1. A source of light emits a train of waves lasting 0.04 μs. The light has a wavelength of 600 nm and the speed of light is 3×10^8 m s^{-1}. How many complete waves are sent out?

A 2.0×10^7

B 4.5×10^7

C 2.0×10^{10}

D 4.5×10^{13}

(Total 1 mark)

2. Which of the following statements about standing waves is true?

A particles between adjacent nodes all have the same amplitude.

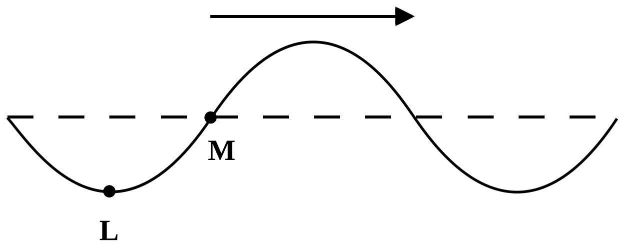
B particles undergo no disturbance at an antinode.

C particles immediately either side of a node are moving in opposite directions.

D particles between adjacent nodes are out of phase with each other.

(Total 1 mark)

3. The diagram shows a wave on a rope. The wave is travelling from left to right.



At the instant shown, point **L** is at a maximum displacement and point **M** has zero displacement. Which row in the table correctly describes the motion of points **L** and **M** during the next half cycle of the wave?

	Point L	**Point M**
A	rises	falls
B	rises	falls then rises
C	rises then falls	rises
D	rises then falls	falls then rises

(Total 1 mark)

4. Electromagnetic waves are produced by oscillating charges. Sound waves are produced by oscillating tuning forks. How are these waves similar?

A they are both longitudinal waves.

B they are both transverse waves.

C they both have the same frequency as their respective sources.

D they both require a medium to travel through.

(Total 1 mark)

5. Two points on a progressive wave differ in phase by $\frac{\pi}{4}$ radian. The distance between them is 0.50 m. The frequency of the oscillations is 10 Hz. The maximum speed of the wave is

A 2.50 m s^{-1}

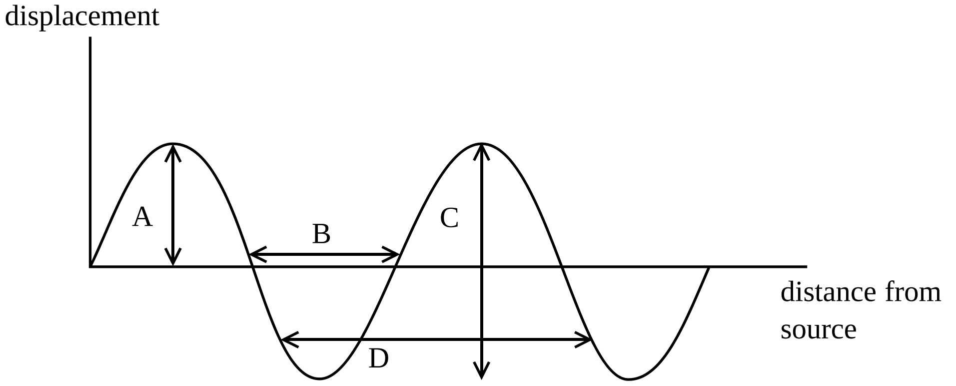
B 5.00 m s^{-1}

C 12.5 m s^{-1}

D 40.0 m s^{-1}

(Total 1 mark)

6. A loudspeaker emits a sound wave of wavelength 0.66 m. The diagram shows how displacement varies with distance from the loudspeaker at one instant of time.



(a) Which letter indicates the wavelength of the sound wave?

....

(1)

(b) Sound travels at 330 m s^{-1} in air. Calculate the period of the wave.

....

....

Period = ...

(3)

(Total 4 marks)

7. State **two** conditions necessary for total internal reflection to occur at an interface between air and water.

Condition 1 ....

....

Condition 2 ....

....

(Total 2 marks)

8. (a) Explain with the aid of diagrams why transverse waves can be polarised but longitudinal ones cannot be polarised.

....

....

....

....

....

(3)

(b) Describe with the aid of a diagram how you could demonstrate that light can be polarised.

....

....

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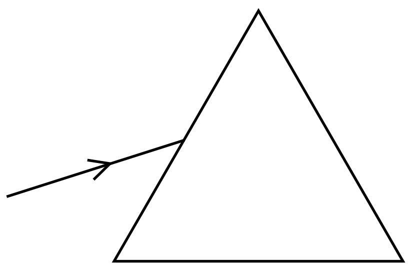
....

....

(3)
(Total 6 marks)

9. A ray of light travelling in air, strikes the middle of one face of an equilateral glass prism as shown.



State what happens to the following properties as the light goes from the air into the glass.

Frequency ....

Wavelength ....

Speed ....

(Total 3 marks)

10. About 100 years ago X-rays were first used in hospitals. At that time, many of the doctors who worked with X-rays died young. Explain why this occurred and the implications it has for the use of new technology today.

....

....

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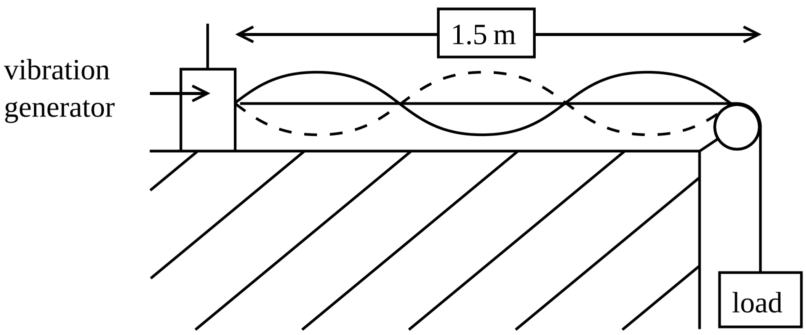
....

....

....

(Total 4 marks)

11. The following apparatus is set up. When the frequency of the vibrator is 60 Hz, the standing wave shown in the diagram is produced.



(a) What is the wavelength of this standing wave?

Wavelength = ...

(1)

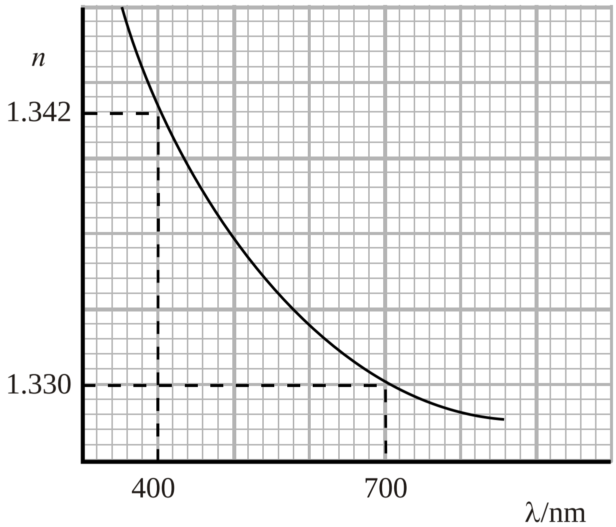
(b) The frequency of the vibrator is altered until the standing wave has two more nodes. Calculate the new frequency.

Frequency = ...

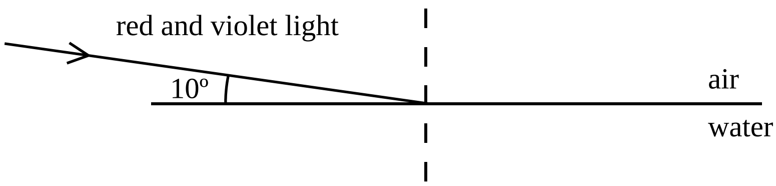
(2)

(Total 3 marks)

12. The graph shows how the refractive index of water, *n* varies with wavelength λ of the light in a vacuum. The values for red and violet light are indicated.



The diagram shows a mixture of red and violet light incident on an air/water interface.



Calculate the angle of refraction for the red light.

Angle of refraction = ...

(3)

On the diagram draw the approximate paths of the refracted rays.

(2)
(Total 5 marks)

13. Until the early 20th century, the wave theory of light was successful at explaining different properties of light such as reflection, refraction and diffraction. With the discovery of the photoelectric effect, scientists had a problem. The wave theory of light assumes that the energy of the wave is spread over the whole wavefront. Using the wave theory, scientists calculated that, if light of very low intensity is shone onto the metal, it should take a very long time for an electron to gain sufficient energy to break free from a metal. It was discovered that, providing the light was above a certain frequency, electrons could escape from a metal surface instantly. The new model that was introduced treated light as being made of particles called photons.

(a) What is meant by diffraction?

....

....

....

(2)

(b) How did considering light as photons enable scientists to explain why electrons could be emitted instantly from a metal surface?

....

....

....

....

(2)

(c) Explain why this effect only happens when the light is above a certain frequency.

....

....

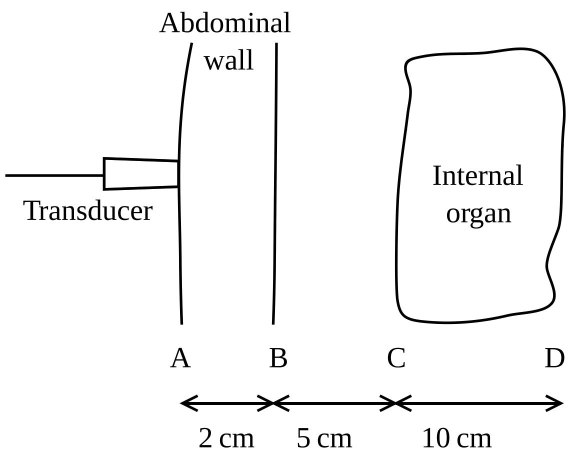
....

....

(2)
(Total 6 marks)

14. (a) Ultrasound images of the body are a useful diagnostic tool for doctors. A single transducer can be used both to send and receive pulses of ultrasound.

The diagram shows a lateral cross-section through part of the abdomen. The diagram is not to scale.



(i) Calculate the time interval between sending out a single pulse and receiving its echo from interface B. The speed of ultrasound in the abdominal wall is 1500 m s^{-1}.

Time interval = ...

(3)

(ii) The time between pulses being emitted by the transducer is 200 μs. At what frequency are the pulses emitted?

Frequency = ...

(2)

(iii) The time interval before the echo returns from interface D is 250 μs. Suggest why this time interval will make reflections from D difficult to interpret and what could be done to overcome this problem.

....

....

....

....

(3)

(iv) State **one** reason why ultrasound rather than X-rays is now used to scan expectant mothers.

....

....

....

(1)

(b) Ultrasound is also used to measure blood flow in the body. It uses the Doppler shift of the reflected pulse to measure the speed of blood through the arteries of the body.

Describe the principle of this method and how it can be used to determine the speed of blood.

....

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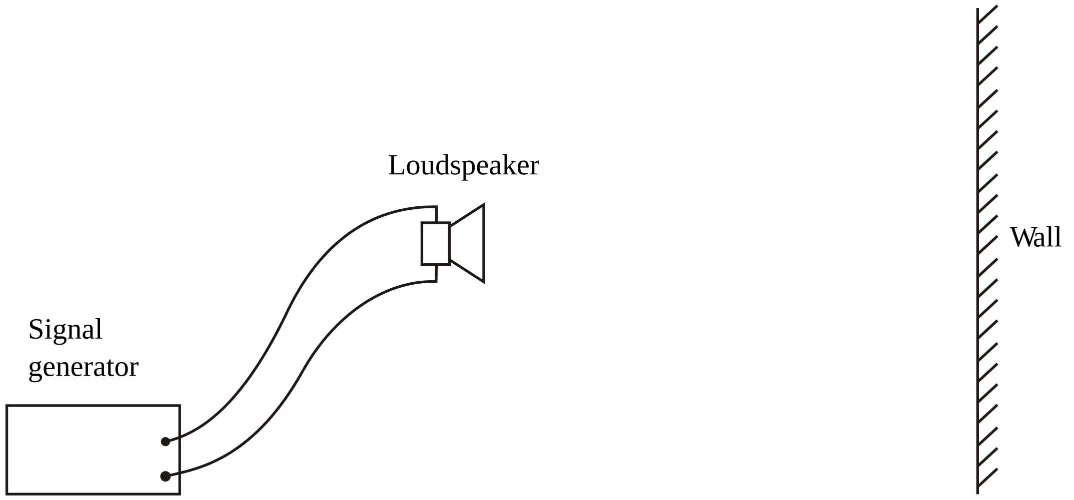
....

....

(4)
(Total 13 marks)

15. A loudspeaker connected to a signal generator is set up facing a wall.



Sound waves from the loudspeaker are reflected from the wall and a stationary wave is produced in the region between the loudspeaker and the wall.

(a) (i) Describe how you would use a small microphone, connected to a cathode ray oscilloscope, to demonstrate the presence of the stationary wave.

....

....

....

....

....

(2)

(ii) Explain how the nodes and antinodes are produced.

....

....

....

....

....

....

....

(3)

(iii) Outline how you would use this apparatus to obtain a value for the speed of sound waves in air.

....

....

....

....

....

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....

....

