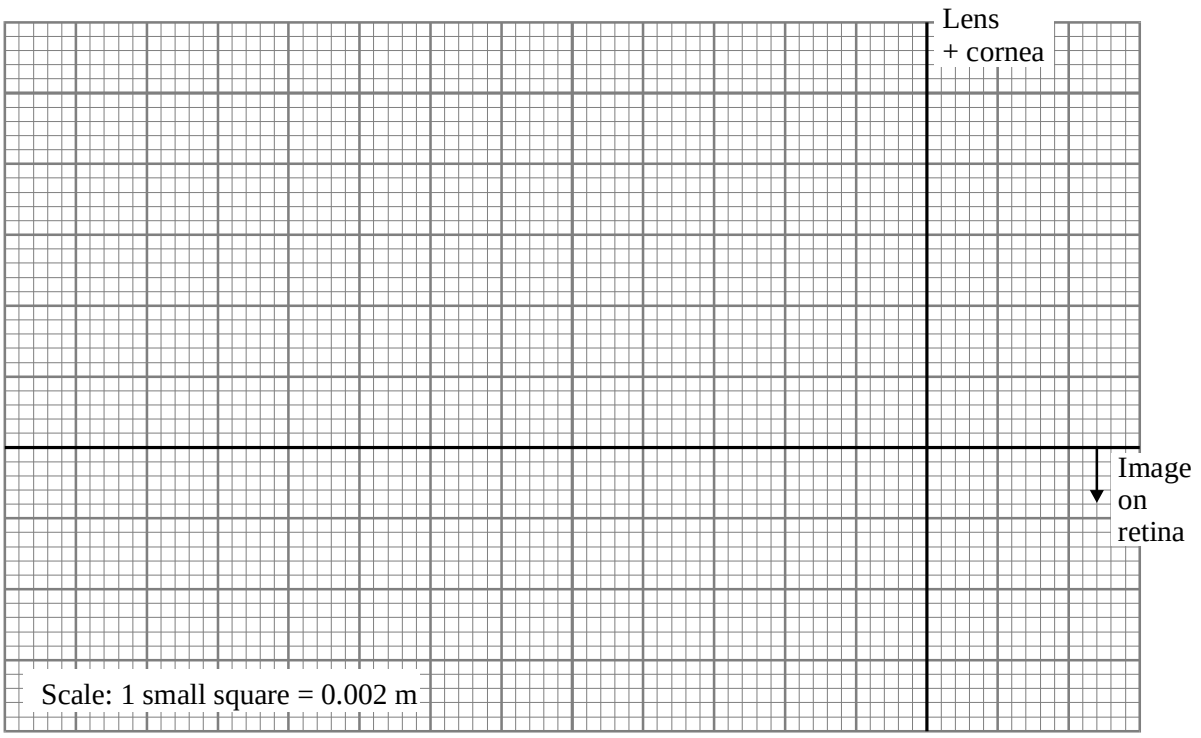
.....

.....

.....

(2)

Complete the ray diagram below to locate the position of the object forming the image shown on the retina when effective focal length of eye is 0.020 m.



(4)

(Total 10 marks)

37. A student has heard that the bright colours that he has noticed in soap bubbles are caused by superposition. To investigate this he sets up an experiment in a darkened laboratory. He bends a piece of wire into a rectangular shape, and mixes up a beaker of soapy water. He puts a sodium lamp (emitting bright yellow light) at one end of the bench. Then he dips the rectangle of wire into the soapy water so that a soap film forms, and puts the wire rectangle with its soap film into a clamp so that it stands vertically in front of the lamp – see Figure 1.

Figure 1

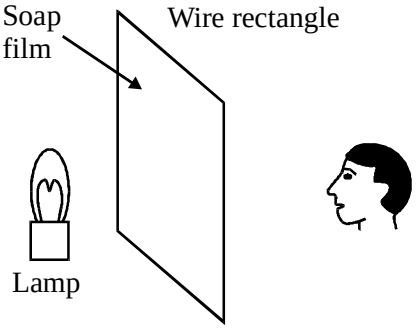


Figure 2

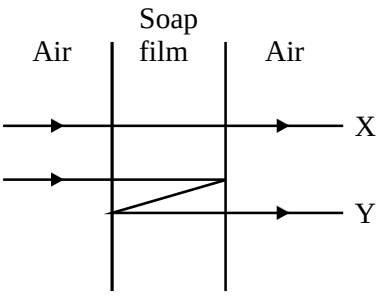


Figure 2 represents two possible paths for light to pass through the film from the lamp to the student. One path (labelled X) shows light passing straight through the film. The light following path Y is reflected twice, once at each side of the film, during its passage from the lamp to the student.

The thickness of the film in Figure 2 is 1.11×10^{-7} m. How much further does light following path Y travel compared with light following, path X?

.....

.....

Path difference = ...

(1)

The wavelength of the yellow sodium light in the soap film is 4.44×10^{-7} m. Explain why the part of the film shown in Figure 2 appears dark to the student.

.....

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(2)

In fact the thickness of the film increases from the top of the film to the bottom.
Suggest a reason for this.

.....

.....

(1)

At another place the thickness of the film is 2.22×10^{-7} m. Explain whether this part of the film appears bright or dark.

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(2)

As the student looks at the whole film, from top to bottom, he sees alternate bright and dark horizontal stripes. Explain this effect.

.....

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(2)

As the student watches, the whole pattern of bright and dark stripes gradually moves downwards. Explain this effect.

.....

.....

.....

(2)

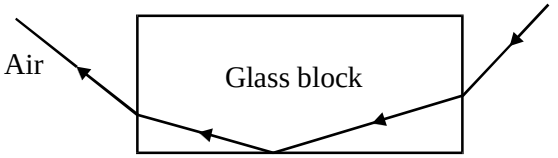
Add to Figure 2 another possible path for light travelling from the lamp to the student.

(1)

(Total 11 marks)

38. Travellers in hot places often think that they see water in the distance, when there is nothing but land there. This effect is called a mirage. The air near the ground is very hot, and light reflects off the top of this layer of hot air.

The diagram below shows how you could demonstrate the effect in a laboratory.



On the diagram draw appropriate normals and mark

(i) an angle of incidence, labelled *I*,

(ii) an angle of refraction, labelled *R*, and

(iii) an angle labelled G which you know is greater than the critical angle.

(3)

What does the way light refracts tell you about the velocity of light in glass compared with the velocity in air?

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.....

(1)

How does the velocity of light in the layer of hot air near the around compare with the velocity in the cooler air higher up?

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.....

(1)

Which property of the air has been changed by the temperature difference, producing this change in velocity?

.....

.....

(1)
(Total 6 marks)

39. A simple camera used for taking portraits has a converging, lens which is 0.050 m away from the film. When the object is 1.00 m away from the lens a clear image is produced on the film.

Calculate the focal length of this lens.

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.....

(3)

State the properties of the image.

.....

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(3)

Explain how the choice of transparent material used for the lens can affect the brightness of the image.

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.....

.....

(2)
(Total 8 marks)

40. A mass oscillating on a spring, is an example of simple harmonic motion.

State the conditions required for simple harmonic motion to occur.

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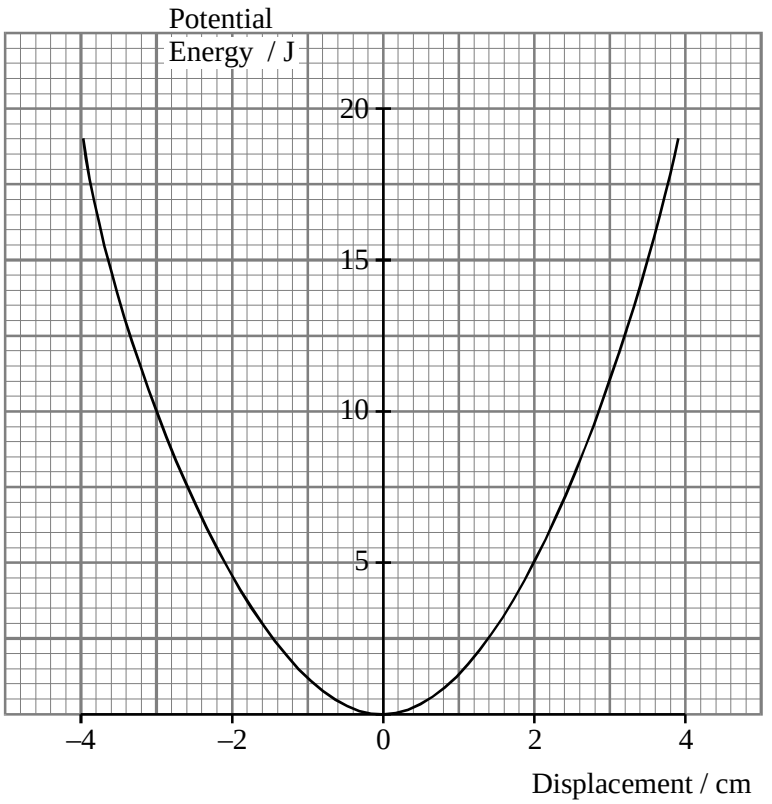
(2)

The graph shows how the potential energy varies with displacement for a particular mass and spring,



On the same axes draw a graph showing how the total energy of the mass-spring system varies with displacement, assuming no energy loss.

(1)

Use the graph to calculate

(i) the kinetic energy of the mass when the displacement is 2.0 cm,

.....

.....

.....

(ii) the stiffness, *k*, of the spring.

.....

.....

.....

(5)
(Total 8 marks)

41. An asteroid is observed heading towards the Earth. To find the speed of the asteroid a radio signal is directed at it from a station on Earth and the reflected signal is collected.

Explain why the reflected signal will have a much lower intensity than the transmitted signal.

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(2)

Explain how the reflected signal can be used to calculate the speed of the asteroid.

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(3)

The time interval between transmitting the signal and receiving its reflection is 120 s. Currently, the asteroid is approaching the Earth with a speed of 4 km s^{-1}.

Calculate

(i) the distance to the asteroid,

.....

.....

.....

(ii) the time the asteroid will take to travel this distance, stating any assumptions you make.

.....

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(3)

Explain why this asteroid is very unlikely to collide with the Earth.

.....

.....

(1)
(Total 9 marks)

42. The following invention will allow you to play your music at top volume without annoying the neighbours:

> A layer of small lead spheres is embedded into rubber. If you line your room with this material then the transmitted sound will be significantly reduced. This coating is particularly effective with low frequency sounds, the ones which most annoy the neighbours, as these cause the spheres to resonate.
>
> Adapted from *New Scientist*, Vol.167, Issue 2256

Explain the phenomenon of resonance in the context outlined above and describe how the intensity of the transmitted sound is reduced.

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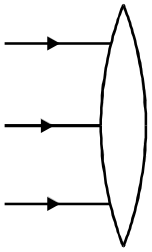
(Total 5 marks)

43. Complete the ray diagram below to show the action of the lens.



(3)

The lens above is replaced by a thinner lens of the same type and material. Explain the difference in power of the two lenses.

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(2)

Briefly describe, with the aid of a diagram, a simple experiment to measure an approximate value for the focal length of a converging lens.

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(3)

Explain, with the aid of ray diagrams, how the liquid lens could be used as part of a bionic eye to focus on **near** and **far** objects.

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(4)

Explain whether the oil or the salt water (see paragraph 2) would have the higher refractive index.

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(2)

Explain, with the aid of a diagram, why the arrangement of oil and film sandwiched between the salt water can be thought of as a capacitor.

.....

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.....

.....

(2)

A liquid lens has a capacitance of 50 pF when the applied voltage is 150 V Calculate the energy stored.

.....

.....

.....

Energy = ...

(3)

What is meant by **viscosity** and **damping**?

Viscosity .....

.....

.....

Damping .....

.....

.....

(2)

Suggest why it might **not** be sensible to remove the oscillations in the shape of a liquid lens by increasing the viscosity.

.....

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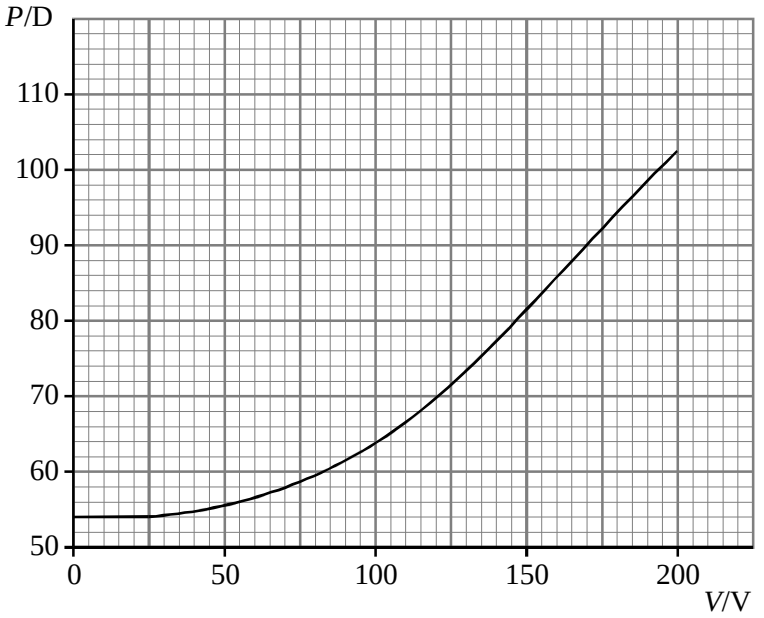
.....

(1)

(Total 22 marks)

44. The graph below (Figure 1) shows the variation in the magnifying power *P* of a liquid lens system with the applied voltage *V*.

Figure 1



Use this graph to draw relevant conclusions about the relationship between *P* and *V* over the full voltage range.

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(3)

The graph below (Figure 2) represents the variation of power *P* of this lens with time *t* following a sudden change in the applied voltage from 50 V to 150 V. Explain how you can tell that the initial and final values of power on Figure 2 are as predicted by the graph in Figure 1.

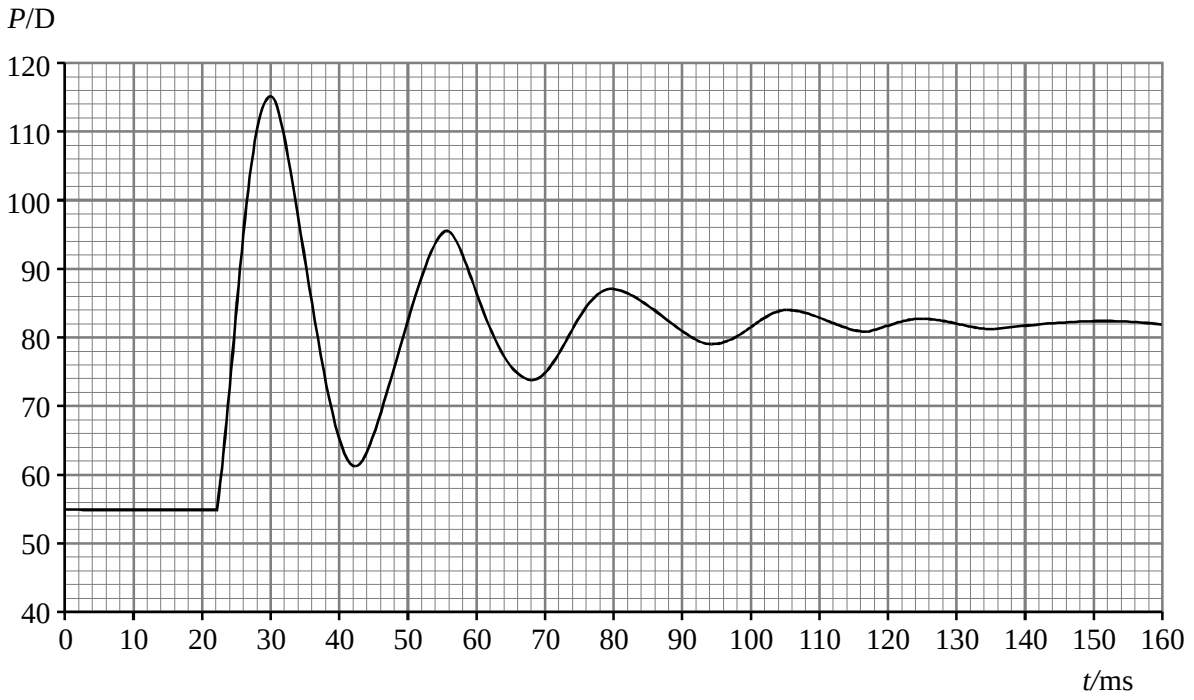
.....

.....

.....

(2)

Figure 2



Deduce the time period of the power oscillations.

.....

.....

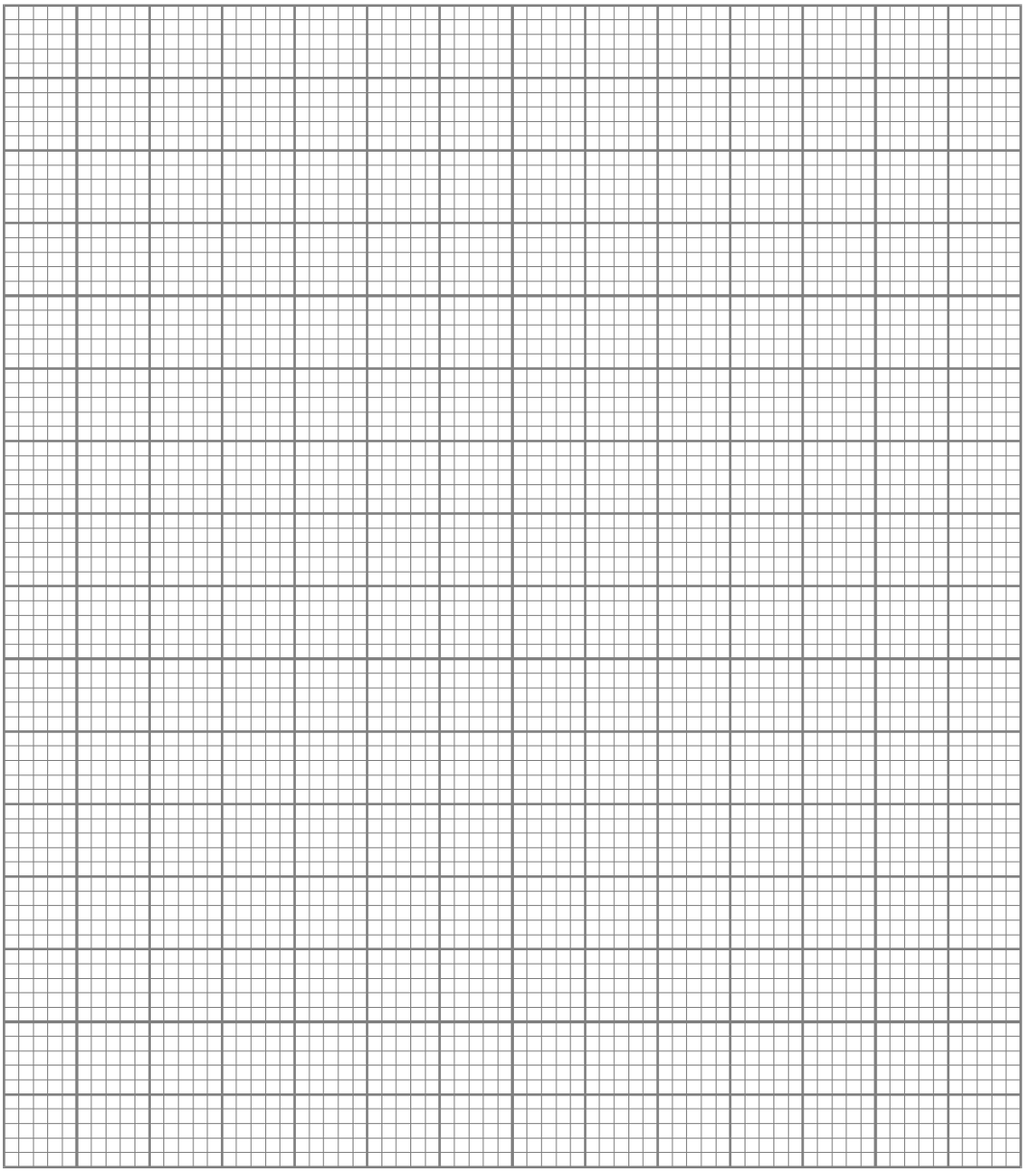
.....

(2)

A researcher suggests that the amplitude of the power oscillations is reduced **exponentially** with time. Complete the table below and draw a suitable graph to test this prediction. Two rows of data have been entered for you.

Time / ms	Power / D	Amplitude / D	ln(amplitude / D)
30	115	33	3.50
55	95	13	2.57

(7)



Explain how your graph tests this prediction.

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.....

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(1)

Use your graph to show that the decay constant of the power oscillations is about 40 s^{-1}.

.....

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(3)
(Total 18 marks)

45. Ultraviolet radiation from the sun can cause sunburn. However, not all ultraviolet wavelengths cause sunburn to the same extent.

What is meant by wavelength?

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.....

(2)

Explain why ultraviolet radiation is more likely to cause sunburn than visible light, which has a longer wavelength.

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(2)

Scientists put a lot of effort into developing suncreams which absorb the damaging wavelengths of ultraviolet radiation. Suggest what might be happening to the atoms within the suncream when they absorb ultraviolet photons.

.....

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.....

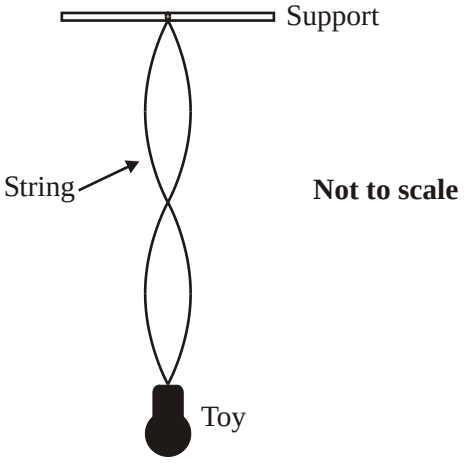
.....

(2)

(Total 6 marks)

46. A child's vibrating toy is made to work by pulling and releasing a string. The toy vibrates, making a buzzing sound, as the string rewinds. A student investigates the action of the toy.

She pulls the string and attaches the free end to a support. When released, the toy climbs up the string, vibrating the string as it rises.



The diagram shows the appearance of the string when its length is 0.24 m. At this position the vibrations show maximum amplitude.

The student observes that standing waves have been set up at this position of the toy. Explain how standing waves are produced.

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(3)

Mark one antinode on the diagram.

(1)

The student then takes the toy apart and records these results.

Length of string	= 0.24 m
Mass of string	= 1.5×10^{-4} kg
Weight of toy	= 0. 17 N

State the tension in the string when supporting the toy as shown in the diagram.

Tension = ...

(1)

Calculate the mass per unit length of the string.

.....

.....

Mass per unit length = ...

(2)

Show that the speed of the wave produced on the string in the diagram is about 20 m s^{-1}.

.....

.....

.....

.....

(2)

Calculate the frequency of the vibration of the string in the diagram.

.....

.....

.....

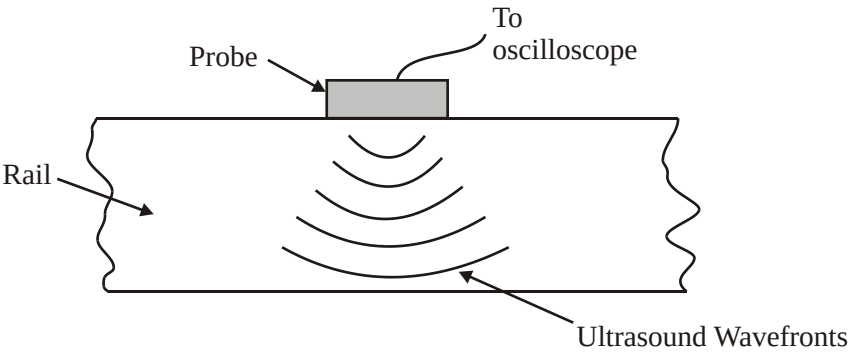
.....

Frequency = ...

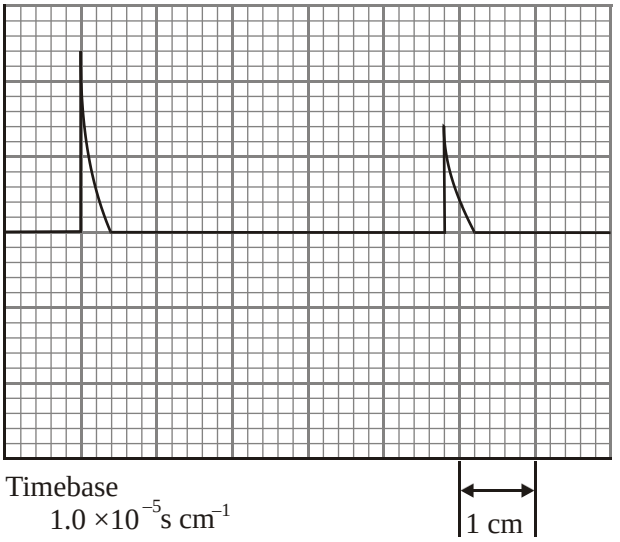
(3)

(Total 12 marks)

47. In testing railway lines for faults, an ultrasonic probe is placed on a rail.



Every 1.0×10^{-1} s, the probe emits a short pulse of ultrasound. The speed of ultrasound in steel is 5100 m s^{-1}. The probe, which also acts as a receiver, is connected to an oscilloscope which displays the trace shown below.



How can you tell that the left peak represents the emitted pulse?

.....

.....

(1)

Calculate the depth of the rail using a measurement from the oscilloscope trace.

.....

.....

.....

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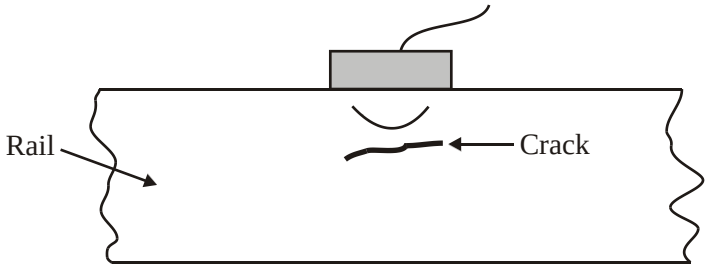
(3)

The probe is now moved to another position on the rail where there is a crack one third of the way down from the top.



Describe how the oscilloscope trace will change.

.....

.....

.....

(2)

The ultrasound diffracts round the crack because the crack behaves like an obstacle.
Draw wavefronts on the above diagram to show what this means.

(2)

When trains pass over rails, the rails deform, but then return to their original shape.
State two properties necessary for the rail material.

1 .....

2 .....

(2)

(Total 10 marks)

48. Explain the term **total internal reflection**.

.....

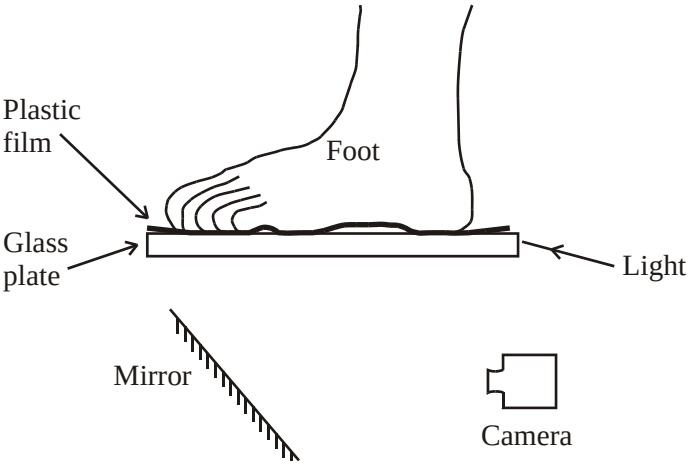
.....

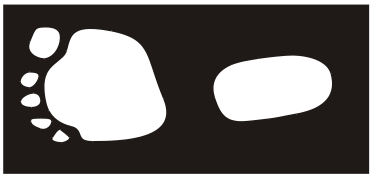
.....

.....

(2)

Below is an illustration of a pedobarograph and an image of a foot. This is a medical instrument used for measuring foot pressure when investigating problems with feet.





Observed image of foot

Calculate the critical angle for total internal reflection to occur at the glass-air interface. The refractive index of the glass is 1.5.

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.....

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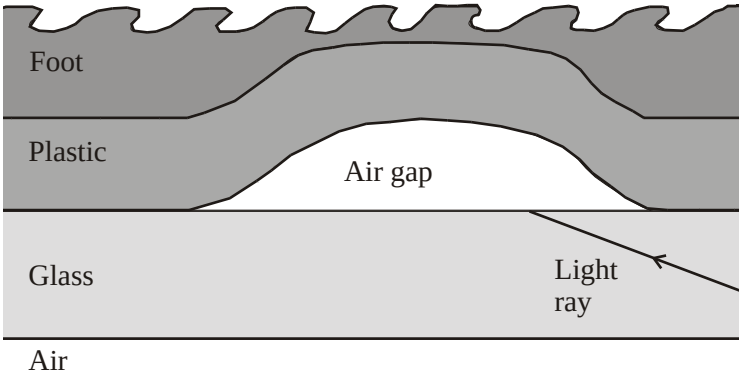
.....

(2)

Light rays are totally internally reflected within the glass plate except at the points where the feet press the plastic film against the glass.

Complete the path of the ray in the diagram below.

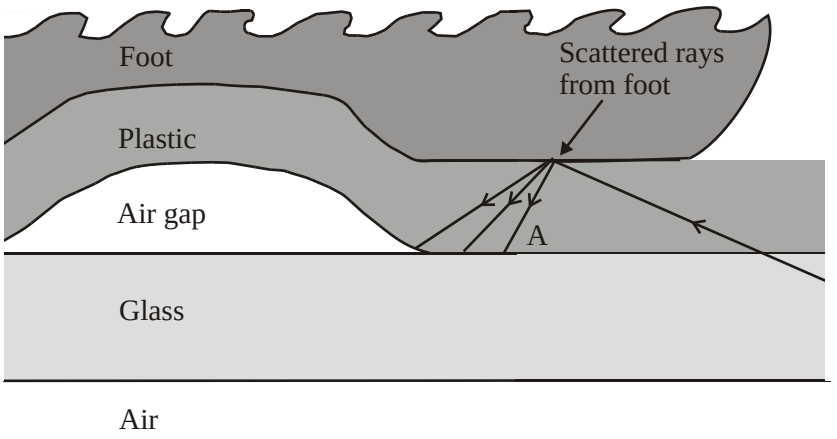


not to scale

(2)

Where the pressure from the foot forces the plastic in contact with the glass the light passes through the plastic and is then scattered from the foot.