(4)

(b) (i) In principle, stationary waves produced in this way could cause problems for listeners in a concert hall. Explain why.

....

....

....

(ii) In practice, the problem is not serious. Suggest a reason why.

....

....

....

(2)
(Total 11 marks)

16. (a) It is important to ensure that as little light as possible is wasted from lighthouses. In 1822 the French physicist Augustin Fresnel developed an efficient combination of lenses and prisms.

The light source is placed at the centre of this combination. This ensures that most of the light emerges as parallel rays. Figure 1 shows the whole arrangement. Figure 2 shows a cross-section of part of the arrangement with incident rays and some of the emergent rays.

Figure 1

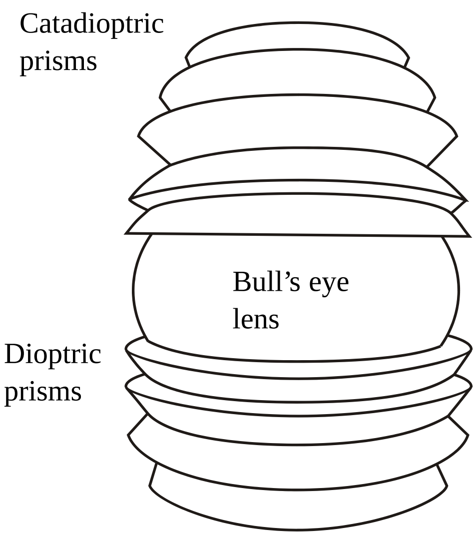


Figure 2

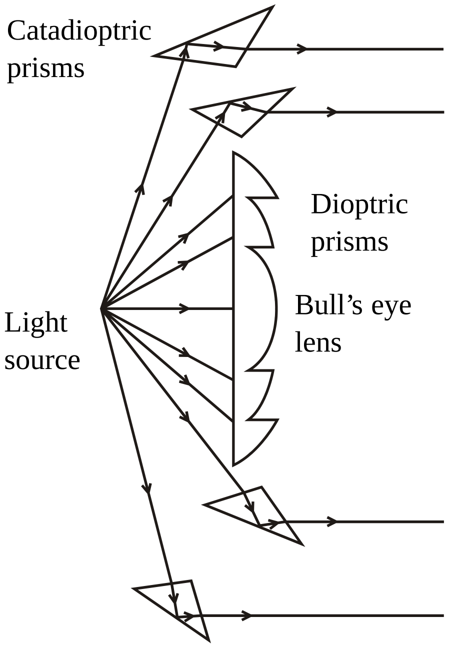
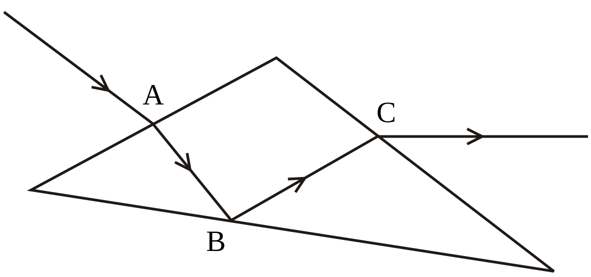


Figure 3 shows an enlarged representation of the path of a light ray through one of the catadioptric prisms. Both reflection and refraction take place.

Figure 3



(i) State the necessary condition for the reflection at B.

....

(1)

(ii) Describe the path of the ray shown in Figure 3 as fully as possible.

....

....

....

....

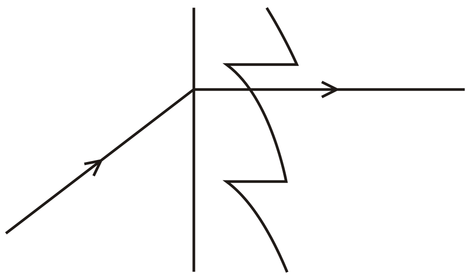
....

....

(2)

(b) (i) Figure 4 shows part of a diagram from an internet site showing the path of a light ray through a dioptric prism.

Figure 4



State two things that are wrong with the diagram.

1 ....

....

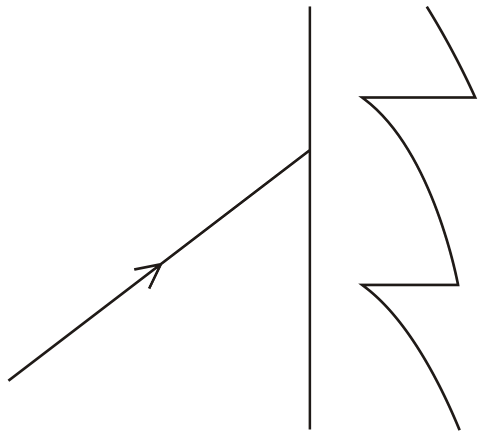
2 ....

....

(2)

(ii) Add to Figure 5 to show the correct path of the light ray.

Figure 5

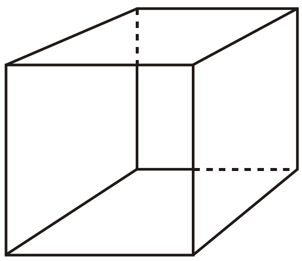


(3)
(Total 8 marks)

17. A student is thinking about how the physics of standing waves might affect music within a room.

She models a room as a completely empty cubic box with reflecting walls, as shown in Figure 1.

Figure 1

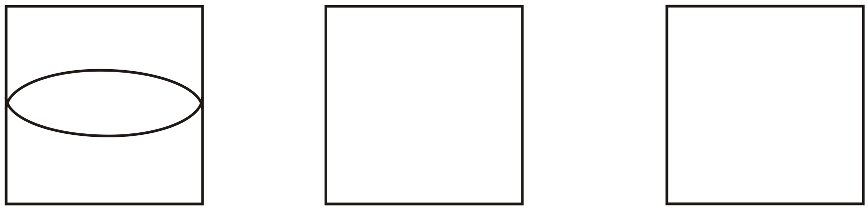


Suppose that sound waves travel across the room from side to side.

(a) The diagrams in Figure 2 are to represent three possible standing wave patterns that might form across the room. One has been drawn in.

(i) Add to Diagrams B and C two other possible patterns.

Figure 2



(2)

(ii) Mark with an X on Diagram A a place where the air particles are oscillating with the largest amplitude.

(1)

(iii) What is the name given to the place you have marked?

....

(1)

(b) Assume the room is a cube of side 2.8 m. The speed of sound is 330 m s^{-1}.

For the standing wave pattern shown in Diagram A, calculate

(i) the wavelength of the waves,

....

Wavelength = ...

(1)

(ii) the frequency of the waves.

....

....

....

Frequency = ...

(2)

(c) Suppose music containing the full range of audible frequencies is being played in the room.

(i) Explain why the frequency calculated in (b)(ii) might sound louder than other frequencies.

....

....

....

(1)

(ii) Suggest one other frequency that might also sound louder in this room.

Explain your answer.

....

....

....

(2)

(d) Now suppose music was being played in a similar but much bigger room. Explain how the frequencies of the standing waves would be different in this bigger room.

....

....

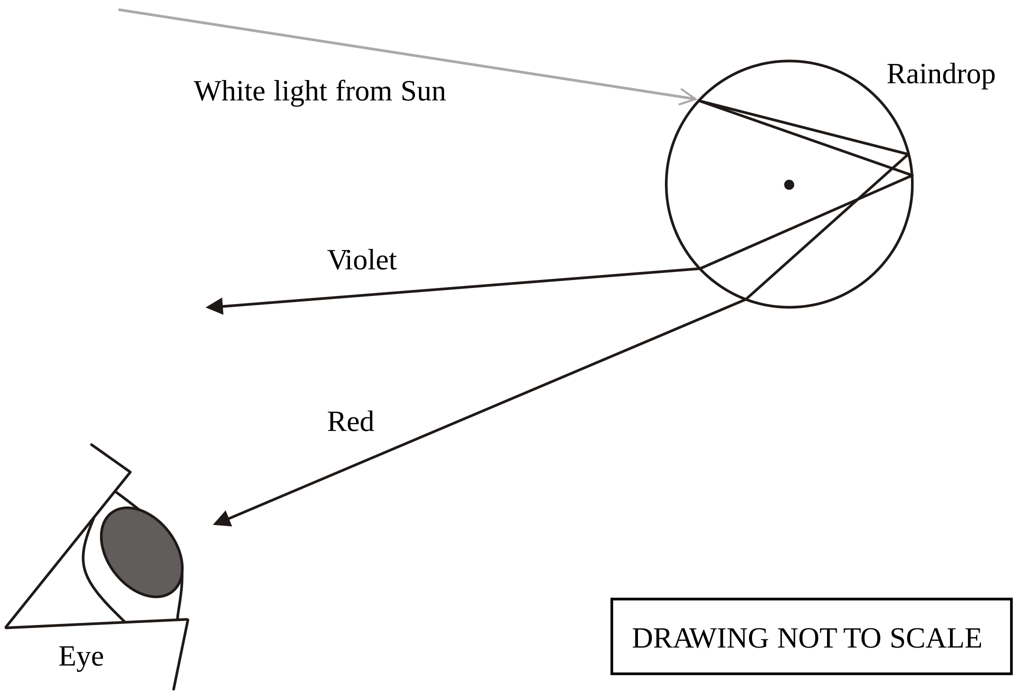
....

....

(2)
(Total 12 marks)

18. A rainbow is one of the most beautiful sights in nature. Each raindrop acts as a circular prism, splitting up the white light into its constituent colours. Some of the light is reflected inside the raindrop. We only see a single colour of light from any one raindrop, as shown in Figure 1.

Figure 1



Only the red light leaves this raindrop at the correct angle to reach the observer's eye. Similarly, there will be another raindrop in which only the violet light leaves at the correct angle to be seen by the observer. This is why a rainbow appears as a range of colours.

(a) On Figure 1 label an angle of incidence with an *i* and an angle of refraction with an *r*.

(2)

(b) The refractive index of water for red light is 1.3. Calculate the angle of refraction when a ray of red light enters the raindrop at an angle of incidence of 27°.

....

....

....

Angle of refraction = ...

(2)

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

....

....

(1)

(ii) Calculate the critical angle for a raindrop.

....

....

....

....

Critical angle = ...

(2)

(d) A ray of light hits the back of a raindrop as shown in Figure 2. Measure the angle of incidence at this back surface and complete Figure 2 to show what will happen to the ray of light.

Figure 2

Angle of incidence = ...

(4)

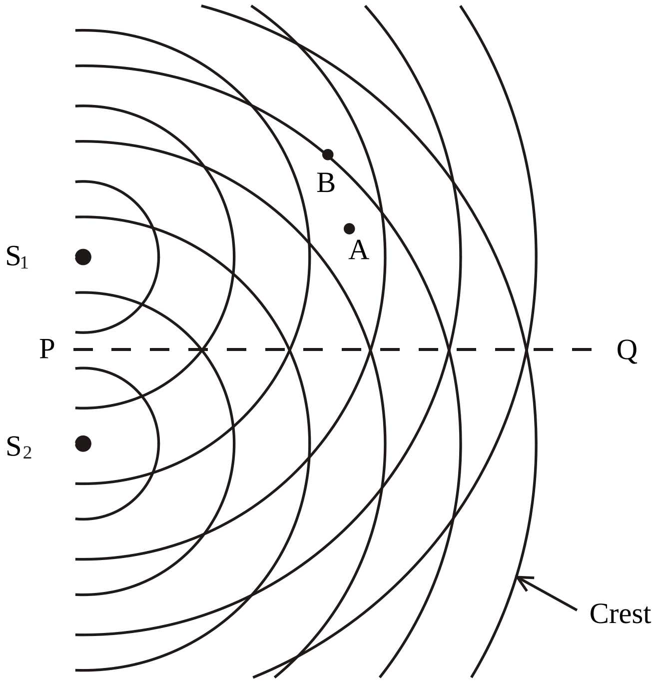
(e) Figure 1 shows that red light is refracted less than violet light by the raindrop. Comment on the refractive index of water for red light compared to that for violet light.

....

....

(1)
(Total 12 marks)

19. Two point sources, S_1 and S_2, emit waves of equal amplitude and frequency. The diagram, which is full size, shows the positions of successive crests of each wave at one particular instant of time.



(a) (i) How can you tell from the diagram that the speed of the waves is the same everywhere?

....

....

(1)

(ii) The frequency of the waves is 40 Hz. Use information from the diagram to determine their speed.

....

....

....

Speed = ...

(3)

(b) On the diagram, draw a line joining points where the waves from S_1 have travelled one wavelength further than the waves from S_2. Label this line X.

(1)

(c) The waves from the two sources superpose.

(i) Describe and explain the result of this superposition along line PQ.

....

....

....

....

....

....