Complete the path of ray A on the diagram below. The refractive index of the plastic used is approximately the same as glass.



not to scale

(3)

With reference to your ray diagrams above, explain why there are bright and dark patches on the image produced by the camera.

.....

.....

.....

(2)

(Total 11 marks)

49. Explain what is meant by the term **polarisation** when referring to light.

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(2)

Sugar is produced from plants such as sugar cane. The stems are crushed and the juice extracted. The concentration of sugar in the juice is used to value the crop.

The concentration can be determined using polarised light.

Explain how to measure the angle of rotation of polarised light when it passes through a sugar solution.

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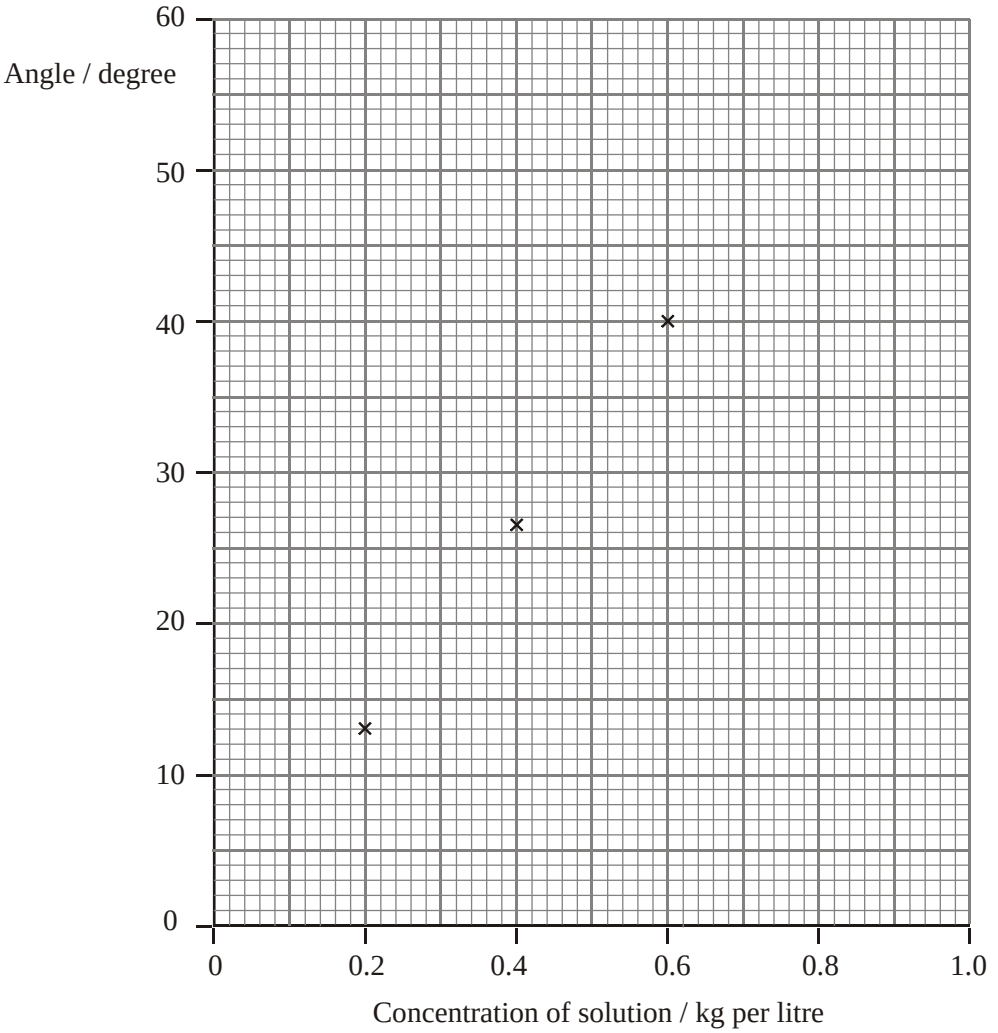
(4)

A student has carried out this experiment and obtains three results. He has plotted them on the graph below. He takes three more results and tabulates them.

Angle of rotation/degrees	Concentration of solution/ kg per litre
17	0.25
33	0.50
50	0.75

Add these results to the graph.

(3)



Use your graph to determine the concentration of an unknown sample which gives a rotation of 38°.

Concentration: ..... kg per litre

(1)

The sugar produced is dissolved in water and then heated. It turns brown and becomes thick and viscous. If it is heated for a long time and then cooled it becomes hard and brittle.

What is meant by the terms viscous and brittle?

Viscous .....

.....

Brittle .....

.....

(2)

(Total 12 marks)

50. Below are some examples of oscillations. For each, state with a reason whether the motion is simple harmonic or not.

Oscillation	SHM ✓ or ✘	Reason
Mass on end of a spring	.....	....
Child jumping up and down	.....	....
Vibrating guitar string	.....	....

(Total 4 marks)

51. A firework is stuck into the ground 400 m from an observer.

The observer sees the flash of the firework, then feels a vibration through the ground and finally hears the bang. Explain these observations.

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(2)

Calculate the time taken for the sound to reach the observer through the ground.

Young modulus of soil = 5.0×10^8 Pa
Density of soil = 1.5×10^3 kg m^{-1}

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(3)
(Total 5 marks)

52. Many people enjoy listening to live musical performances in concert halls. They expect the same quality of sound wherever they sit and do not expect to hear any interference or distortion in the music. Problems can occur from echoes inside the hall, noise from outside, vibrations from fittings and selective absorption of specific frequencies.

Write a short account of the relevant physics involved in the provision of good acoustics in a concert hall.

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(Total 8 marks)

53. In the film 'Contact', astronomers listen for signals from space as part of the Search for Extra-Terrestrial Intelligence (SETI).

The discovery of a signal is followed by this dialogue between two astronomers.

Astronomer 1: "What's the frequency?"

Astronomer 2: "4.4623 gigahertz – that's hydrogen times π."

By 'hydrogen', she was referring to the '21 cm' line in the spectrum of atomic hydrogen, a wavelength used by radio astronomers because it is not absorbed by the Earth's atmosphere. (1 gigahertz = 1×10^9 Hz)

Explain how hydrogen atoms emit radiation.

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(2)

Why do hydrogen atoms emit radiation at specific frequencies?

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(3)

Show that the statement by astronomer 2, "4.4623 gigahertz – that's hydrogen times π" is consistent with a hydrogen wavelength of about 21 cm.

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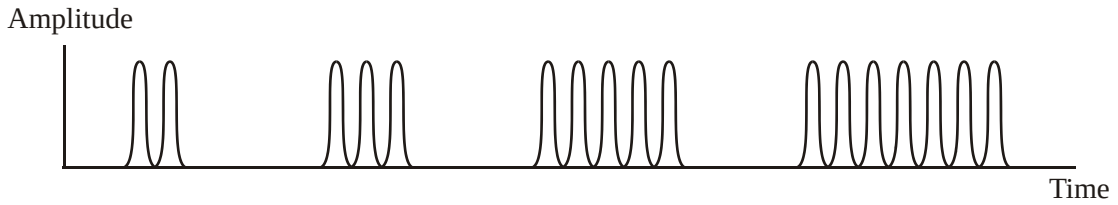
(3)

There are many natural sources of radiation, so SETI scientists look for evidence that the signals they receive are produced by intelligent beings. In the film 'Contact' there were two such pieces of evidence. One was the use of π as a factor in the frequency. The other was that a series of pulses was received – first 2, then 3, then 5, 7, 11, 13 etc, forming a series of prime numbers.

This series can be shown by the following graph of amplitude against time.



For each piece of evidence, explain whether it best fits the description of analogue or digital.

Use of π as a factor in the frequency: .....

.....

.....

(2)

Use of pulses to form a series of prime numbers:.....

.....

.....

(2)

(Total 12 marks)

54. A student records the note from one string of a piano onto a computer software package. The waveform of the note is shown in figure 1. The frequency spectrum of the note is shown in figure 2. This shows the relative amplitudes of the lowest 'fundamental' frequency and four further frequencies (overtones) that produce the note.

Figure 1

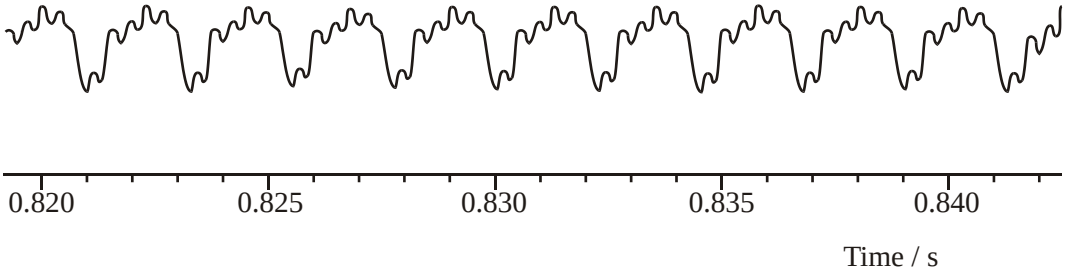
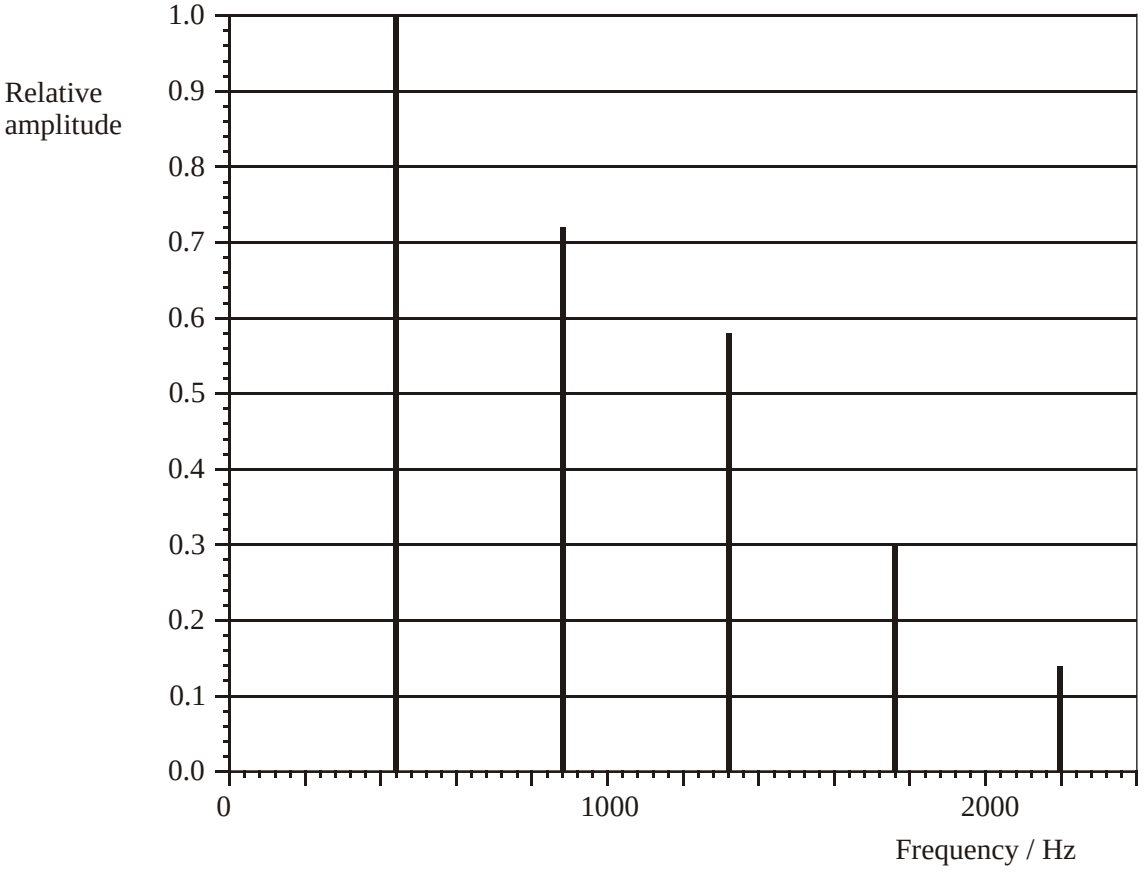


Figure 2



By reading from the frequency spectrum (figure 2) state

(i) the fundamental frequency of the note

.....

(1)

(ii) the frequencies of the first three overtones

.....

(2)

Comment on any pattern you see in these frequencies.

.....

.....

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(2)

From the waveform trace (figure 1) make the best measurement you can of the period. Show how you reach your answer.

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.....

Period = ...

(2)

Use this value for the period to calculate the frequency.

.....

.....

.....

Frequency = ...

(2)

The piano string which made this note had length 1.23 m. State the wavelength of the oscillation of this string that produces the fundamental frequency.

.....

.....

Wavelength = ...

(1)

(Total 10 marks)

55. The diagrams below illustrate the formation of a rainbow. Figure 1 shows the general arrangement and Figure 2 shows the path of a ray through a raindrop.

Figure 1

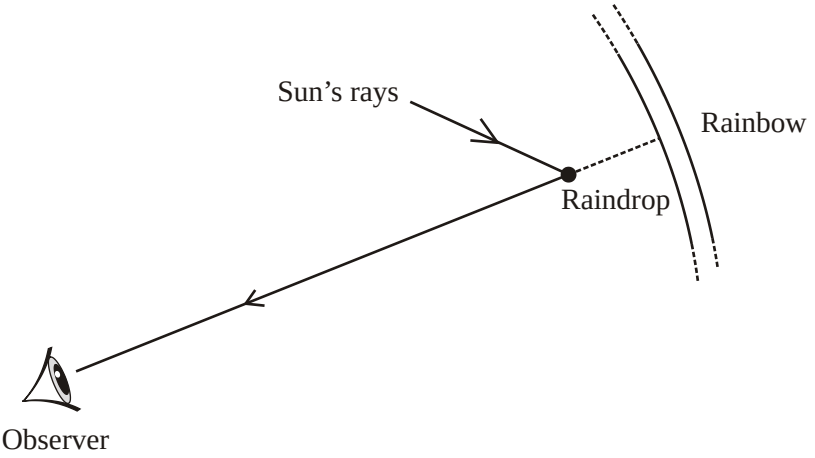
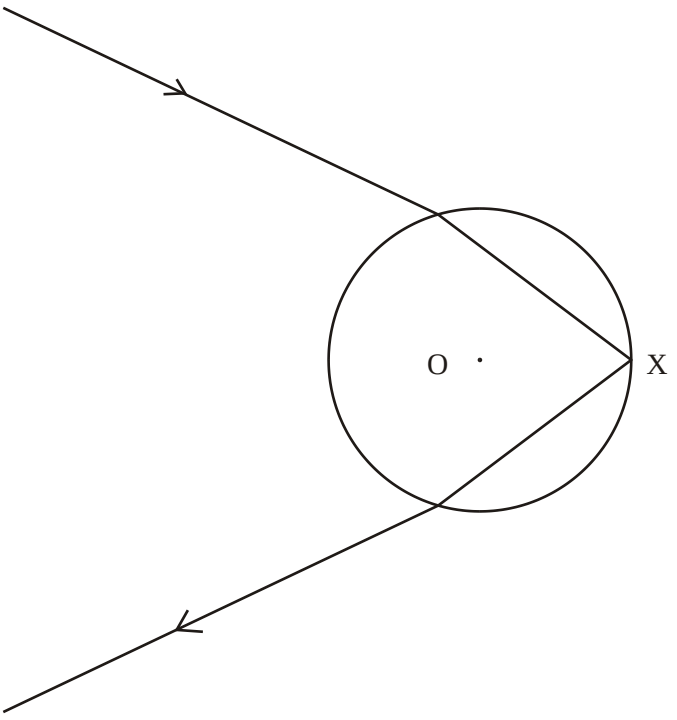


Figure 2



Where the ray enters the raindrop in Figure 2, mark the angle of incidence *i* and the angle of refraction, *r*. The centre of the raindrop is labelled O.

(2)

Figure 2 is drawn to scale. By taking suitable measurements, show that the refractive index of water is about 1.3.

.....

.....

.....

.....

(2)

Calculate the critical angle for water.

.....

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.....

.....

Critical angle = ...

(2)

Using another measurement from Figure 2, explain whether the reflection of the ray at X is partial or total.

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.....

.....

.....

(3)

A rainbow consists of a spectrum of colours. What does this suggest about the refractive index of water?

.....

.....

(1)
(Total 10 marks)

56. Explain what is meant by

(i) refraction

.....

.....

.....

(ii) diffraction.

.....

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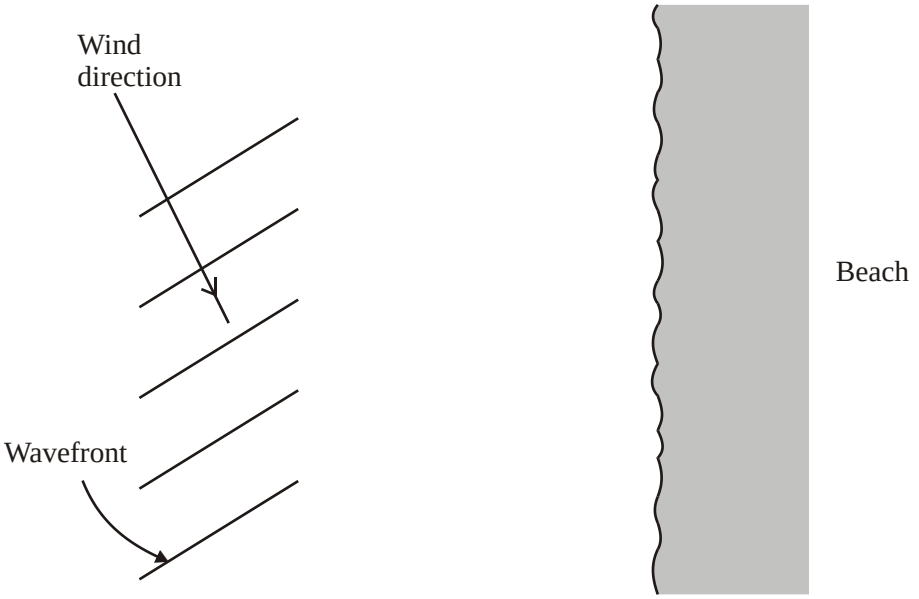
.....

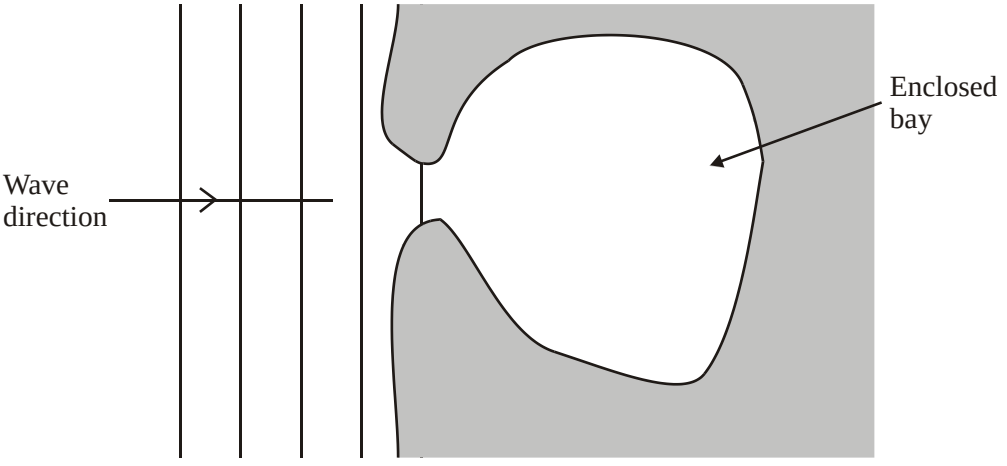
(2)

Out at sea, waves follow the direction of the wind. As they near a beach, their speed decreases as the water **gradually** becomes shallower. The diagram shows water waves out at sea. Complete the diagram to show the wavefronts as they near the beach.



(3)

The diagram below shows waves heading directly towards an enclosed bay. Assume the depth of water in the bay is constant. Complete the diagram to show what happens to the wavefronts in the bay.



(2)

In 'The Last Word' section of the *New Scientist* a reader has asked the following question: "Why do waves travel towards the shore no matter which way the wind blows?"
Suggest an explanation.

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.....

(1)
(Total 8 marks)

57. Ultrasound is used to produce pictures of the fetus in the womb. One of these appears below.

What is ultrasound?

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(1)

Explain how ultrasound can be used to build up a picture of a fetus within the womb.

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(3)

How can reflected ultrasound provide information about a beating heart?

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(2)
(Total 6 marks)

58. The oscillations of a child on a swing are approximately simple harmonic. State the conditions which are needed for simple harmonic motion.

.....

.....

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(2)

Why is the child's motion only **approximately** simple harmonic?

.....

.....

(1)

The child completes six oscillations of amplitude 1.2 m in 20 s.

(i) Calculate the period and the frequency of the oscillations.

.....

.....

Period = ...

Frequency = ...

(ii) The quantity ω in the equations for simple harmonic motion is defined as $2\pi f$, where f is the frequency of the oscillations.

Calculate ω for these oscillations.

.....

.....

ω = ...

(iii) Calculate the child's acceleration when the displacement is maximum.

.....

.....

Acceleration = ...

(5)

Explain how pushing a child on a swing can be an example of resonance.

.....

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.....

(2)

(Total 10 marks)

59. An advertisement for an active noise cancellation headset for aircraft pilots contains the following information:

Requires 9 V battery
Active noise attenuation over 20 – 800 Hz
Rubberized foam earcups

Explain the physics principles in each statement of this advertisement. You could start by saying why a battery is required and go on to explain how the noise is attenuated.

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(6)

A student asks the following question: “If sound is being introduced to cancel out the noise, then where does the energy go?”

What is the explanation?

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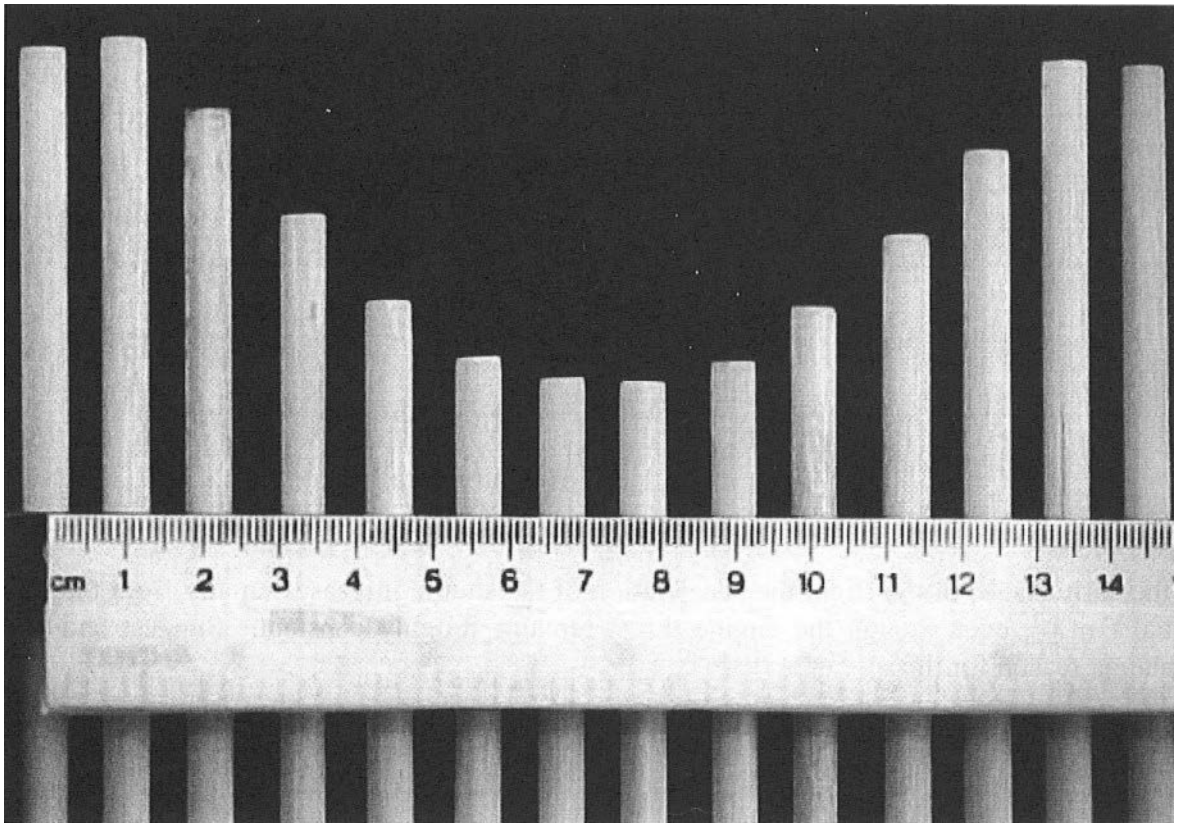
(2)
(Total 8 marks)

60. The photograph shows a laboratory machine for illustrating a sinusoidal transverse wave. Beside the machine is a rule. (You may make marks on the photograph if you wish.)



Find a value for the wavelength of the waves.

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.....

Wavelength = ...

(2)

Find a value for the amplitude of the waves.

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.....

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Amplitude = ...

(2)

The machine is operated so that every rod along the wave moves up and down through a complete cycle every 2 s. Calculate the frequency of the waves.

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Frequency = ...

(1)

What is meant by a transverse wave?

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(2)

Discuss whether this machine would be helpful in illustrating how a sound wave travels.

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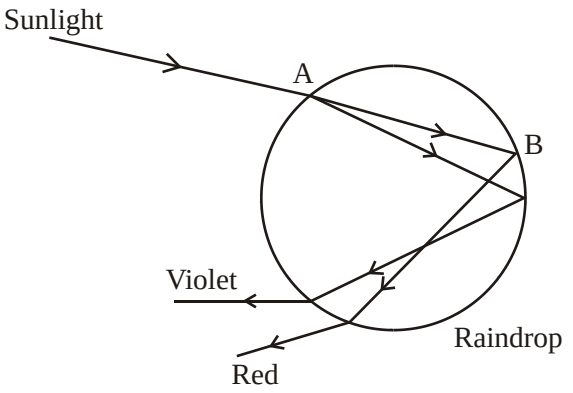
(3)

(Total 10 marks)

61. Rainbows are caused when sunlight is dispersed by raindrops. The different colours follow separate paths.

The diagram shows some of the rays of light passing through a raindrop.



Name the process which occurs at A.

.....

(1)

The ray at B is actually only partially reflected at the surface of the water. Continue the ray to show the path of the red light which is not reflected.

(1)

Explain the condition that would be required to prevent the red light from emerging at B.

.....

.....

.....

(2)

Light changes its direction at A because of a change of speed on entering the water.

Red light has a frequency of 4.2×10^{14} Hz. Calculate its wavelength in a raindrop.

Speed of light in water = 2.2×10^{8} m s^{-1}.

.....

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.....

.....

Wavelength = ...

(2)

(Total 6 marks)

62. When a person is looking at a distant object, all the refraction of light can be assumed to be taking place at the cornea (the front surface of the eye). The lens is used to help the cornea bring nearer objects into focus.

Explain the phrase “refraction of light”.

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.....

(1)

State the cause of refraction.

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(1)

A person is looking at a distant object. A clear image is formed on the retina which is 2.0 cm from the cornea. Calculate the power of the cornea.

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(2)

As people get older, the lens in an eye can develop a cataract. The lens can then be removed in an operation and replaced by a plastic lens of fixed focal length. Explain the effect that this operation will have on a person’s normal range of vision.

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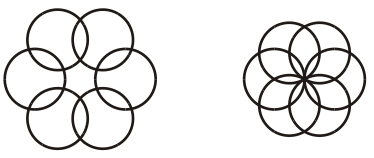
(2)

A new device is being developed which contains six overlapping lenses as shown in diagram A. This device will replace the single eye lens. As the muscles in the eye contract when looking at something close up, the six lenses overlap more as shown in diagram B.

A B



The maximum combined power produced by this device and the cornea is 54 D. Calculate the closest distance at which an object can be placed and still be clearly seen. Assume the device and cornea are 2.0 cm from the retina.

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(3)

State and explain the advantage this device has compared to a conventional plastic lens replacement.

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(2)

(Total 11 marks)

63. An advertisement for sunglasses claims:

> **ELIMINATE GLARE WITH POLARISING SUNGLASSES**
>
> Glare is created when bright sunlight reflects off horizontal surfaces, such as roads. Polarising sunglasses are special sunglasses that eliminate 99.9% of this type of glare by only letting in light at a certain angle or in a certain direction.

Use diagrams to explain the difference between **polarised** and **unpolarised** light.

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.....

(2)

In physics terms what does the advertisement mean by 'light at a certain angle or in a certain direction'?

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(1)

What is the evidence in this advertisement that 'glare' consists of **polarised** light?

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(1)

Normally sunglasses are worn so as to eliminate glare. Explain what would happen if the sunglasses were turned through 90°.