(3)

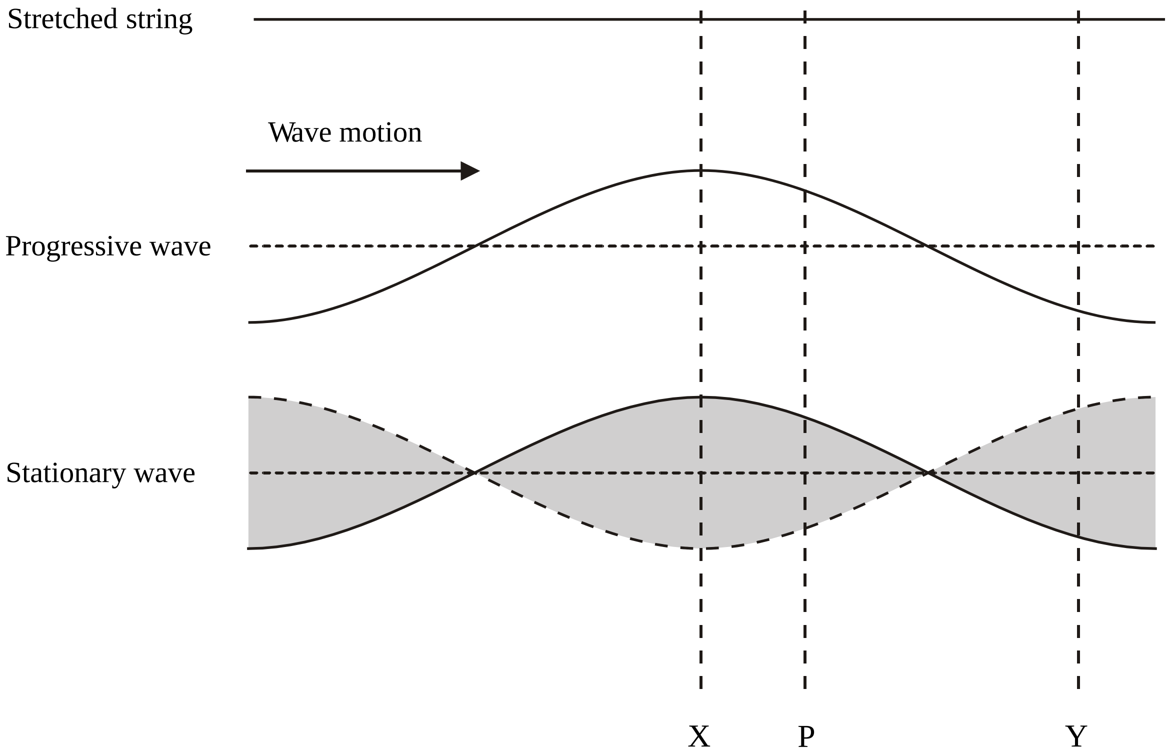
(ii) Tick the appropriate boxes in the table to show what is observed at the points marked A and B in the diagram.

Point	**What is observed**		
	Constructive interference	**Destructive interference**	**Neither**
A			
B			

(2)
(Total 10 marks)

20. The diagrams show

- a stretched string
- a sinusoidal progressive wave travelling to the right along the string
- a stationary wave on the same string.



P is at a distance from X which can be varied.

(a) How, if at all, does the **amplitude** of oscillation at P vary as P moves from X to Y

(i) in the progressive wave?

....

(1)

(ii) in the stationary wave?

....

....

....

(2)

(b) How, if at all, does the **phase difference** between the oscillations at X and at P vary as P moves from X to Y

(i) in the progressive wave?

....

(1)

(ii) in the stationary wave?

....

....

....

(2)
(Total 6 marks)

21. (a) Light changes direction when it passes from air to water.

(i) Name the process of light changing direction in this way.

....

(1)

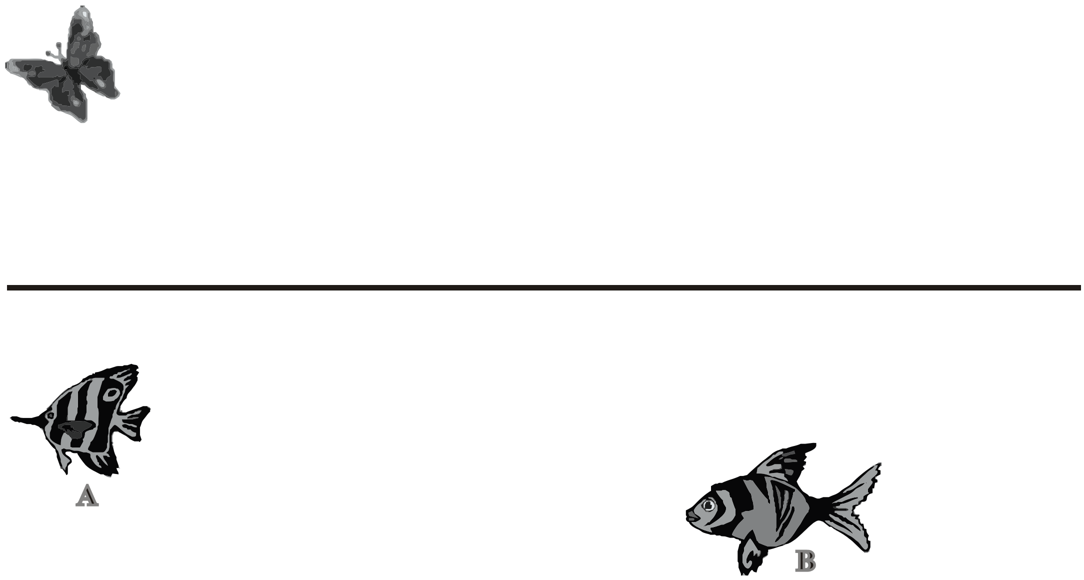
(ii) Explain why this process takes place.

....

....

(1)

(b) The diagram represents some fish under water and a butterfly above the water.



(i) Draw a ray to show the path of light travelling from the butterfly to the eye of fish **B**.

(2)

(ii) Explain what is meant by **critical angle**.

....

....

....

....

....

(2)

(iii) Explain how rays from fish **A** could reach the eye of fish **B** along two different paths. Add rays to the diagram to illustrate your answer.

....

....

....

(4)
(Total 10 marks)

22. Many species of bat detect their prey using ultrasound.

(a) What is meant by ultrasound?

....

(1)

(b) A bat emits short pulses of ultrasound up to 200 times each second. These pulses reflect off the prey and are detected by the bat.

(i) Explain why the bat uses pulses rather than a continuous beam of ultrasound.

....

....

....

(ii) Suggest why a high rate of pulses is important for the bat's success in hunting.

....

....

....

(2)

(c) The bat can detect any object whose size is at least as large as the wavelength of the emitted ultrasound. Calculate the size of the smallest object which can be detected for emitted ultrasound of maximum frequency 70 kHz.

Speed of ultrasound in air = 340 m s^{-1}.

....

....

....

....

Size = ...

(2)

(d) A bat detects a moth 0.5 m away. Calculate the time between the bat emitting a pulse and detecting the reflected pulse from the moth.

....

....

....

Time = ...

(2)

(e) As the moth moves away from the bat the ultrasound is reflected with a different frequency from that emitted.

Describe how the frequency of the reflected pulse changes as the moth moves away from the bat and how this relates to the movement of the moth.

....

....

....

....

(2)
(Total 9 marks)

23. (a) Use a diagram to show what is meant by diffraction.

(2)

(b) X-ray diffraction images such as the one shown below led scientists to the first understanding of the structure of DNA. The image shown is a negative on photographic film. The dark bands correspond to maximum X-ray detection.

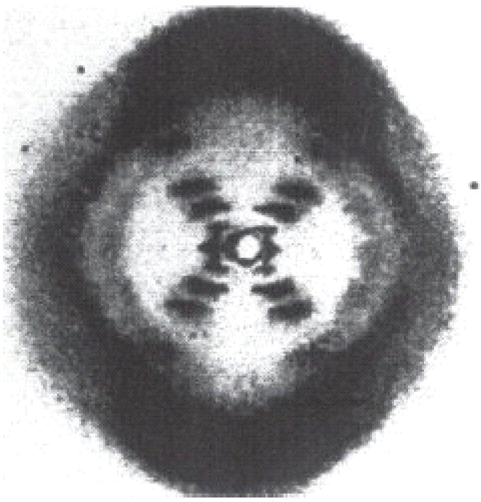


Figure 1

Use diagrams to explain how two X-ray waves overlap to produce maximum intensity.

(2)

(c) State two pieces of information about the structure of DNA that can be deduced from Figure 1.

1 ....

2 ....

(2)

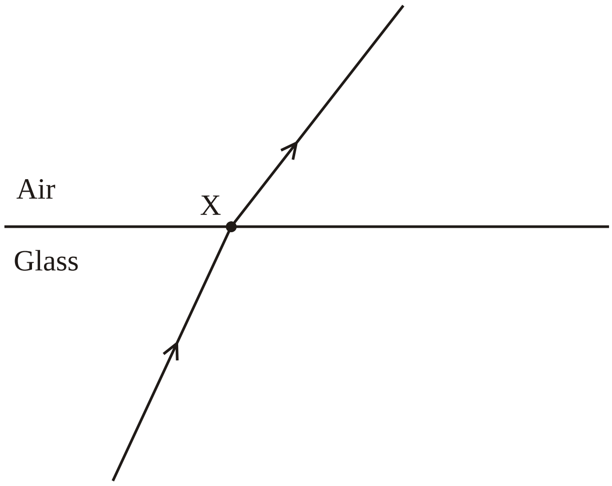
(d) Electrons can also be used to produce diffraction patterns and hence to study materials in this way.

What does this tell you about the behaviour of electrons when passing through such materials?

....

(1)
(Total 7 marks)

24. A student carries out an experiment to investigate the refraction of light as it passes from glass into air. He shines a ray of light through a glass block and into the air as shown.



(a) (i) Add to the diagram to show *i* the angle of incidence and *r* the angle of refraction. Measure these two angles.

i = ...

r = ...

(3)

(ii) Hence, calculate the refractive index from air to glass ${}_a\mu_g$.

....

....

....

${}_a\mu_g$ = ...

(2)

(b) At X, some of the light takes a path different from that shown on the diagram. Add another ray to the diagram showing the path of this light.

(1)

(c) The student increases the angle of incidence and notices that, above a certain angle, the light no longer passes into the air. Explain this observation.

....

....

....

....

....

(2)

(d) Determine the largest angle of incidence which allows the light to pass into the air from this block.

....

....

....

Angle = ...

(2)

(Total 10 marks)

25. (a) Describe how you would demonstrate that light waves can be polarised. Include a diagram of the apparatus that you would use. Describe fully what you would observe.

....

....

....

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....

....

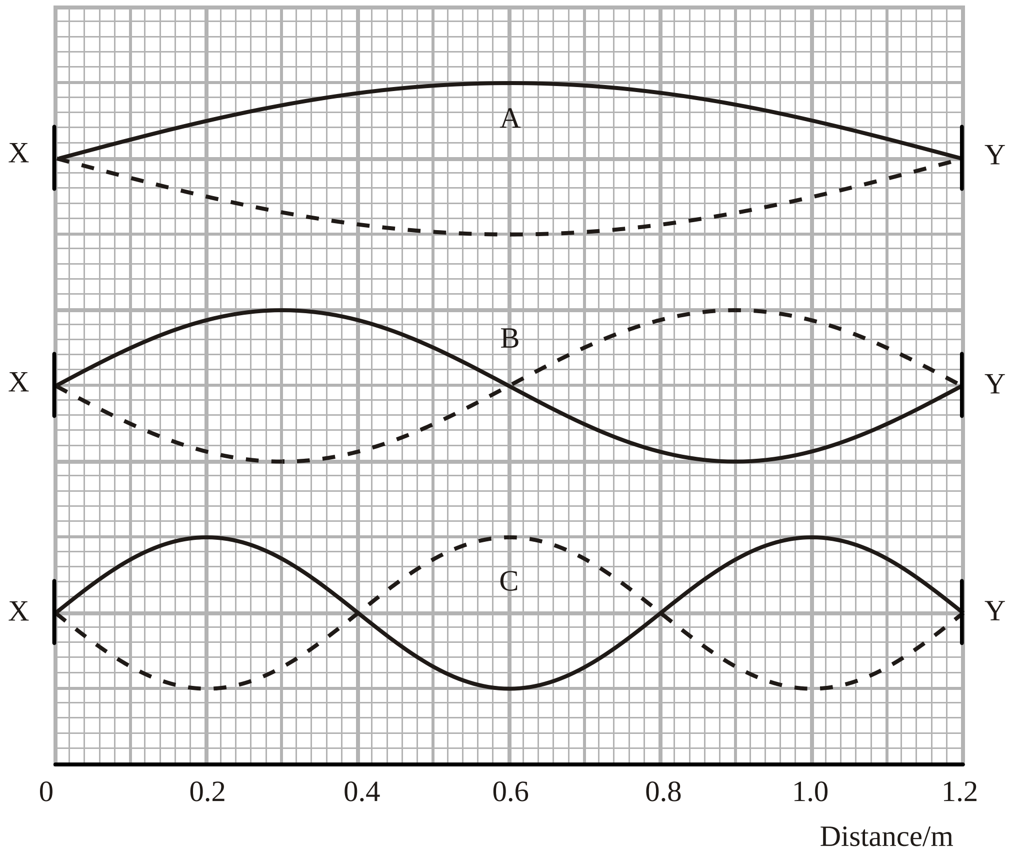
(5)

(b) State why it is not possible to polarise sound waves.

....