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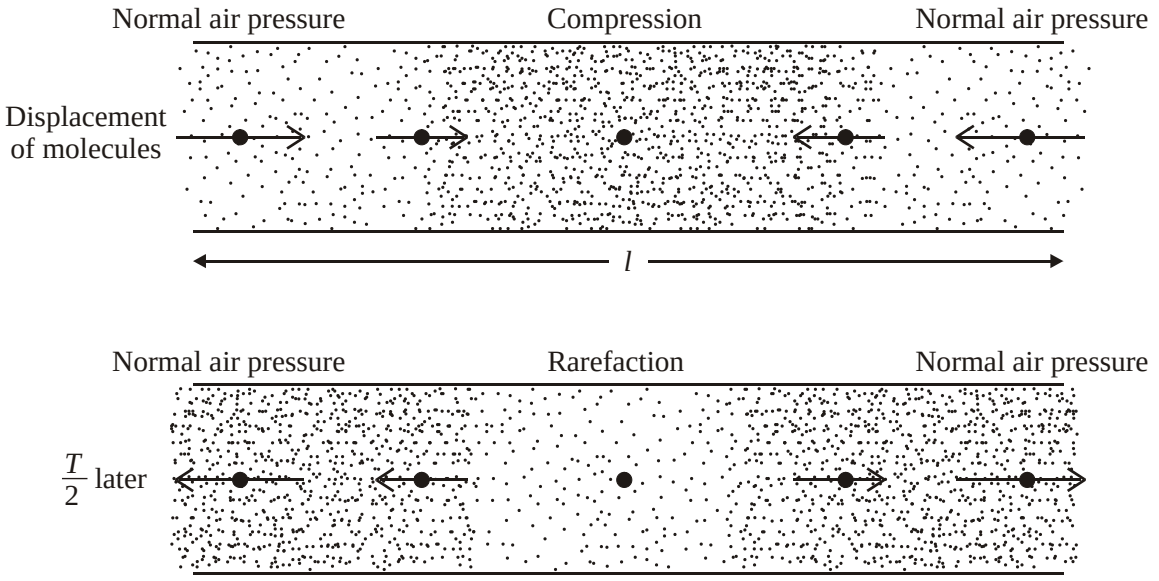
(2)

(Total 6 marks)

64. A recorder, a common musical instrument, can be modelled as a tube of air open at both ends. The air at both ends therefore remains at normal air pressure. The diagrams below show how the air molecules in the recorder are displaced at two different moments during one cycle of the fundamental note. The two moments are separated by $T/2$, where T is the time period.



Explain whether the ends of the recorder have nodes or antinodes for pressure.

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(2)

Write down a relationship between the length l of the recorder and the wavelength λ of the fundamental note it produces.

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(1)

The length *l* of the recorder is 0.28 m. Calculate the fundamental frequency of the note it produces. Speed of sound in air = 330 m s^{-1}.

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.....

Frequency = ...

(3)

Calculate the period *T* of the fundamental note.

.....

.....

.....

.....

Period = ...

(2)

State one other frequency which might be present in the note produced by this recorder. Explain your choice in terms of nodes and antinodes for pressure along the recorder.

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(3)
(Total 11 marks)

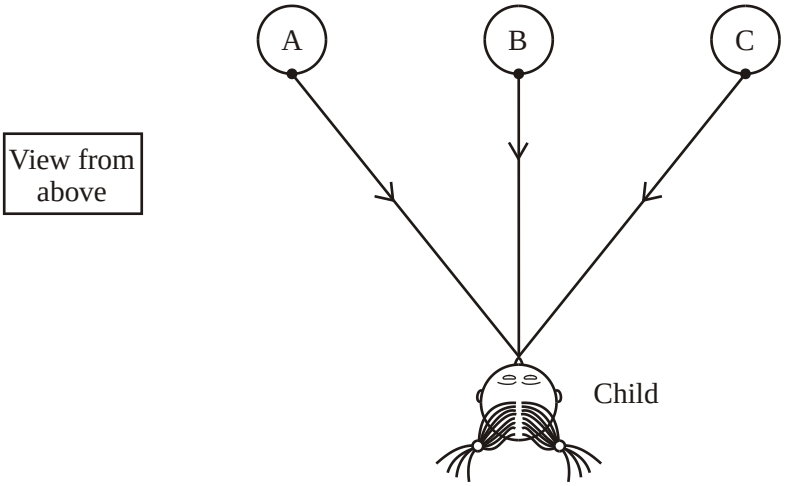
65. A three-year-old child at a barbecue was heard to remark: "The trees look like jelly – they're all wobbly". She was looking at the trees over the top of the hot barbecue. Heated, less dense air was rising from the barbecue in uneven layers, changing the direction of the light from the trees in a varying pattern.

Name this process of changing the direction of the light by air of different densities.

.....

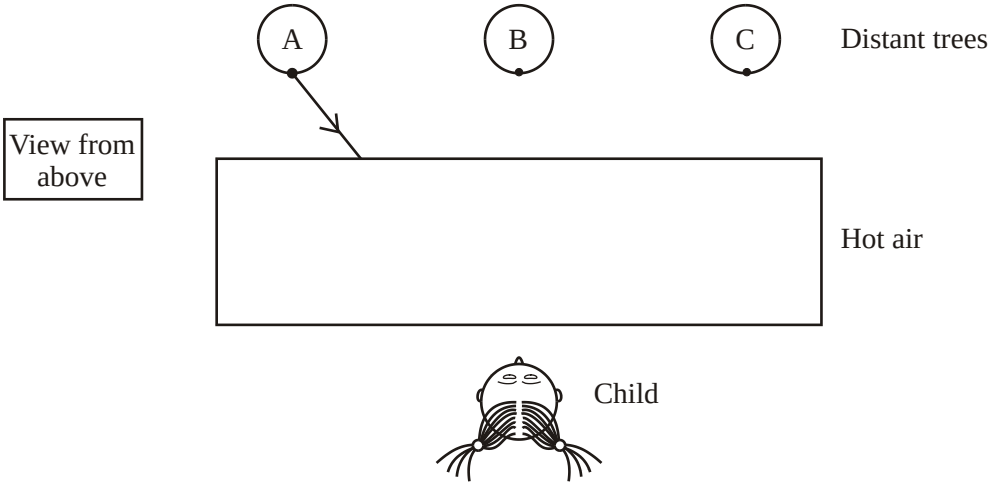
(1)

The diagram shows a ray of light from the trunk of each tree reaching the child before the barbecue is lit.



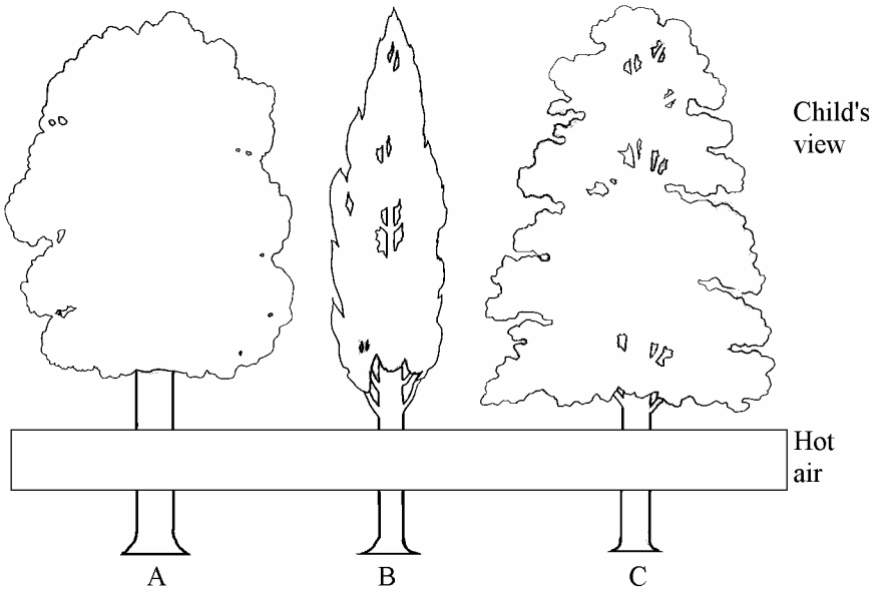
After the barbecue is lit, a layer of hotter, less dense air is between the child and the trees.

Complete the diagram below to show a ray of light from each of the trees A, B and C reaching the child. The ray A has been started for you.



(3)

Complete the diagram below to show the apparent position of the tree trunks as viewed through the layer of hot air.



(2)

Explain why the trees look “all wobbly”.

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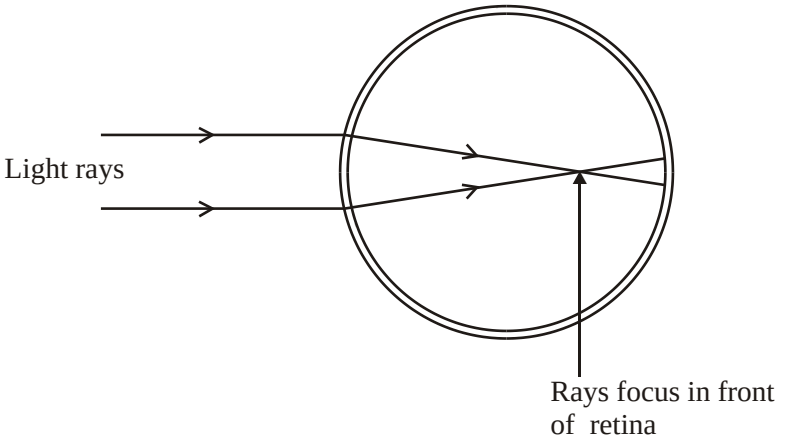
(2)

(Total 8 marks)

66. In normal sight, the human eye focuses rays of light from a distant object to form a sharp image on the retina. In the eye of a short-sighted person, light focuses in front of the retina. This is shown in the simplified eye diagram below.



A diverging lens which could be used to correct this defect has a power of –3.0 D.
Calculate its focal length.

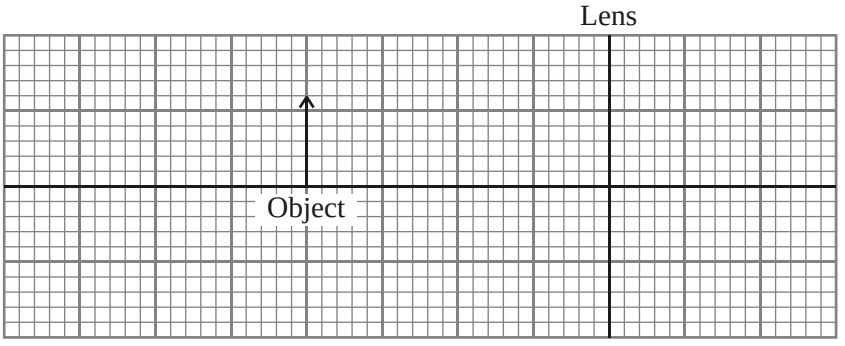
.....

.....

Focal length = ...

(1)

Draw a labelled ray diagram showing the exact position of the image formed when an object is placed 1 m away from this lens.



(3)

Add this lens to the simplified eye diagram. Draw the path that the light rays would follow now.

(2)

Scientists have found that many short-sighted people struggle to focus on near objects when wearing their glasses. Often the image forms behind the retina. Over time, the eye compensates for this by the eyeball getting longer.

Explain why it is more difficult for the eye to focus on close objects than on distant ones.

.....

.....

(2)

In a trial, short-sighted children were given glasses with lenses weaker than they needed so as to

produce images in front of the retina. It was believed that this would prevent the eyeball getting longer. The lengths of the children's eyeballs were measured regularly using ultrasound.

Describe how ultrasound could be used to make these measurements.

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(3)

Surprisingly, the trial found that the eyeballs of children given these weak lenses lengthened faster than the eyeballs of those who wore the correct strength glasses. State the effect that the weak lenses had on the sight of the children in the trial.

.....

(1)
(Total 12 marks)

67. The screen of a laptop computer makes use of polarised light.

Draw labelled diagrams to show what is meant by unpolarised and plane polarised light.

(2)

The screen contains a polarising filter. The dark parts of an image are formed where polarised light is blocked by this filter; the light parts are where unpolarised light gets through.

As a security measure, the images on the screen can be made invisible by removing the polarising filter from the front of the screen.

State the appearance of a computer screen whose polarising filter has been removed.

.....

Explain your answer.

.....

.....

(2)

The computer operator would wear glasses containing polarising lenses. The glasses can do the same job as the polarising filter. State and explain what a computer operator wearing the glasses would observe if he tilted his head from side to side while looking at the screen.

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(2)

It has been suggested that this security measure could be defeated by anyone wearing a pair of simple 3-dimensional movie glasses. These have a horizontal polarising filter on one eye and a vertical filter on the other.

Comment on this suggestion.

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(2)
(Total 8 marks)

68. What evidence do we have for the 'Big Bang'?

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(2)

Calculate the fractional change in frequency of the light from a distant galaxy.

Hubble constant, $H_0 \approx 100$ km s^{-1} Mpc^{-1}
Distance of galaxy = 2×10^3 Mpc

(The megaparsec, Mpc, is a measure of cosmological distance.)

.....

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.....

(3)

A recent poem about the Big Bang by Philip Rogers contains the lines

From a nowhere
crystal-thought
to the outer rim
of everywhere

Suggest what is meant by "*to the outer rim of everywhere*".

.....

.....

.....

(1)
(Total 6 marks)

69. After the first bounce of a bungee jump, a jumper oscillates on the end of the rope. These oscillations have an initial amplitude of 4.0 m and a period of 5.0 s.

The velocity of the jumper is given by $v = -\omega A \sin \omega t$. Show that the maximum velocity of the jumper is about 5 m s^{-1}.

.....

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(2)

Explain why the tension in the rope and the jumper's weight must be balanced when the velocity of the jumper is maximum.

.....

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(2)

The time period T of the oscillations is given by $T = 2\pi\sqrt{\frac{m}{k}}$.

Calculate the stiffness k for the rope. The jumper has a mass m of 70 kg.

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.....

k = ...

(2)

Verify, with a suitable calculation, that the rope is never slack during these oscillations.

.....

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(3)

Briefly describe the oscillations experienced by the jumper during the minute after the first bounce.

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(1)

(Total 10 marks)

70. In order to reduce the engine noise heard by a car driver, some cars are designed so that noise is also emitted by the car's speakers. This technique is known as active noise control.

With the aid of sketch graphs showing relevant wave forms, explain how sound from the speakers can reduce the intensity of the sound heard by the driver.

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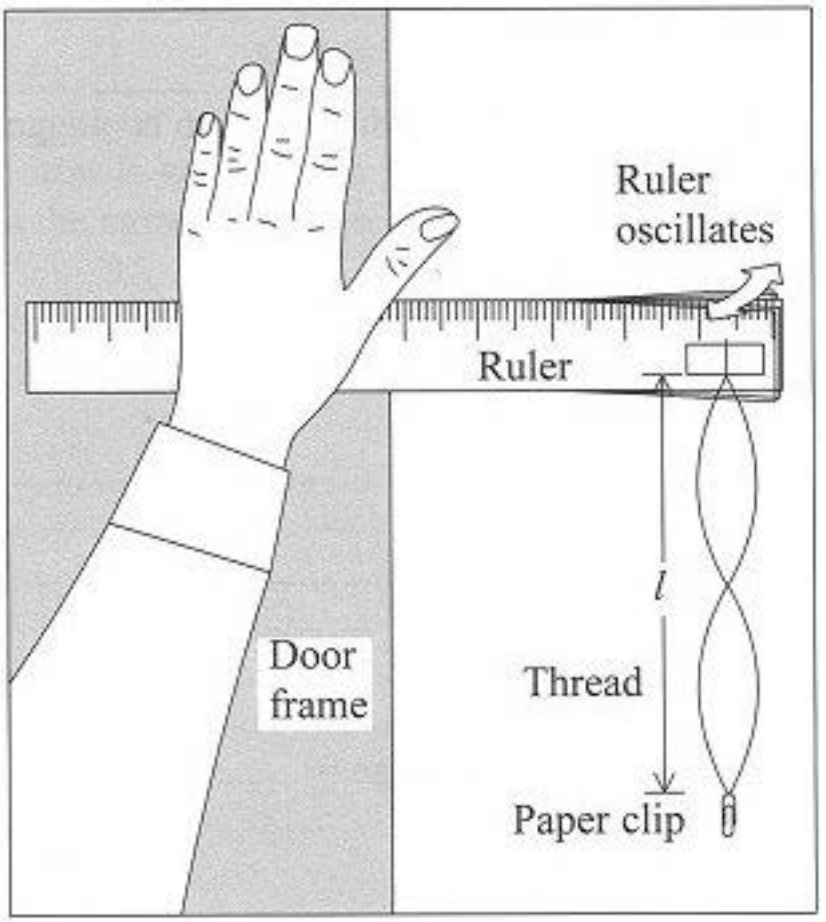
(Total 6 marks)

71. The diagram below illustrates a simple experiment you can do at home. A fixed length *l* of thread suspends a paper-clip from the edge of a flexible ruler. One end of the ruler is held against a door frame. When you bend the ruler sideways and release it, it oscillates. By adjusting the position of the ruler carefully, you can make it oscillate at such a frequency that it produces the standing wave pattern shown along the thread.