(1)
(Total 6 marks)

26. (a) The diagram shows three possible stationary waves on a string of length 1.20 m stretched between fixed points X and Y.



(i) Wave A has a frequency of 110 Hz.

Complete the table below to show the wavelengths and frequencies of the three waves.

Wave	Wavelength / m	Frequency / Hz
A		110
B		
C		

(3)

(ii) Each of the waves has nodes at X and Y. Explain why these points must be nodes.

....

....

(1)

(b) There is a similarity between the behaviour of the string in part (a) and that of the electron in a hydrogen atom. Electron states can be represented by stationary waves which have to fit inside the atom.

Stationary waves with greater numbers of nodes represent electrons in higher energy levels. Explain why this is the case.

....

....

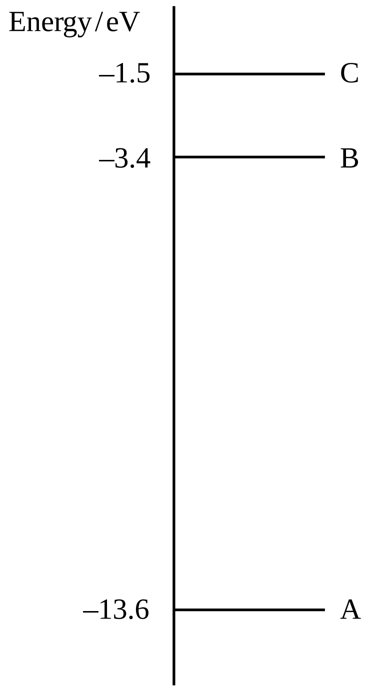
....

....

....

(2)
(Total 6 marks)

27. The diagram shows the lowest three energy levels of atomic hydrogen.



(a) Excited hydrogen atoms can emit light of wavelength 656 nm. By means of a suitable calculation, determine which transition between energy levels is responsible for this emission.

....

....

....

....

....

Transition: from level .... to level ....

(4)

(b) The spectrum of light from the Sun contains a dark line at a wavelength of 656 nm. With reference to the energy level diagram, explain how this line is produced. You may be awarded a mark for the clarity of your answer.

....

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....

....

....

....

(4)

(c) In the spectrum of light received from another galaxy, the same line appears at a wavelength of 695 nm.

How can we deduce from this that the galaxy is receding from the Earth?

....

....

(1)
(Total 9 marks)

28. An earthquake under the ocean floor may cause a tidal wave. It has been suggested that elephants may be able to give advance warning of the arrival of such a tidal wave by detecting the seismic p-waves produced by the earthquake.

(a) P-waves travel through the Earth's crust as longitudinal waves. Describe how longitudinal waves propagate.

....

....

....

(2)

(b) Some p-waves have a frequency of 9.0 Hz and a wavelength of 0.8 km.

Calculate the speed of these waves.

....

....

....

Wave speed = ...

(2)

(c) An elephant is 2500 km from the epicentre of an earthquake. A tidal wave would take about two hours to travel this distance. Determine whether it is possible for the elephant to detect the earthquake significantly earlier than the arrival of the tidal wave.

....

....

....

....

(2)
(Total 6 marks)

29. (a) Explain what is meant by superposition of waves.

....

....

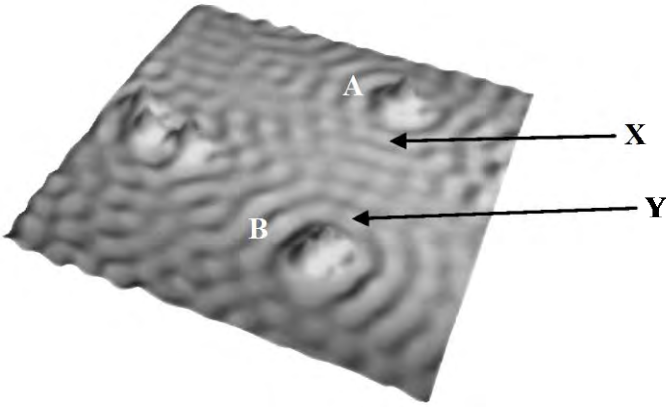
....

....

....

(2)

(b) The electron micrograph shows a small area of the surface of a copper sample.



Electrons move over the surface and behave like waves. When a wave reaches an edge or an atom, it reflects, and a standing wave is formed.

(i) Explain how a standing wave is formed by the reflection of a wave.

....

....

....

....

....

(3)

(ii) A standing wave is visible on the micrograph between atoms A and B. There are nodes at X and Y. The dark lines between X and Y show antinodes.

The distance between points X and Y on the micrograph is 4.2×10^{-9} m.
Use this information to calculate the wavelength of the electron waves.

....

....

....

....

Wavelength = ...

(2)

(iii) Explain the meaning of the terms amplitude and antinode.

Amplitude

....

....

....

(1)

Antinode

....

....

....

(1)
(Total 9 marks)

30. At night, particles in the atmosphere scatter moonlight causing it to become plane polarised.

(a) What is meant by the term plane polarised?

....

....

(2)

(b) Scientists have discovered recently that the dung beetle can navigate using polarised moonlight. The beetles hunt for fresh dung. When they find some each beetle makes a small ball. To keep this ball for itself it needs to remove it quickly. The beetle pushes the ball along with its back legs while moving with its front legs and keeping its head down. Using the plane of the polarised moonlight as a guide lets the beetle run away in a straight line.

The beetles have sensors in their eyes which act as polarising filters.

Describe and explain the effect of rotating a polarising filter in front of a source of plane polarised light.

....

....

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....

(3)

(c) Scientists held a polarising filter over one of the beetles as it was retreating with a dung ball. The filter changed the polarisation plane by 90°.

Suggest how the beetle responded.

....

....

(1)

(d) Suggest what would happen to the beetles on nights when the moon is not visible.

....

(1)
(Total 7 marks)

31. (a) Explain with the aid of a diagram why transverse waves can be plane polarised but longitudinal waves cannot be plane polarised.

....

....

....

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(3)

(b) (i) A filament lamp is observed directly and then through a sheet of Polaroid. Describe and explain the effect of the sheet of Polaroid on the intensity of the light seen.

....

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....

....

(2)

(ii) The sheet of Polaroid is now rotated in a plane perpendicular to the direction of travel of the light. What effect, if any, will this have on the intensity of the light seen?

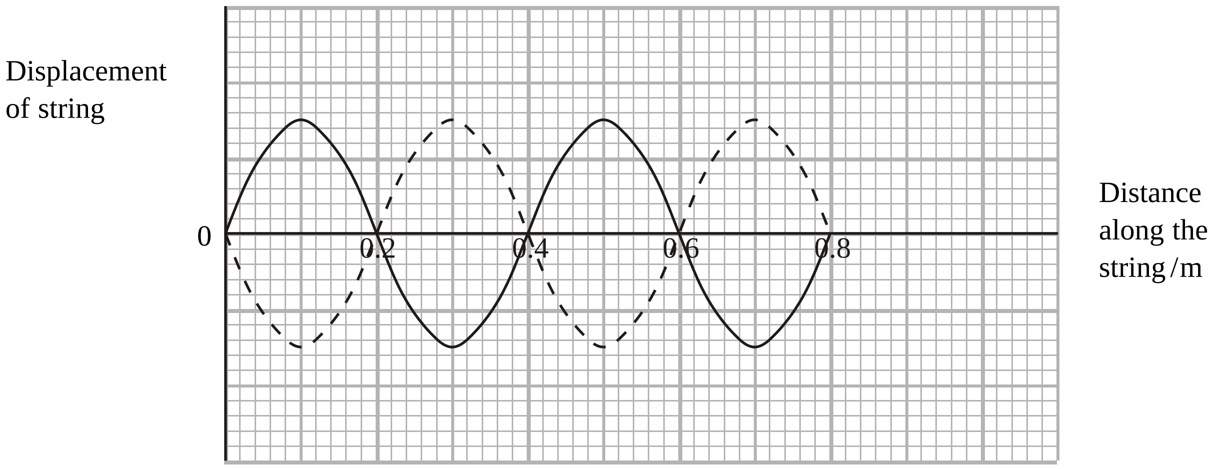
....

....

(1)
(Total 6 marks)

32. The cello is a stringed musical instrument that may be played either by stroking the strings with a bow or by plucking the strings with the fingers.

(a) One of the attached strings on the cello has a vibrating length of 0.80 m. The string is made to oscillate as a stationary wave by means of a bow and the following pattern of oscillations is seen. The position of the string at two different times is shown.



(i) Explain how the movement of the bow causes this wave pattern.

....

....

....

....

(3)

(ii) Using the diagram calculate the wavelength of the wave.

....

....

Wavelength = ...

(2)

(iii) State two differences between the wave on the string and the sound wave it produces.

1 ....

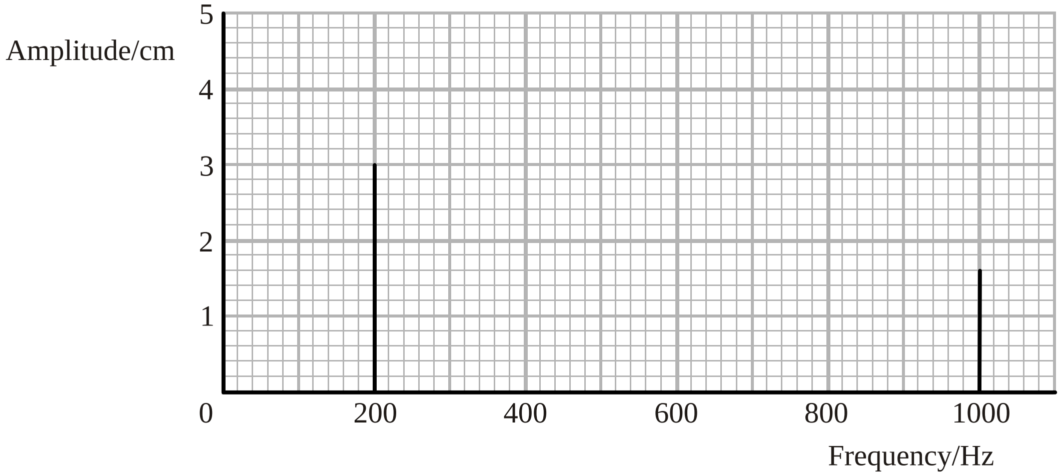
....

2 ....

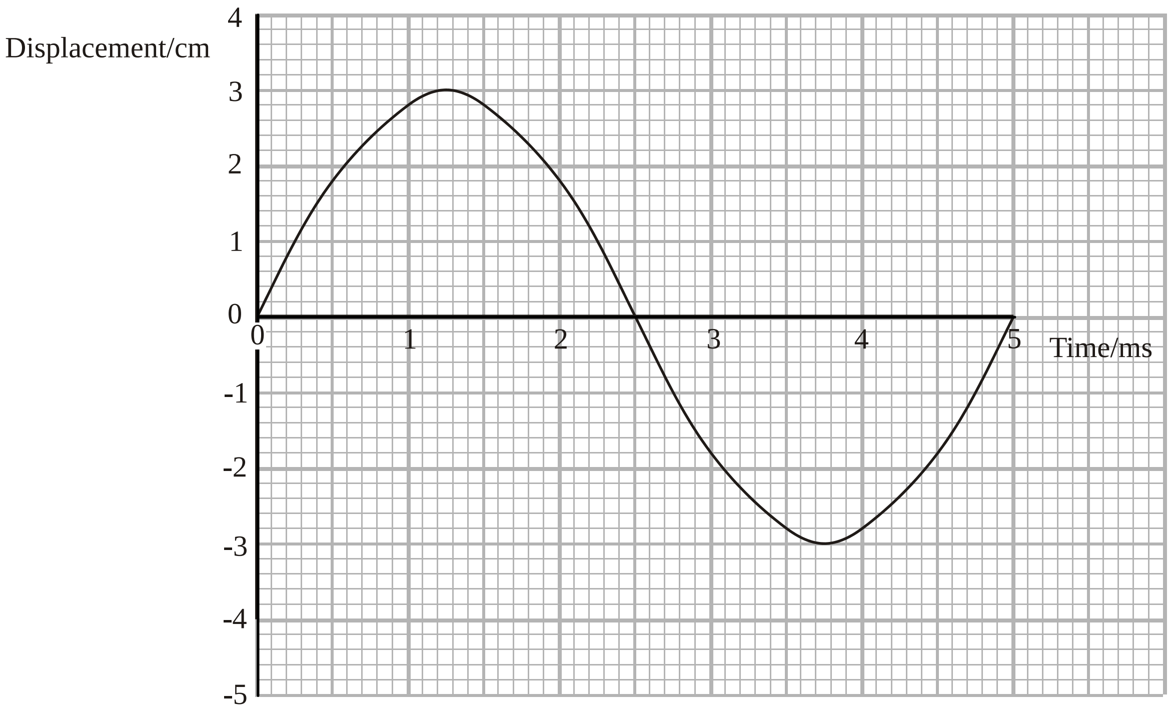
....

(2)

(b) The cello string is then plucked and the waveform of the resulting sound is analysed by an oscilloscope. It is found to consist of two frequencies of different amplitudes. The frequency spectrum is shown below.