Explain how a standing wave is formed along the thread.

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(3)

Mark with a letter X a place along the thread where it moves with its greatest amplitude.

(1)

The mass of one metre of the thread is 3.1×10^{-5} kg.
The mass of the paper-clip is 4.8×10^{-4} kg.

Show that the speed of waves along the thread is about 10 m s^{-1}.

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(3)

Write an equation relating the length l of the thread in the diagram to the wavelength λ of the standing waves.

.....

(1)

Calculate the frequency of the oscillations of the ruler when producing the standing wave shown.
The length l of the thread is 0.45 m.

.....

.....

.....

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.....

.....

Frequency = ...

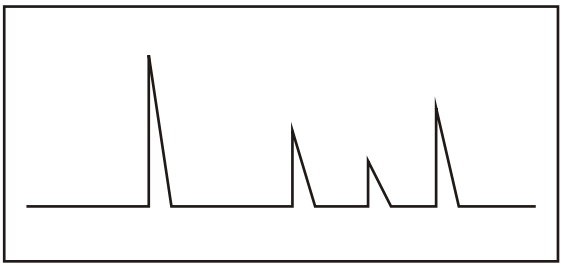
(3)

(Total 11 marks)

72. According to a study carried out by Bell Labs in New Jersey, the signal from a mobile phone could be used to detect your pulse and breathing rate. The phone does not need to be answered and so could be used to locate unconscious survivors of earthquakes.

When the phone rings, microwaves are emitted which then reflect back to the phone from different parts of the owner's body such as the chest, heart and lungs.

The following diagram shows some of these reflected waves being displayed on the screen of a cathode ray oscilloscope.



Explain why the microwaves are reflected off different parts of the body.

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(1)

Give **two** reasons why the amplitudes of the peaks vary.

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(2)

Give one reason why the time between the peaks varies.

.....

.....

(1)

If the microwaves are reflected from a moving object, such as a beating heart, a Doppler shift is observed.

Explain what is meant by the term **Doppler shift** and how it occurs.

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(2)

Describe and explain the observed changes in the **wavelength** and the **frequency** of the detected microwave signal when the heart is contracting (moving away from the microwave source).

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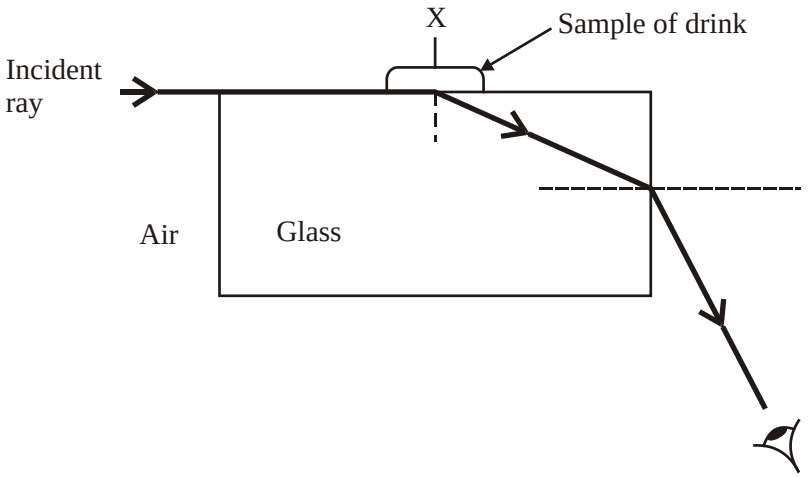
(3)
(Total 9 marks)

73. A student decided to carry out an investigation using a Pulfrich refractometer. Her uncle was diabetic and she thought he would find it useful to know the sugar concentration of various drinks.

The diagram shows the refractometer she used.



Label the critical angle *C* on this diagram.

(1)

One of the samples studied was found to have a refractive index of 1.09 between the liquid and the glass. Show that the critical angle for light in the refractometer is about 67° for this sample.

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(2)

A black line is drawn on the glass block at position X. When looking through the glass block from different angles this black mark is not always seen. Explain why this is the case.

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(3)

These are some of the results obtained by the student.

Drink sample tested	Refractive index between liquid and glass
Orange Squash	1.05
Summer Fruits	1.10

Which has a higher concentration of sugar, Orange Squash or Summer Fruits? Explain your answer.

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(2)
(Total 8 marks)

74. It has been suggested that tigers use infrasound – low frequency sounds inaudible to humans – to keep rivals away from their territory and to attract mates.

Sound is a longitudinal wave. Describe how sound travels through the air.

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(3)

State what is meant by frequency.

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(1)

The frequency range of the sound produced by the tigers extends down to 18 Hz. Calculate the wavelength in air for sounds of this frequency. Speed of sound in air = 330 m s^{-1}.

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.....

.....

Wavelength = ...

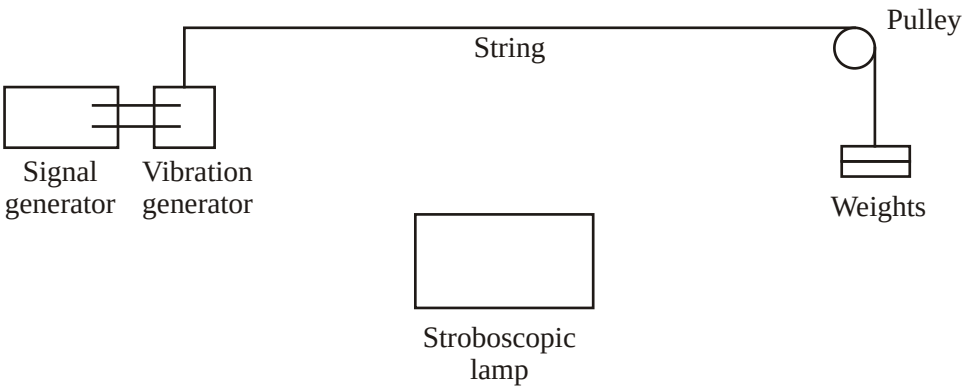
(2)

(Total 6 marks)

75. Some Physics students studying standing waves decide to play a trick on visitors to their Open Evening.

They set up the apparatus shown in Figure 1 in a dark corner of their laboratory.

Figure 1



They switch on the vibration generator and the stroboscopic lamp, which flashes on and off. The frequency of the flashing is adjusted until the illuminated portion of the string appears as in Figure 2.

Figure 2

The visitors are invited to put their fingers between the two ‘strings’ they think they see and are taken by surprise when it is impossible.

Explain how standing waves have been produced on the string.

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(3)

Mark one node with N and one antinode with A on Figure 2.

(1)

Add a labelled line to Figure 2 to show the wavelength.

(1)

The string vibrates at a frequency of 170 Hz. The stroboscopic lamp is flashing on and off at a frequency of 340 Hz. Explain why the string appears to be in two different positions at the same time as shown in Figure 2.

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(2)

Calculate the speed of the waves in the string.

Tension in string = 1.96 N

Mass per unit length of string = 6.00×10^{-4} kg m^{-1}

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Speed = ...

(2)

(Total 9 marks)

76. Radar is the use of radio waves to detect the position and speed of an object. Air traffic control uses radar in this way to track the position of aircraft.

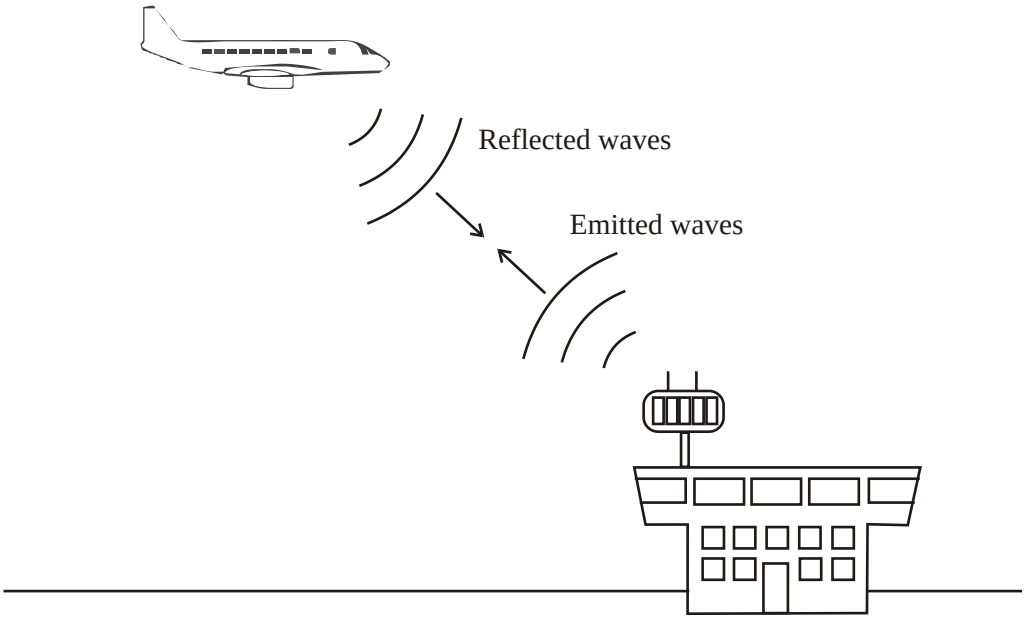

Diagram from: http://electronics howstuffworks.com/radar htm

A short pulse of high frequency radio waves is transmitted from the control tower and is reflected back from an aircraft. There is an interval of 48 μs between the transmitted pulse and the detected echo. Show that the distance of the aircraft from the control tower is about 7 km.

[1 μs = 1×10^{-6} s]

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Distance = ...

(2)

Give two reasons why **pulses** of radio waves are needed.

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(2)

The ‘Doppler shift’ of the reflected radar signal can be used to measure the speed of the moving aircraft. Describe the principle of this method and how it can be used to determine the aircraft’s speed.

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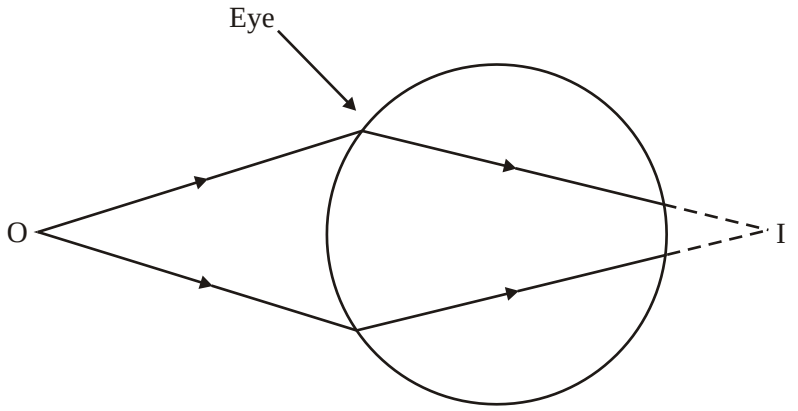
(3)
(Total 7 marks)

77. An eye lens is thinner when focusing on distant objects and fatter when bringing close objects into focus. As a person gets older the lens hardens, making it more difficult to form the fatter shape. The person is said to be long-sighted and the focused image of a near object would be behind the eye as shown in the simplified eye diagram below.



This defect can be corrected by wearing suitable glasses.

Add a lens to the diagram to show how this is achieved.

(1)

Show the effect this would have on the rays of light from the object O.

(1)

Researchers are developing a polymer with similar properties to those of the eye lens.

What is meant by the term polymer?

.....

(1)

An eye lens that has hardened can be removed and replaced by one made from the new polymer. Early tests show that a polymer lens can help the eye reach a power of up to 150D.

Calculate the shortest distance between the object and the eye that would produce a focused image on the back of the eye.

The effective distance between the eye lens and the back of the eye is 2.0 cm.

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Shortest distance = ...

(3)

(Total 6 marks)

78. When the Moon is full, bright moonlight makes it difficult for astronomers to study the stars. Moonlight is scattered by atoms in the atmosphere causing it to become plane polarised.

Draw labelled diagrams to show how the polarised light differs from unpolarised light.

Polarised light Unpolarised light

(2)

Explain how an astronomer's telescope could be adapted to overcome the problem of the bright moonlight.

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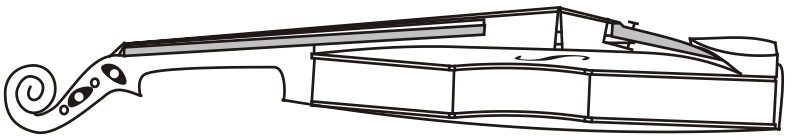
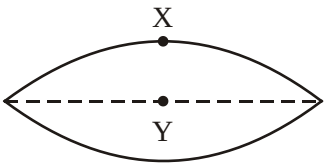
(2)

(Total 4 marks)

79. Violin strings oscillate with simple harmonic motion.



When a violin is played, a standing wave is set up in a string. The diagram below shows a string in three positions of the standing wave: the two extreme ones and the dotted central one.



Comment on the energy changes in the string making reference to points X and Y.

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(2)

Describe the acceleration of the string, again making reference to points X and Y.

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(2)

The vibrating strings make the wooden body of the violin resonate over a wide range of frequencies.

Explain the meaning of the word **resonate** in the previous sentence.

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(2)

Why is it desirable that the body should resonate?

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(1)

One violin maker decides to use maple wood to make a violin. Show that the velocity of sound in this wood is about 4000 m s^{-1}.

Density of maple = 640 kg m^{-3}.
Young modulus of maple = 10 GPa.

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(2)

The length of the violin body is 35 cm. Calculate the lowest frequency at which this violin body will resonate.

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Frequency = ...

(2)

At one frequency, the amplitude of the vibrations in the wood is increased by a factor of 5. Suggest how this could affect the intensity of the sound produced at this frequency.

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(1)
(Total 12 marks)

80. In July 2003 astronomers announced the discovery of a planet orbiting a star 90 light years from Earth. The astronomers used the Doppler effect to detect the planet.

You may have heard the Doppler effect when an ambulance using its siren passes you. Describe what would be heard as the ambulance approaches and then passes.

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(2)

The method used by the astronomers is called the Doppler Wobble effect. When a planet orbits a star it pulls on the star, making it move slightly or ‘wobble’. The larger the planet, the more the star wobbles.