The waveform of the 200 Hz wave has been drawn on the axes below. On the same axes sketch the waveform of the 1000 Hz wave.



(2)
(Total 9 marks)

33. (a) State three conditions which must be satisfied if two waves are to produce an observable interference pattern.

1 ....

2 ....

3 ....

(3)

(b) (i) Describe an experiment using microwaves to produce and detect a two slit interference pattern. You may find it useful to draw a diagram.

....

....

....

....

....

(3)

(ii) The dimensions of a microwave experiment are such that the equation $\lambda = xs/D$ is not valid. Explain how you would find a value for the wavelength of the microwaves from your experiment.

....

....

....

....

....

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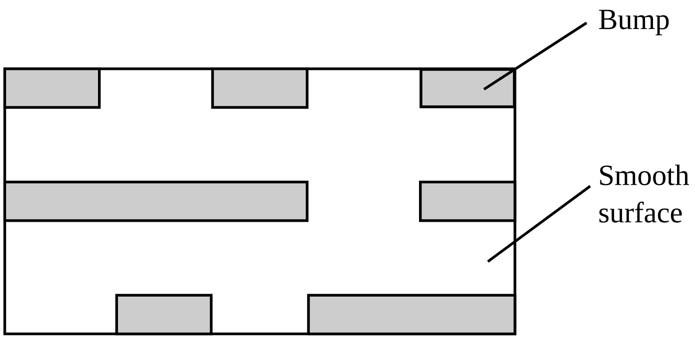
(3)
(Total 9 marks)

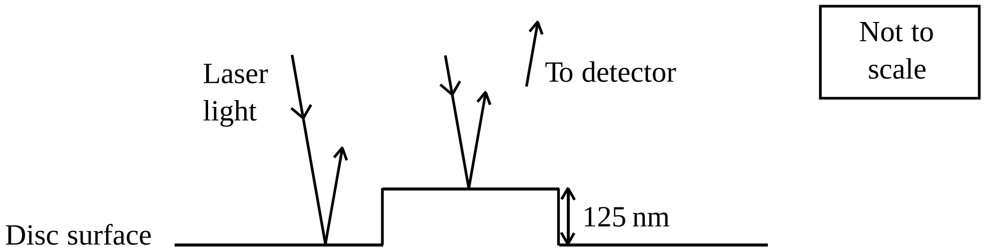
34. Figure 1 shows an enlargement of a small rectangular area of the surface of a compact disc (CD). It shows a series of small bumps on an otherwise smooth surface.

Figure 1



The presence or absence of a bump is detected by shining laser light perpendicularly onto the disc surface. Where there is a bump, some of the light hits the top of the bump, and some hits the disc surface next to the bump.

Figure 2



The height of the bumps on the surface of the disc is 125 nm. The wavelength of the light used to read the disc is 500 nm.

(a) Explain whether the light received by the detector when a bump is present has a maximum or minimum intensity.

....

....

....

(3)

(b) For this detection system to work, the light reflected from the disc must be coherent. Explain the meaning of coherent.

....

....

....

(1)
(Total 4 marks)

35. 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.

....

....

....

(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}.

....

....

....

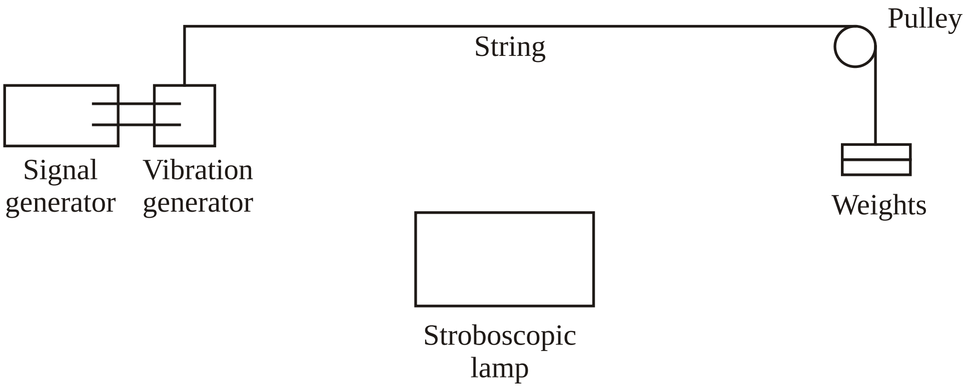
Wavelength = ...

(2)
(Total 6 marks)

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

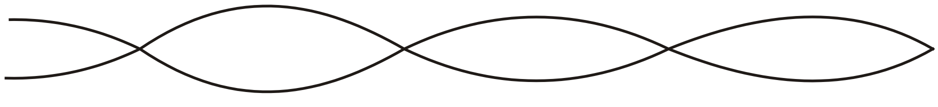
They set up the apparatus shown in Figure 1 in a dark corner of their laboratory.

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.

....

....

....

....

....

(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}

....

....

....

Speed = ...

(2)

(Total 9 marks)

37. 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.

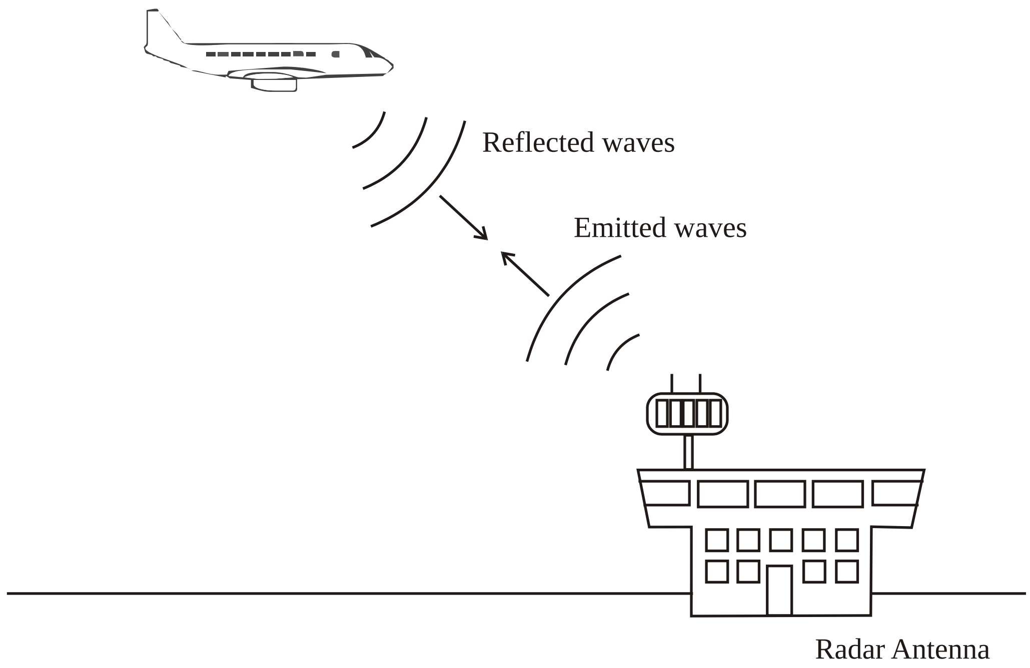

Diagram from: http://electronics howstuffworks.com/radar htm

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]

....

....

....

Distance = ...

(2)

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

....

....

....

....

(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)

38. 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.

....

....

....

(2)

(Total 4 marks)

39. The Raman effect can be used to identify the chemical composition of solid materials in a non-destructive manner, e.g. to identify fake diamonds. When laser light is shone on a material some of the light is scattered. The scattered light will be plane polarised and some of it will have been frequency shifted (that is, it will have undergone a change in frequency). This happens when the light interacts with the vibrating atoms in the materials. Analysis of these Raman frequency shifts reveals the chemical composition of the material.

What is meant by **plane polarised light**?

....

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....

....

(2)

Some of the light will have been frequency shifted by the moving atoms. Name the phenomenon which caused the frequency shifting and briefly explain how it arises.

....

....

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(4)

The Raman frequency shifts are often measured in wavenumbers. Wavenumber is defined as $\dfrac{1}{\text{wavelength}}$.

When laser light of wavelength 1064 nm is shone onto diamond, the scattered light has a Raman wavenumber shift of +1300 cm^{-1}.

Show that the frequency of this scattered light is about 3×10^{14} Hz.

....

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....

(5)

A student correctly remarks that if the frequency of the laser light has changed then its energy must have changed.

State which model of light is being used by this student, and explain what must have happened to the vibrating atoms in the diamond during this interaction.

....

....

....

....

....

....

(3)
(Total 14 marks)

40. A microwave generator produces plane polarised electromagnetic waves of wavelength 29 mm.

(a) (i) Calculate the frequency of this radiation.

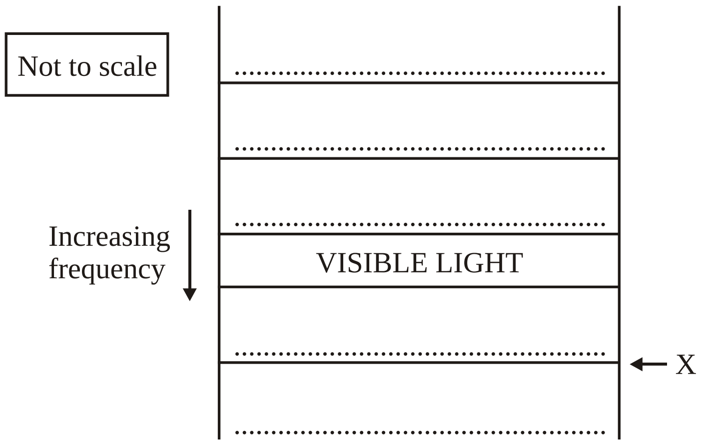
....

....

Frequency = ...

(1)

(ii) Complete the diagram of the electromagnetic spectrum below by adding the names of the parts of the electromagnetic spectrum.



(2)

(iii) State a typical value for the wavelength of radiation at boundary X.

....

(1)

(b) (i) Explain what is meant by 'plane polarised'.

....

....

....

....

(2)

(ii) Describe, with the aid of a diagram, how you would demonstrate that these microwaves were plane polarised.

....

....

....

....

....

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....

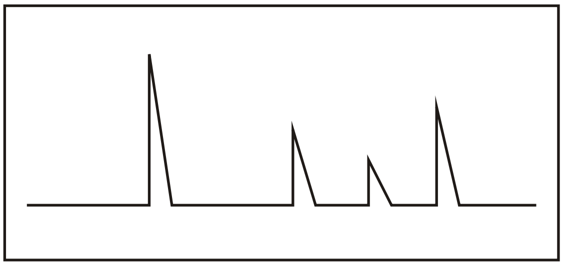
....

(4)
(Total 10 marks)

41. 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.



Time / μs ⟶

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

....

....

(1)

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

....

....

....

....

(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.

....

....

....
(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).

....

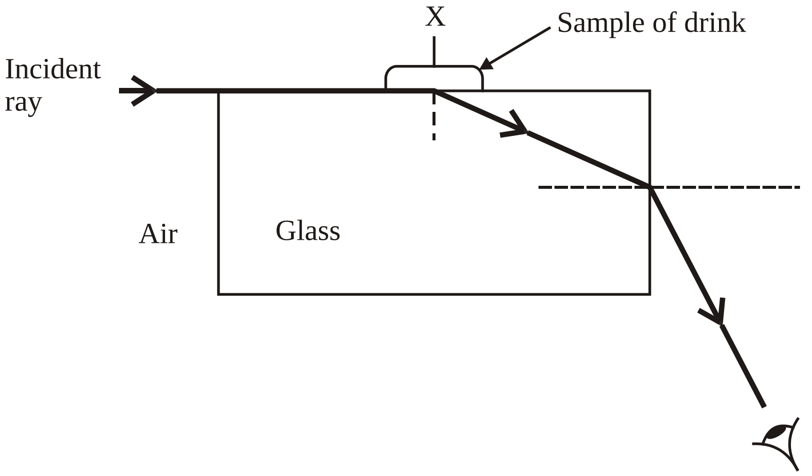
....

....

....
(3)
(Total 9 marks)

42. 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.

....

....

....

(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.

....

....

....

....

(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.

....

....

....

....

(2)
(Total 8 marks)

43. The table below summarises some features of the electromagnetic spectrum. Complete the table by filling in the missing types of radiation, wavelengths and sources.

Radiation	Typical wavelength	Source
Visible light		Very hot objects
Gamma		
	100 m	High frequency electrical oscillator
	10^{-6} m	

(Total 6 marks)

44. A stationary wave of amplitude 4.0 cm is produced by the superposition of two progressive waves that travel in opposite directions.

(a) Define the term **amplitude**.

....

....

(1)

(b) The graph below shows the positions of the stationary wave and of one of the two progressive waves at a particular instant. Apply the principle of superposition to determine the displacement of the other progressive wave at positions A, B and C on the distance axis at this same instant.

Displacement at A ....

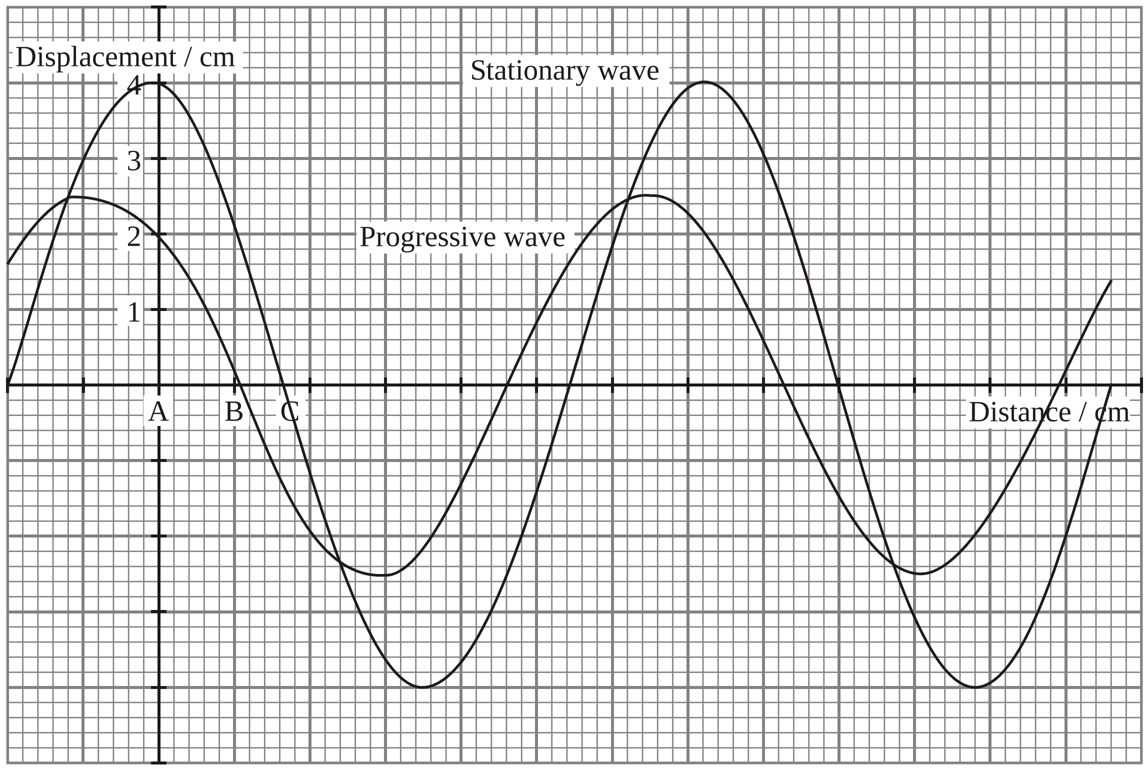
Displacement at B ....

Displacement at C ....

(3)

Plot these displacement values on the graph.

Hence draw one complete wavelength of this progressive wave.



(3)
(Total 7 marks)

45. (a) Explain what is meant by the term **transverse wave.** You may wish to illustrate your answer with the help of a simple diagram.

....

....

....
(3)

(b) State two differences between a stationary wave and a progressive wave.

Difference 1 ....

....

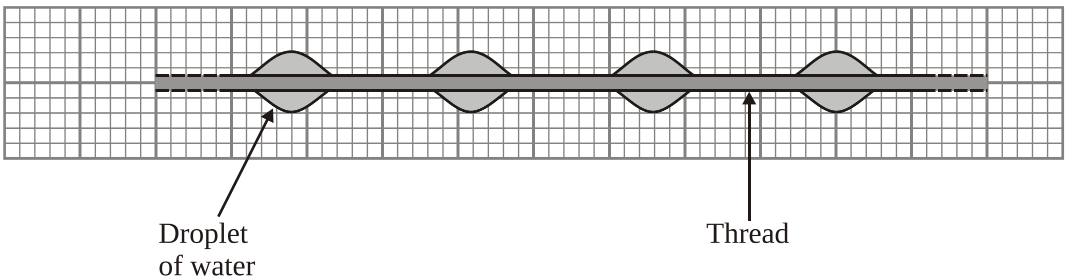
Difference 2 ....

....

(2)

(c) Spiders are almost completely dependent on vibrations transmitted through their webs for receiving information about the location of their prey. The threads of the web are under tension. When the threads are disturbed by trapped prey, progressive transverse waves are transmitted along the sections of thread and stationary waves are formed.

Early in the morning droplets of moisture are seen evenly spaced along the thread when prey has been trapped.



1 cm on diagram represents 0.25 cm of thread

(i) Explain why droplets form only at these points.

....

....

(1)

(ii) The speed of a progressive transverse wave sent by trapped prey along a thread is 9.8 cm s^{-1}. Use the diagram to help you determine the frequency of the stationary wave.

....

....

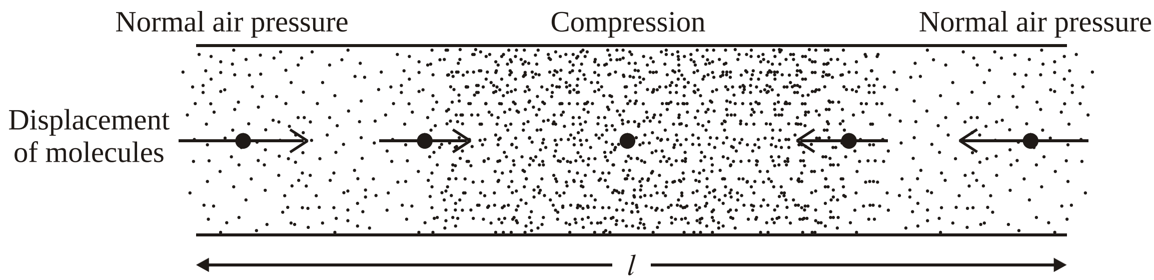
....

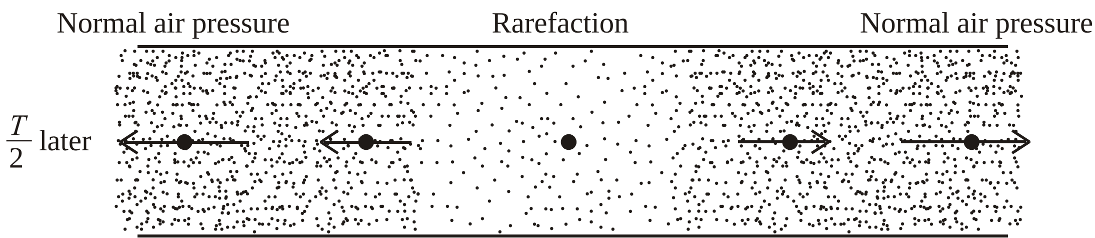
....

Frequency = ...

(4)
(Total 10 marks)

46. 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.

....

....

....

(2)

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

....

(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}.

....

....

....

....

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.

....

....

....

....

....

....

(3)
(Total 11 marks)

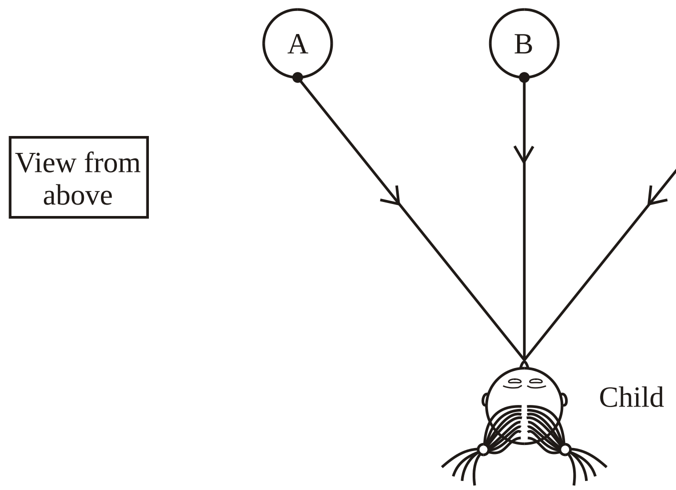
47. A three-year-old child at a barbecue was heard to remark: "The trees look like jelly – they're all wobbly". She was looking at the trees over the top of the hot barbecue. Heated, less dense air was rising from the barbecue in uneven layers, changing the direction of the light from the trees in a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

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

....

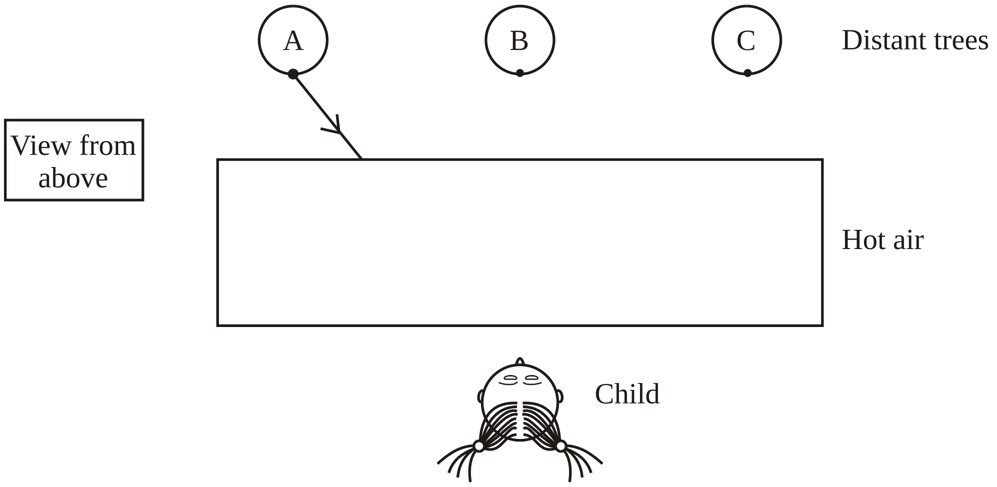
(1)

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



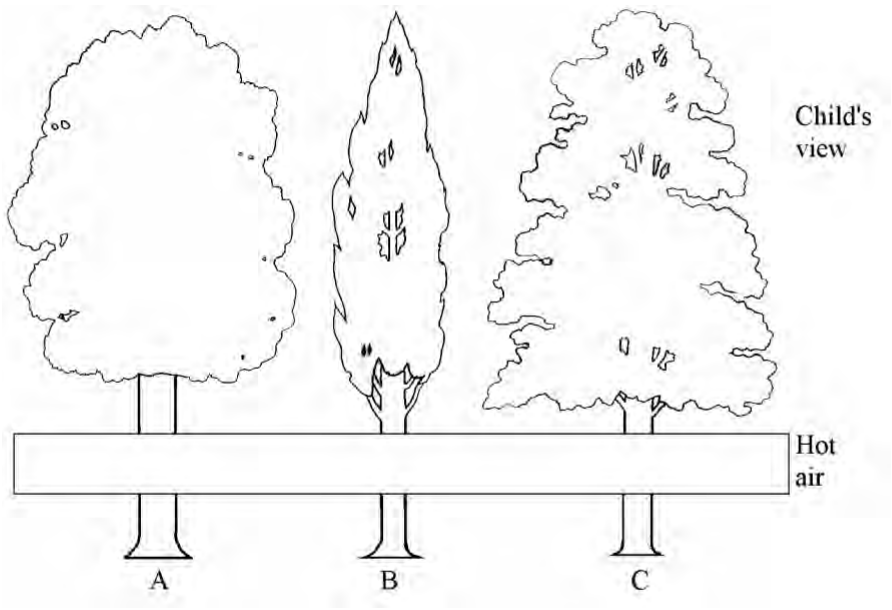
After the barbecue is lit, a layer of hotter, less dense air is between the child and the trees.

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”.

....

....

....

....

....

....

(2)
(Total 8 marks)

48. 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.

....

....

....

(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.

....

....

....

(2)
(Total 8 marks)

49. 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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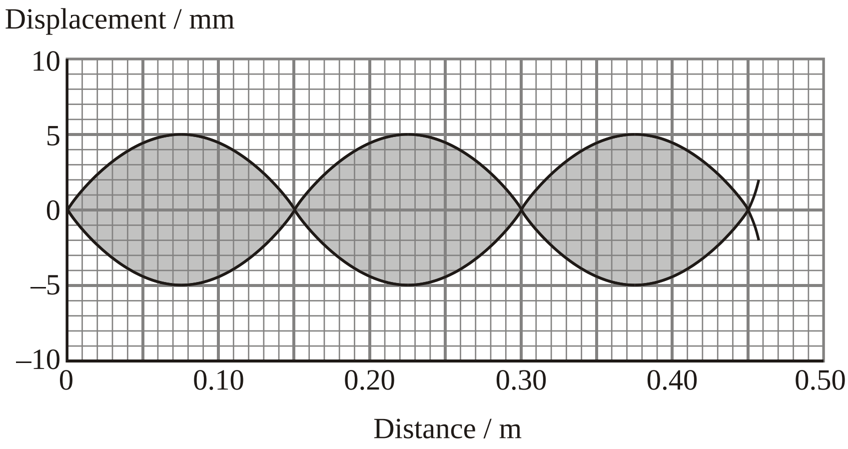
(Total 6 marks)

50. A stationary wave is produced on a stretched string by a vibration generator attached to one end. The graph shows part of the wave. The two full lines represent the extreme positions of the string.



State the wavelength of this wave.

....