Explain the use of the Doppler technique to discover the new planet. Include diagrams of the planet and star when the Doppler effect is most useful. Label your diagrams and show the direction of the Earth.

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(4)

The astronomers discovered that the time for the planet to make one orbit around its star was six years. How did they determine this from their observations?

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(1)

Use a gravitational force equation to explain why the method that astronomers used to discover this planet will not reveal any planets the size of Earth.

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(4)
(Total 11 marks)

81. X-rays are used in hospitals to aid diagnosis. The X-ray image is formed because more X-ray photons are absorbed by denser materials such as bones, thus changing the intensity of parts of the image.

The principal method of absorption of X-rays is the photoelectric effect.

The photoelectric effect is also observed when light falls on a clean metal surface. It is only observed when the frequency of the light is above a threshold frequency. Explain why this is so.

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(2)

X-rays of a frequency of 1.70×10^{18} Hz can be used to form an image of a bone. The energy required to free a tightly bound-electron from a calcium atom in bone is 9.61×10^{-16}J.

Calculate the maximum kinetic energy with which one of these electrons is emitted from the calcium atom.

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…….……

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Kinetic energy = ……..……..

(3)

(Total 5 marks)

82. Astronomers can identify different gases present in the outer parts of stars by analysing the line spectra of the starlight.

Explain the meaning of *line spectra.*

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(2)

Explain how line spectra provide evidence for the existence of energy levels in atoms.

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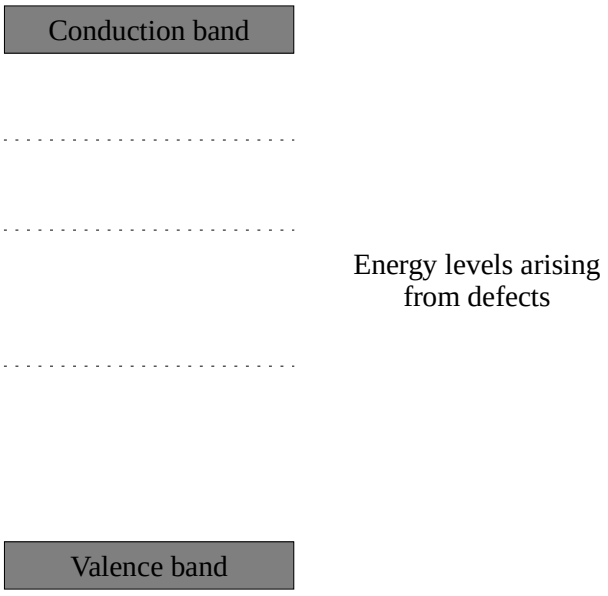
(3)

(Total 5 marks)

83. Thermoluminescence can be used for dating old artefacts and so finding out how long ago humans lived in an area.



The diagram above shows some electron energy levels in an old artefact. Suggest how electrons are provided with the energy to rise to defect levels in artefacts buried underground.

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(1)

Radiation is emitted from the artefact when electrons make transitions from the defect levels. Draw an arrow on the diagram to represent the transition needed for the highest frequency of radiation to be emitted.

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(1)

Calculate the wavelength of this emitted radiation when the energy transition is 4.2×10^{-19} J.

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Wavelength = ……..

(3)

Explain why the artefact emits radiation with a range of frequencies.

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(2)

What must he done to the artefact for this radiation to be emitted?

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(1)

Thermoluminescence dating techniques used on one stone artefact found in Australia suggests that humans lived there 50 000 years ago.

A similar sized stone artefact found in another site emitted twice as much light. Estimate when this was last used by humans.

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(1)

State one assumption made in this estimate.

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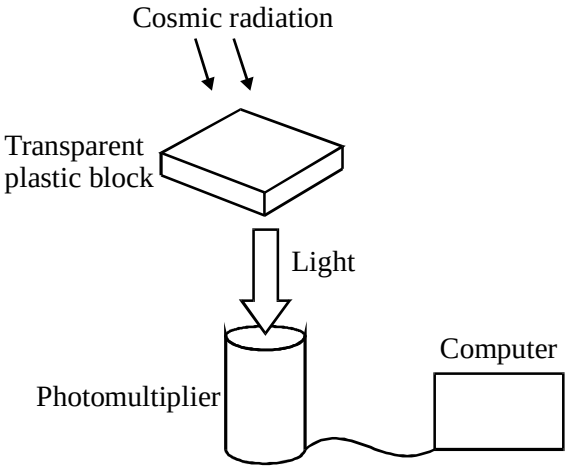
(1)

(Total 10 marks)

84. Scientists from Leeds University are involved in an experiment at the South Pole to look for cosmic radiation from a supernova observed in 1987. Cosmic radiation consists of high energy particles from space.

Their equipment involves the following:



Cosmic radiation causes this plastic block to emit light. If this light enters the photomultiplier, photoelectrons are released and the signal is sent to a computer which records the event.

A photomultiplier which has a photocathode made from antimony–caesium has a threshold wavelength of 700 nm. Explain why a photocathode has a threshold wavelength.

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(4)

Show that the work function of antimony-caesium is about 3×10^{-19} J.

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(3)

The scientists' generator at the South Pole produces a voltage of 600 V and the photomultiplier needs potential differences of 200 V, 400 V and 600 V. Draw a circuit to show how a series of resistors could provide all of these potential differences from one 600 V supply.

(2)

Suggest why cosmic radiation from the supernova was not detected at the same time as the supernova was observed.

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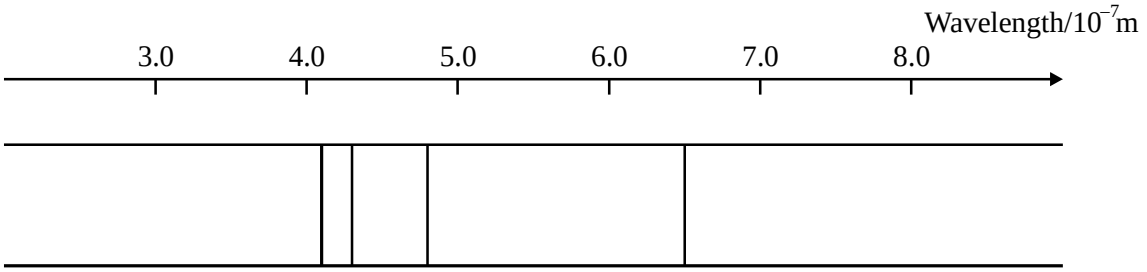
(1)

(Total 10 marks)

85. The following diagram illustrates a simplified emission line spectrum of the element hydrogen.



Outline the atomic processes leading to the formation of a line spectrum.

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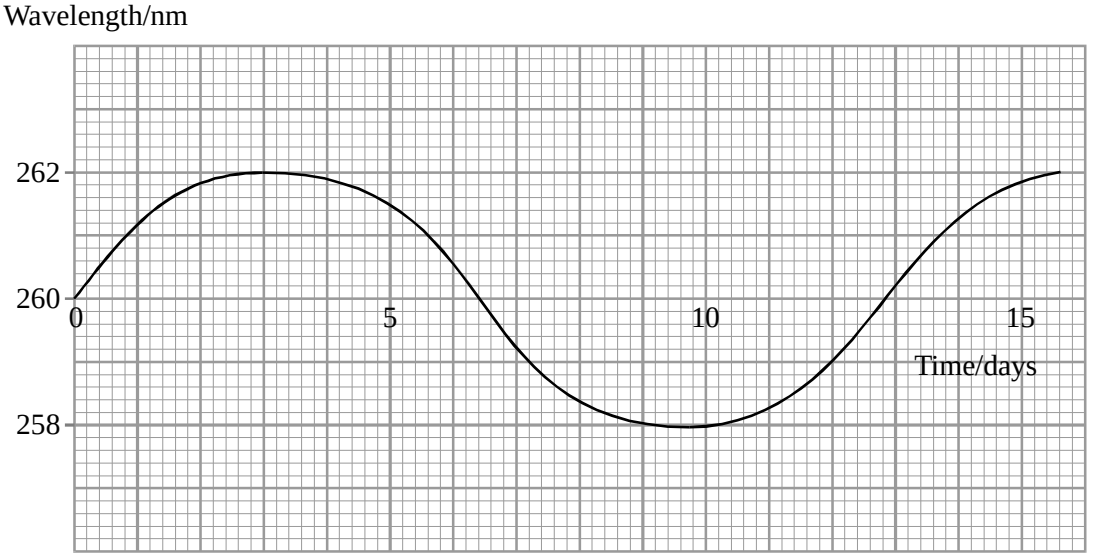
(5)

Beta Lyrae is part of a binary star system. Two stars revolve around a common centre of mass. The wavelength of an iron absorption line from Beta Lyrae is measured at intervals of time. The graph below shows how it varies.



What type of force maintains each of these two stars in their orbit.?

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(1)

Explain why the wavelength of the light received from this star varies in this manner.

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(2)

Calculate the orbital speed of this star.

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Orbital speed = ...

(2)

Calculate the radius of orbit of this star about the centre of mass.

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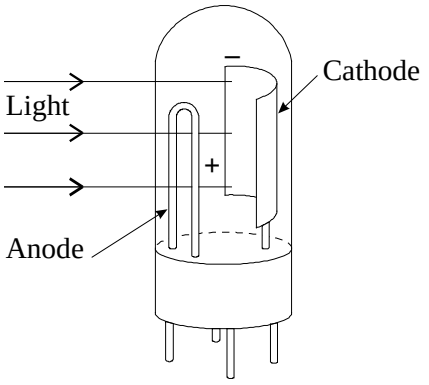
Radius of orbit = ...

(3)

(Total 13 marks)

86. The intensity of the light falling on the photocell shown in the diagram below controls the electric current flowing in a circuit.



An electron is sometimes released when a photon hits a metal surface. This is known as the photoelectric effect and can be expressed mathematically by the Einstein equation.

$$hf = \phi + \frac{1}{2}m\upsilon_{max}^2$$

Show that the energy of a photon of light of frequency 6.0×10^{14} Hz is about 4×10^{-19}J.

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.....

(1)

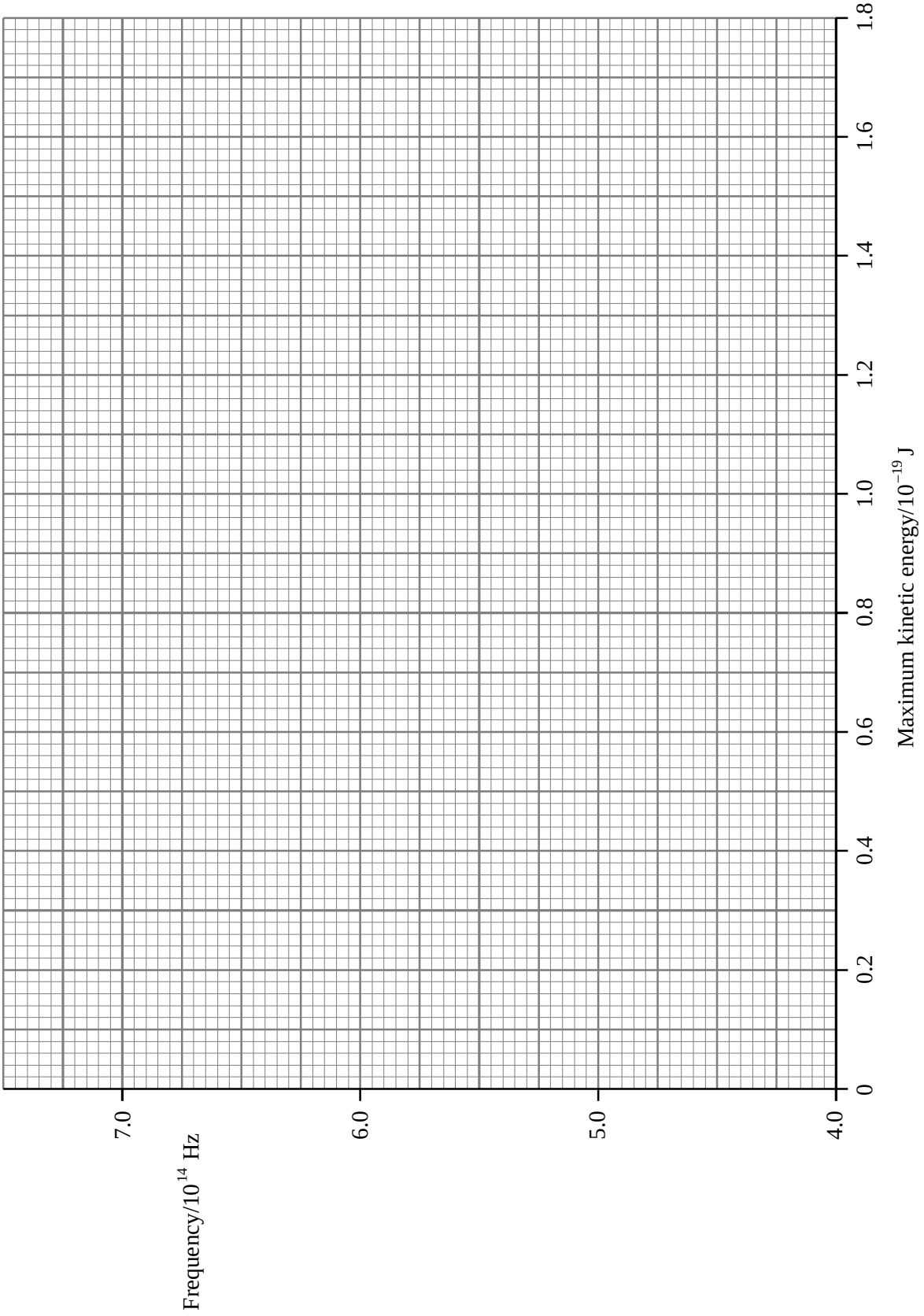
A student is investigating the photoelectric effect and selects light of various frequencies to shine on to a metal surface. Using his experimental data, he calculates the maximum kinetic energy of the electrons emitted from the surface. The results are given below.

Frequency/10^{14} Hz	**Maximum kinetic energy/10^{-19} J**
7.0	1.65
6.5	1.29
6.0	0.96
5.5	0.65
5.0	0.30

Plot the points on the grid below. Add the line of best fit.

The Einstein equation can be rearranged to give

$$f = \frac{\phi}{h} + \frac{\frac{1}{2}mv_{max}^2}{h}$$


Frequency/10^{14} Hz
7.0
6.0
5.0
4.0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Maximum kinetic energy/10^{-19} J

(4)

Use the graph you have plotted to find a value for *h*.

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(3)

Hence show that ϕ is about 3×10^{-19} J.

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(2)

The student continues the experiment and shines light with a frequency of 4.5×10^{14} Hz on to the surface but finds that he cannot detect any photoelectrons. Explain why photoelectrons are not being emitted from the surface.