(1)

Mark a letter A on the graph to label an antinode.

(1)

The stationary wave is formed by the superposition of two waves travelling along the string in opposite directions. The frequency of the vibrator is 36.0 Hz. Calculate the speed of the travelling waves.

....

....

Wave speed = ...

(2)

State the phase relationship between the two travelling waves at an antinode.

....

(1)

Determine the amplitude of each of the travelling waves.

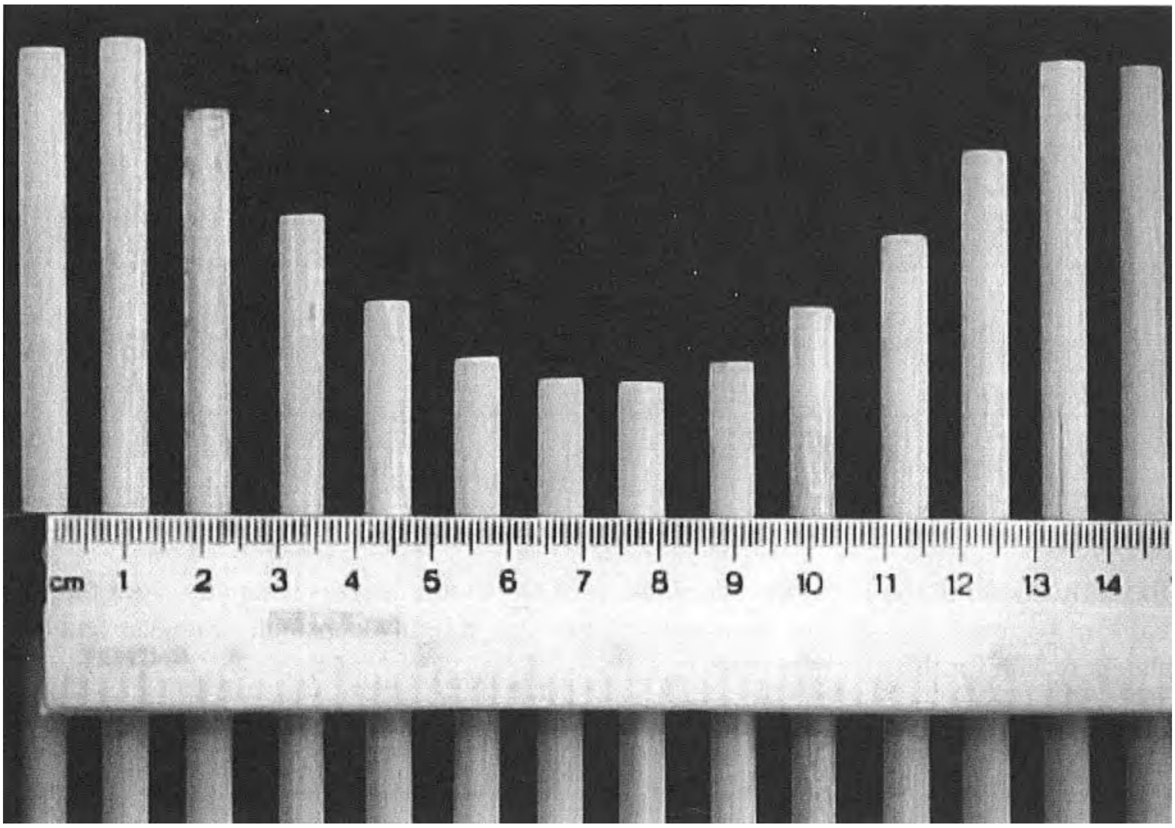
....

Amplitude = ...

(1)

(Total 6 marks)

51. 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.

....

....

Wavelength = ...

(2)

Find a value for the amplitude of the waves.

....

....

....

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.

....

....

....

Frequency = ...

(1)

What is meant by a transverse wave?

....

....

....

(2)

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

....

....

....

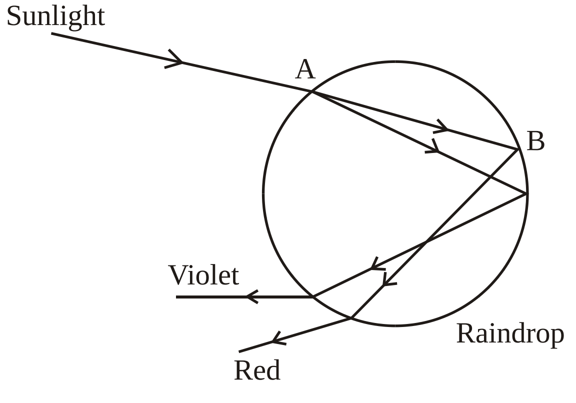
....

....

(3)
(Total 10 marks)

52. 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}.

....

....

....

....

Wavelength = ...

(2)

(Total 6 marks)

53. 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.

....

.... **(2)**

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

....

....

.... **(1)**

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

....

.... **(1)**

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

....

....

....

....

(2)
(Total 6 marks)

54. Describe, with the aid of a diagram, an experiment to demonstrate stationary waves using microwaves.

....

....

....

....

(4)

Using the idea of wave superposition, explain what is observed in your experiment.

....

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....

....

....

(2)

Describe how you could use the experiment to measure the wavelength of microwaves.

....

....

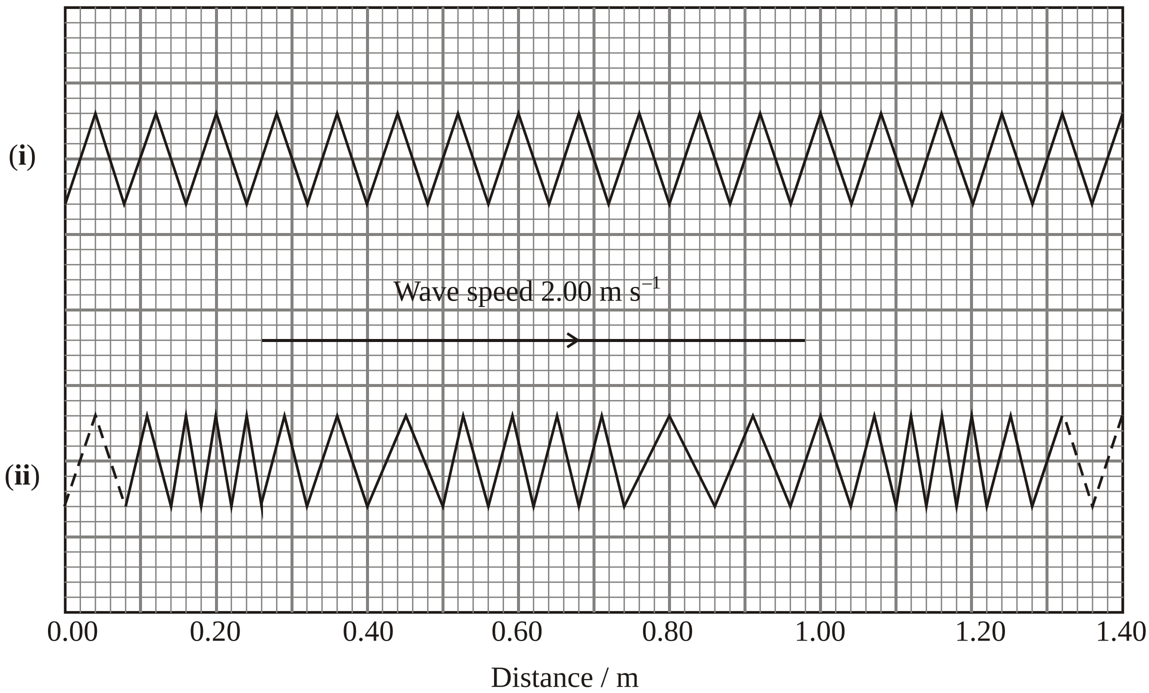
....

....

....

(2)
(Total 8 marks)

55. Diagram (**i**) represents part of a stretched spring. Diagram (**ii**) represents the same section of the spring at one instant of time when a sinusoidal longitudinal wave is travelling along it.



Use the diagram (**ii**) to determine the wavelength of the longitudinal wave.

....

Wavelength = ...

(1)

The wave speed is 2.00 m s^{-1}. Calculate the frequency of this wave.

....

Frequency = ...

(1)

Describe qualitatively the motion of an individual coil of this spring as the longitudinal wave travels along the spring.

....

....

....

....

(3)
(Total 5 marks)

56. 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.

....

....

....

....

....

(2)

Why do hydrogen atoms emit radiation at specific frequencies?

....

....

....

....

....

....

(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.

....

....

....

....

....

(3)
(Total 8 marks)

57. 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

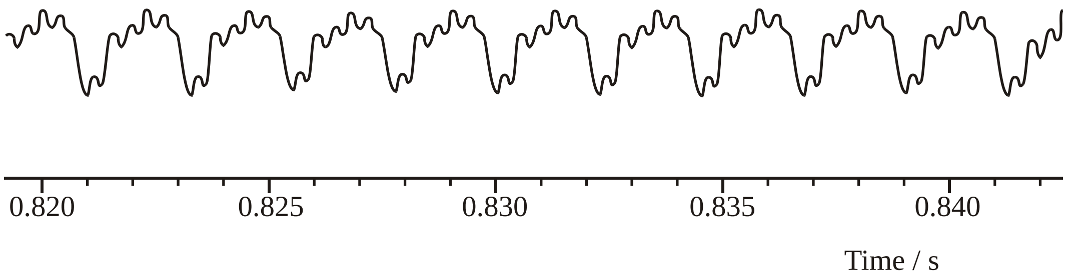
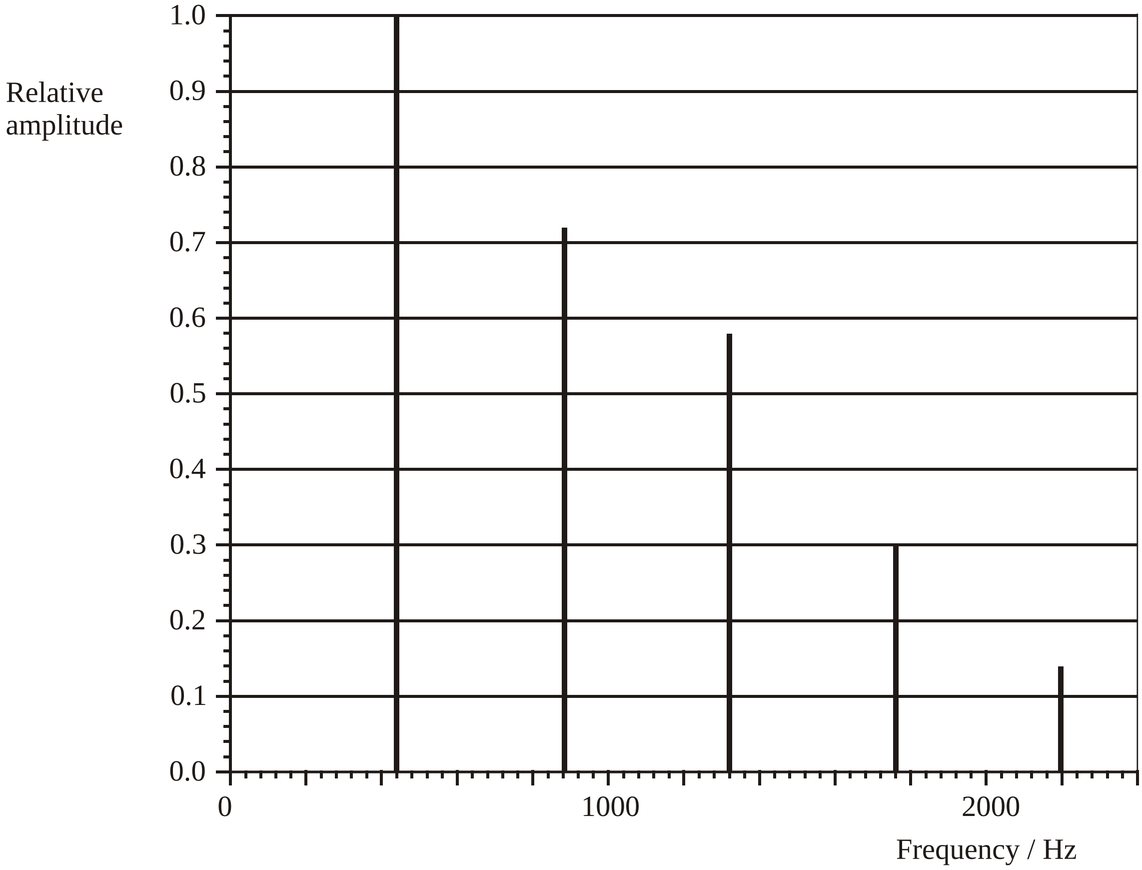


Figure 2



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.

....

....

....

....

(2)

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

....

....

....

....

Period = ...

(2)

Use this value for the period to calculate the frequency.

....

....

....

Frequency = ...