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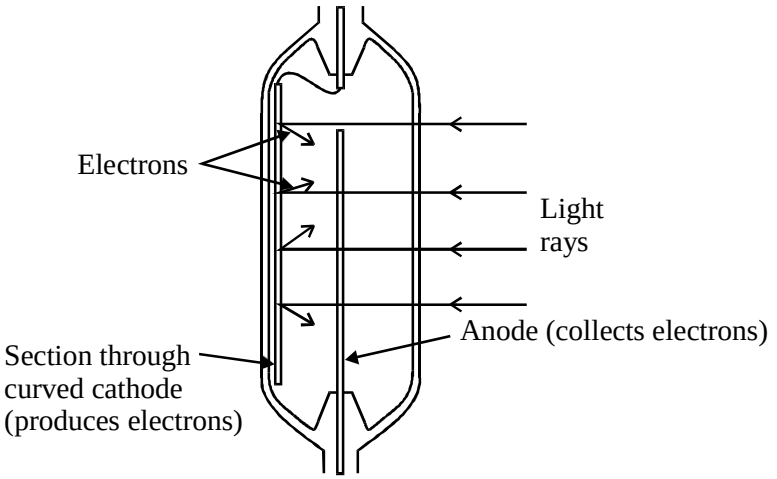
(2)
(Total 12 marks)

87. Many modem cameras have built-in exposure meters. These can detect the intensity of light falling, on to the film and automatically adjust how long the film is exposed to the light. One type of device that can be used is the photocell below.



Photons hitting the cathode cause **photoelectrons** to be released from the surface of the cathode if it is made from a material with a suitable **work function**.

Describe how an electron escapes from the surface of the cathode. Include the terms in **bold** from the passage above.

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(3)

Potassium has a work function of 2.90×10^{-19} J. Calculate the lowest frequency of radiation that will produce photoelectrons from a potassium surface.

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(3)

The exposure meter will produce the best results if it responds to light over most of the visible spectrum. This has a range of wavelengths from 4.0×10^{-7} m to 7.0×10^{-7} m.

Explain with the aid of an appropriate calculation whether potassium is a suitable material for use in an exposure meter.

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(2)

A potassium cathode is exposed to visible light, with a complete range of wavelengths. Show that the maximum kinetic energy of an emitted photoelectron is about 2×10^{-19} J.

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(3)

Give one reason why some photoelectrons will be emitted with less than this kinetic energy.

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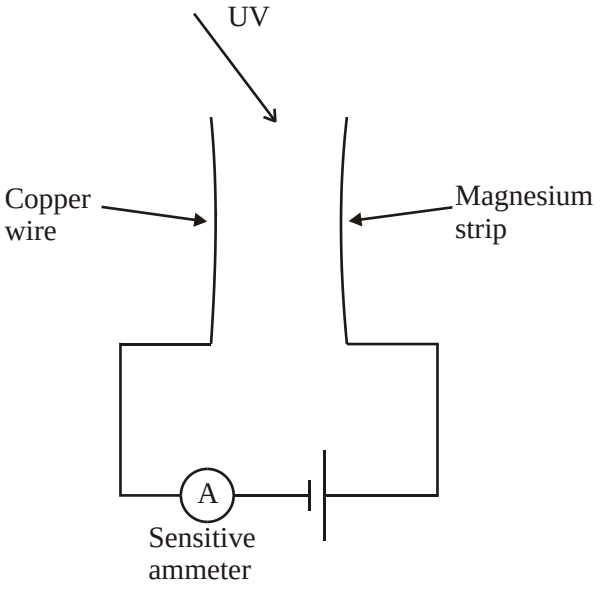
(1)
(Total 12 marks)

88. A student writes up an experiment on the photoelectric effect.

We scratched the surface of a magnesium strip and set it up in front of a UV light. When we switched on the UV light, the ammeter showed a current but, when we put a sheet of glass in between the light and the magnesium, the current stopped. There was also no current when visible light shone on the magnesium.

The student included this circuit diagram:



However, the experiment would not work with this circuit. State the error in the circuit diagram, giving your reasoning.

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(2)

The student gives the following wrong explanation:

This shows that UV light is made up of particles called electrons. Visible light is just transverse waves, since there was no current when this was used.

Finish the first sentence correctly:

This shows that UV .....

.....

(1)

The student has not understood the difference between UV and visible light. How are UV and visible light.

(i) different .....

.....

(ii) similar? .....

.....

(2)

Low-intensity UV produces a current in this experiment but even bright visible light does not. Explain why this is.

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(3)

Suggest why the current stopped when the sheet of glass was used.

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(1)

(Total 9 marks)

89. In an early model of a hydrogen atom, scientists thought that the single electron travelled in a circle round the proton, with the necessary centripetal force being provided by attraction between their opposite charges.

A hydrogen atom emits a photon of radiation when the energy of its electron changes. Suppose that all the kinetic energy of the orbiting electron goes into emitting a single photon. Using the model suggested, show that the wavelength of the photon would be about 9×10^{-8} m.

(Radius of hydrogen atom = 5.4×10^{-11} m)

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(Total 5 marks)

90. Polymers have been developed which absorb ultraviolet (UV) light and emit visible blue light. They could be used for large posters.

What is a polymer?

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(2)

Calculate the energy of a photon of UV light of wavelength 2.5×10^{-7} m.

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Energy = ...

(3)

Explain with the aid of an energy level diagram the process of absorbing UV and emitting blue light.

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(4)

The polymers can absorb a **range** of wavelengths of UV light. What does this imply about the energy level diagram for these polymers?

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(1)

Why would the poster using the polymer look brighter than an ordinary poster?

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(2)

(Total 12 marks)

91. When a photon of sunlight is incident on a photovoltaic cell, an electron in the cell gains sufficient energy to move through a potential difference of 0.48 V.

What is a photon?

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(2)

Show that the energy required to move an electron through a potential difference of 0.48 V is about 8×10^{-20}J.

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(2)

Photons of sunlight typically have energy 4.0×10^{-19} J. Calculate the efficiency of conversion of the energy of the photon.

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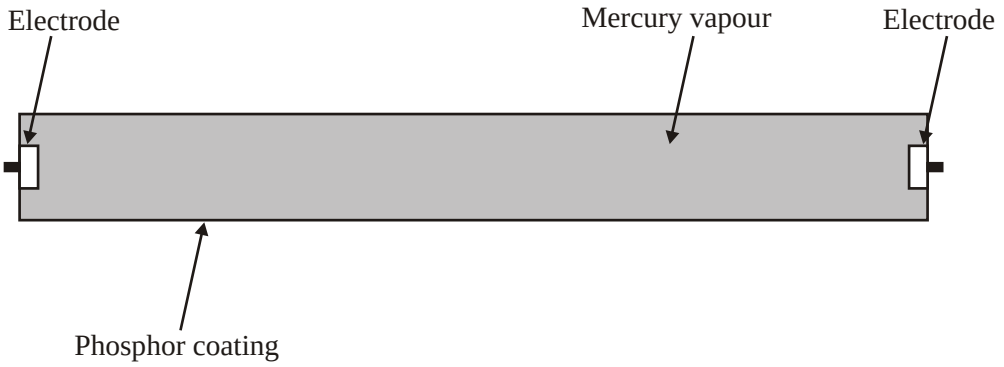
.....

Efficiency = ...

(2)

(Total 6 marks)

92. The diagram shows some of the main components of one type of fluorescent light tube.



When the tube is switched on a charge flows between the electrodes and the mercury atoms become excited. The mercury atoms then emit radiation.

Explain the meaning of the word **excited** as used above.

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(2)

Explain how the excited mercury atoms emit radiation.

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(2)

Explain why only certain wavelengths of radiation are emitted.

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(3)

Some of the radiation emitted by the mercury atoms is in the ultraviolet part of the spectrum.

Humans cannot see ultraviolet radiation, so the tube is coated with phosphor. The atoms of phosphor absorb the ultraviolet radiation and then emit visible light.

Suggest why the phosphor emits different wavelengths from the mercury.

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(1)

A typical fluorescent tube has a current of 0.15 A.

Calculate the amount of charge which flows in 20 minutes.

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Charge = ...

(2)

(Total 10 marks)

93. Most physicists believe that light can behave as both a wave and a particle. Name a property of light which shows it can behave as a wave.

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(1)

In 1916, Millikan published the results of an experiment on the photoelectric effect. This proved that light also behaves as particles.

He shone **monochromatic** light onto plates made of different types of metal.

What is meant by the term **monochromatic**?

.....

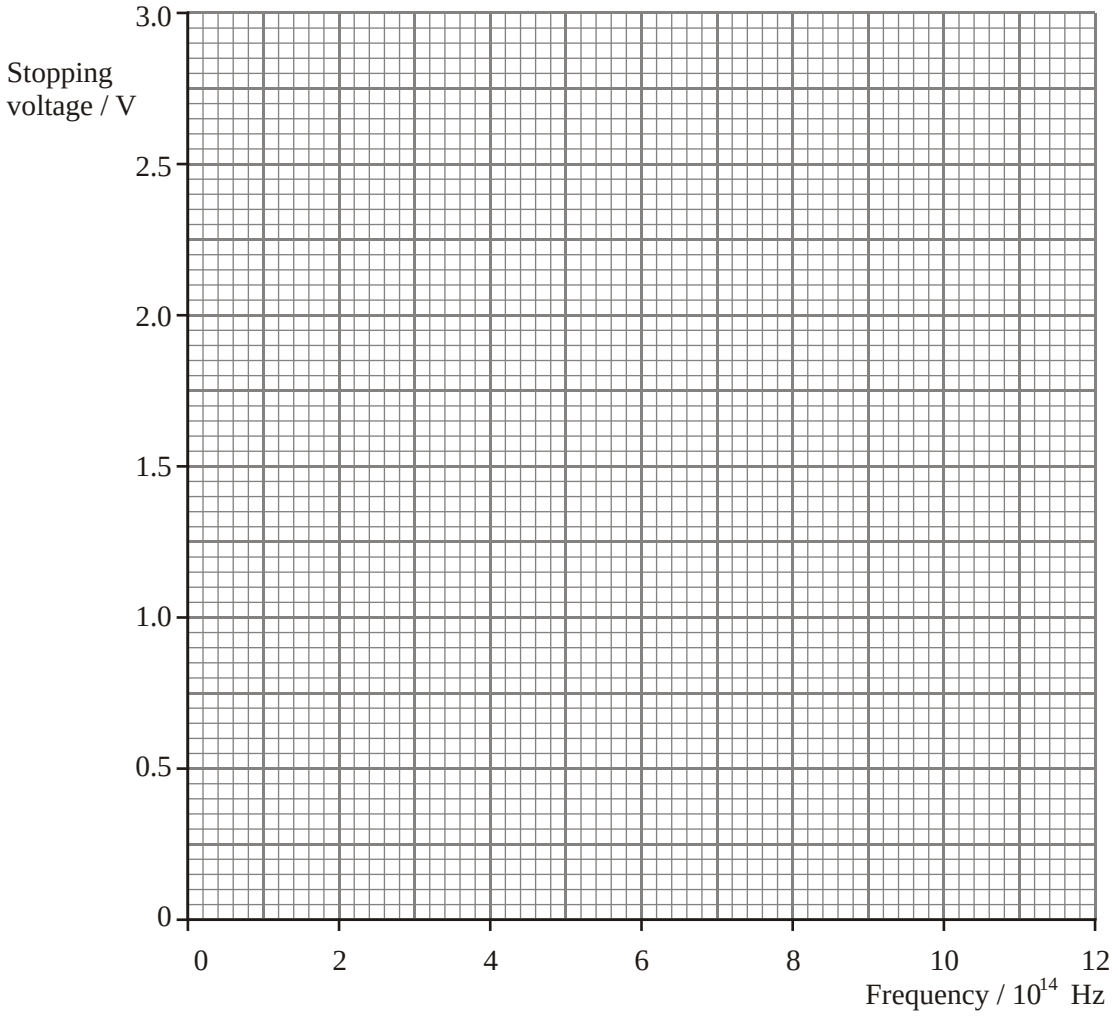
(1)

When the light hit the plates, photoelectrons were produced. Millikan found the potential difference that was just large enough to stop these electrons being released. He also investigated how this stopping voltage varied with the frequency of light used.

The table below shows the results of an experiment like Millikan's using sodium as the metal plate.

Stopping voltage V_s /V	Frequency of light f / 10^{14} Hz
0.43	5.49
1.00	6.91
1.18	7.41
1.56	8.23
2.19	9.61
3.00	11.83

On the grid below, plot a graph of V_s against f.



(3)

The following equation applies to the photoelectric effect:

$$hf = \phi + eV_s$$

where ϕ is the work function of the metal and e is the charge on an electron.

What information about the electrons emitted does the value of the term eV_s give?

.....

.....

(2)

Use your graph to determine the threshold frequency for sodium.

.....

(1)

Hence calculate the work function of sodium.

.....

.....

Work function = ...

(2)

No electrons are emitted below a threshold frequency. Explain why this is so.

.....

.....

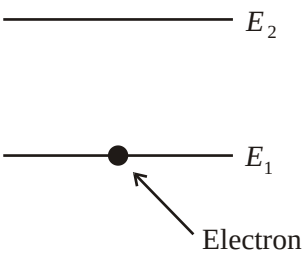
.....

(2)

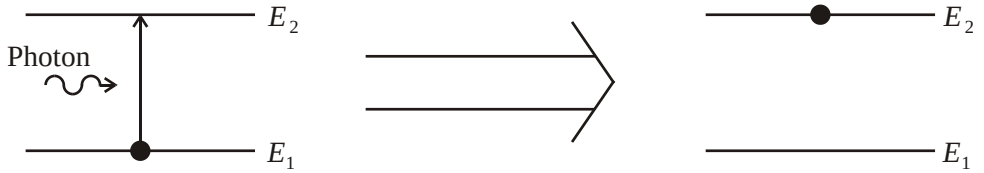
(Total 12 marks)

94. The diagrams below are taken from a description of how a laser works. Each diagram illustrates some aspect of a "two energy level system". The system consists of an electron in an isolated atom.

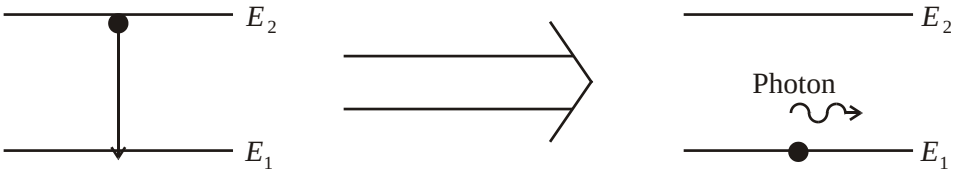
A two energy level system



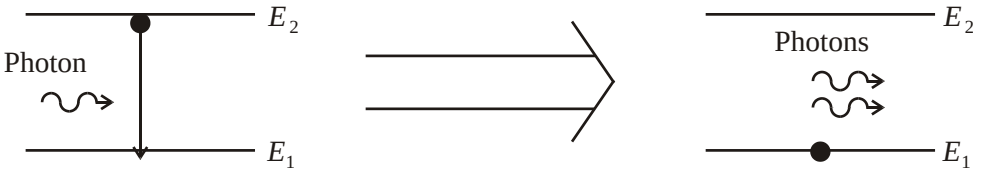
Absorption



Spontaneous emission



Stimulated emission (laser)



What is meant by energy level?

.....

.....

(1)

What is a photon?

.....

.....

(1)

Write down a formula in terms of E_1 and E_2 for the energy of the photon in the absorption diagram.

Energy = ...

(1)

The laser light emitted by the stimulated emission process must have the same wavelength as the photon in the spontaneous emission diagram. Explain this.

.....

.....

.....

(1)

The laser light is said to be coherent. Explain the meaning of coherent.

.....

.....

.....

(1)

(Total 5 marks)