(2)

(Total 9 marks)

58. 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

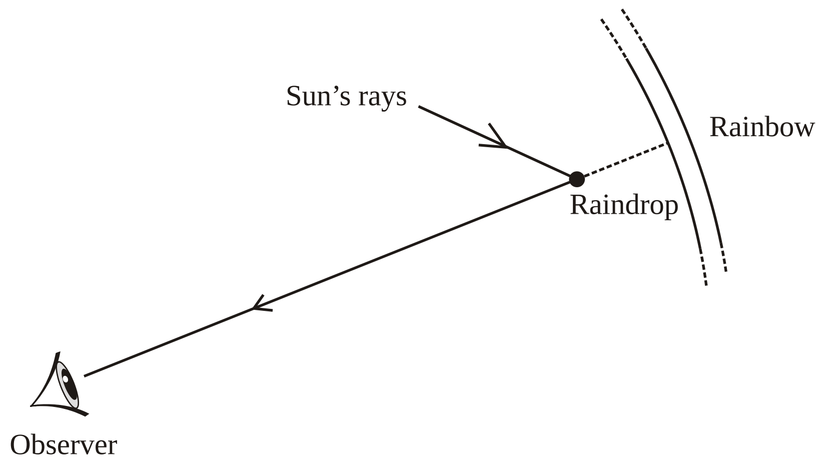
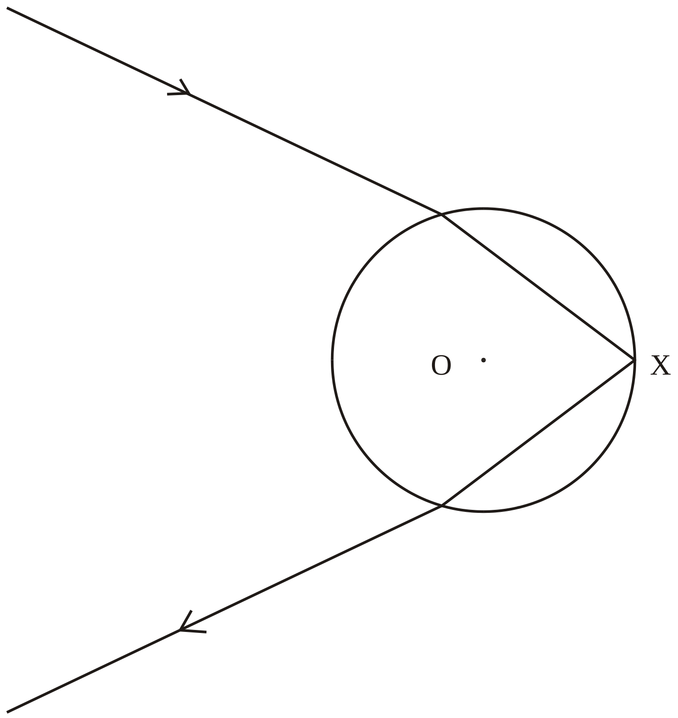


Figure 2



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.

....

....

....

....

Critical angle = ...

(2)

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

....

....

....

....

(3)

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

....

....

(1)

(Total 10 marks)

59. Explain what is meant by

(i) refraction

....

....

....

(ii) diffraction.

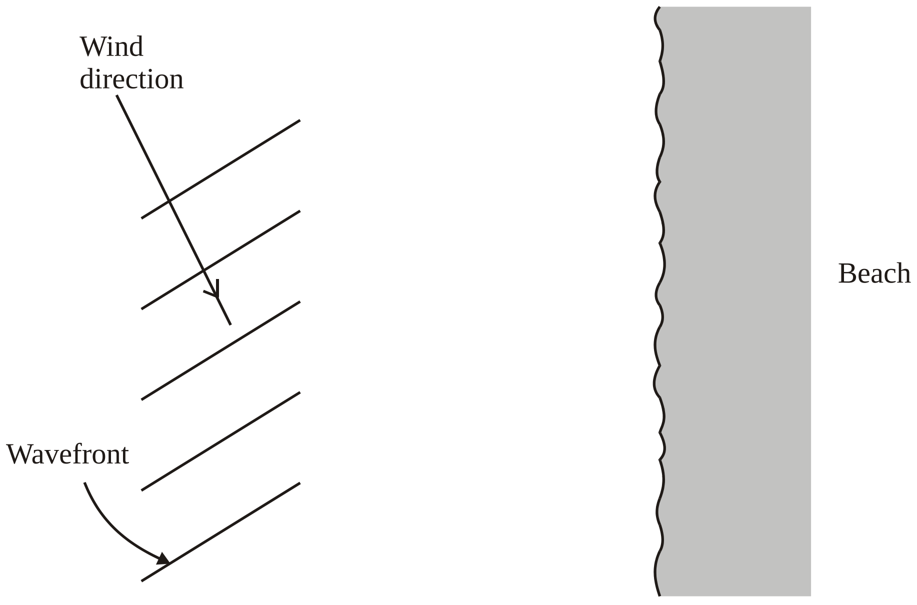
....

....

....

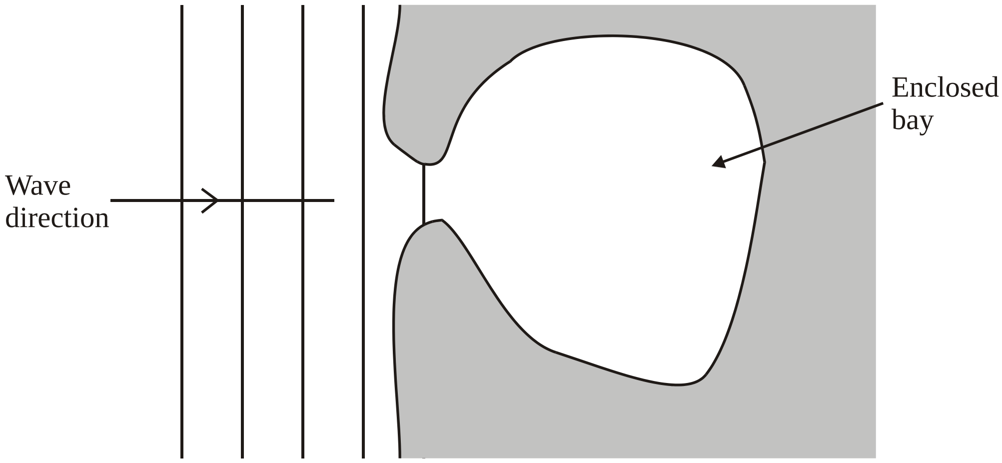
(2)

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.

....

....

....

(1)
(Total 8 marks)

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

What is ultrasound?

....

....

(1)

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

....

....

....

....

....

....

....

(3)

How can reflected ultrasound provide information about a beating heart?

....

....

....

....

(2)
(Total 6 marks)

61. 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.

(Allow one lined page)

(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?

....

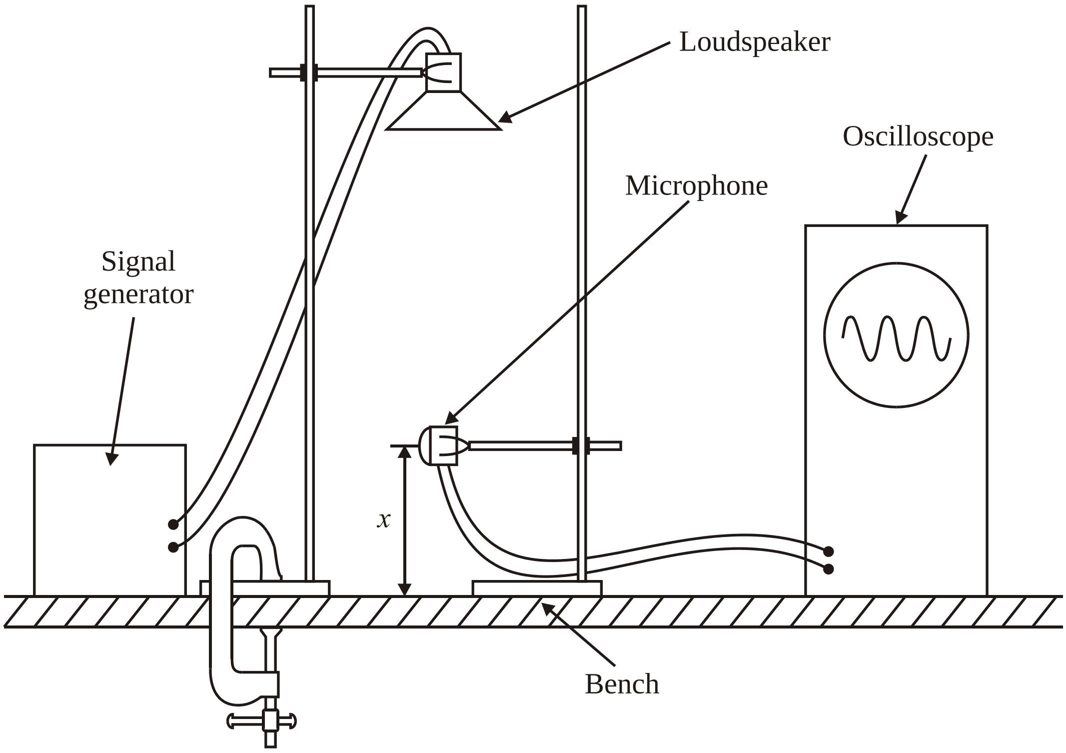
....

....

....

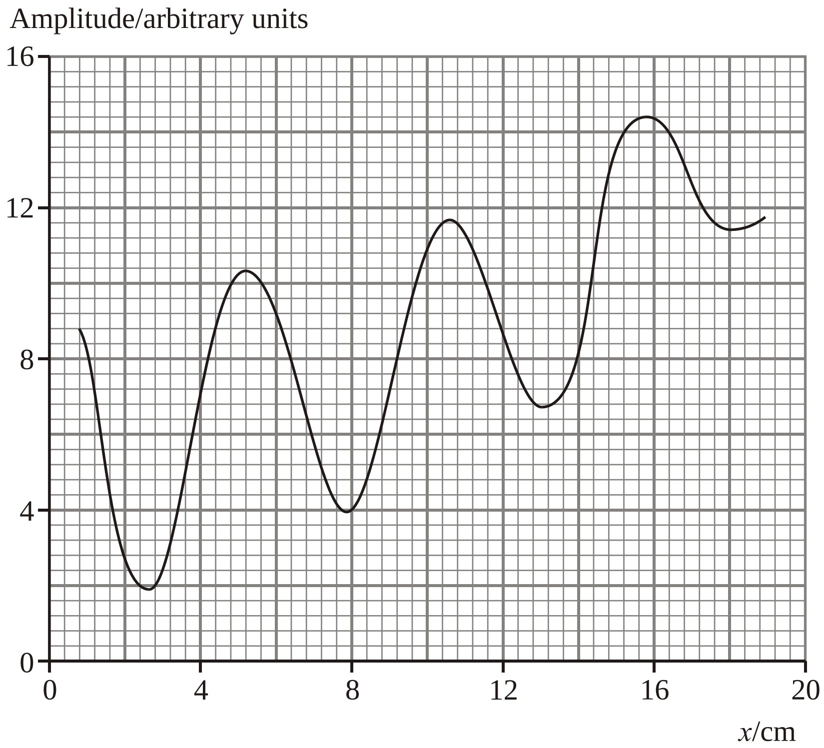
(2)
(Total 8 marks)

62. The diagram shows an experiment with sound waves.



A loudspeaker connected to a signal generator is mounted, pointing downwards, above a horizontal bench. The sound is detected by a microphone connected to an oscilloscope. The height of the trace on the oscilloscope is proportional to the amplitude of the sound waves at the microphone.

When the vertical distance *x* between the microphone and the bench is varied, the amplitude of the sound waves is found to vary as shown on the graph.



Explain why the amplitude of the sound has a number of maxima and minima.
You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

....

....

(5)

The frequency of the sound waves is 3.20 kHz. Use this, together with information from the graph, to determine a value for the speed of sound in air.

....

....

....

....

Speed of sound = ...

(4)

The contrast between the maxima and minima becomes less pronounced as the microphone is raised further from the surface of the bench. Suggest an explanation for this.

....

....

....

....

....

(2)
(Total 11 marks)

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

What is meant by wavelength?

....

....

....

(2)

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

....

....

....

....

(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.

....

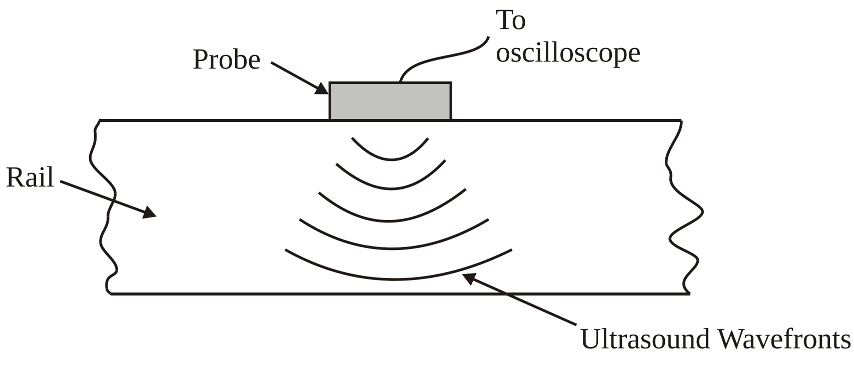
....

....

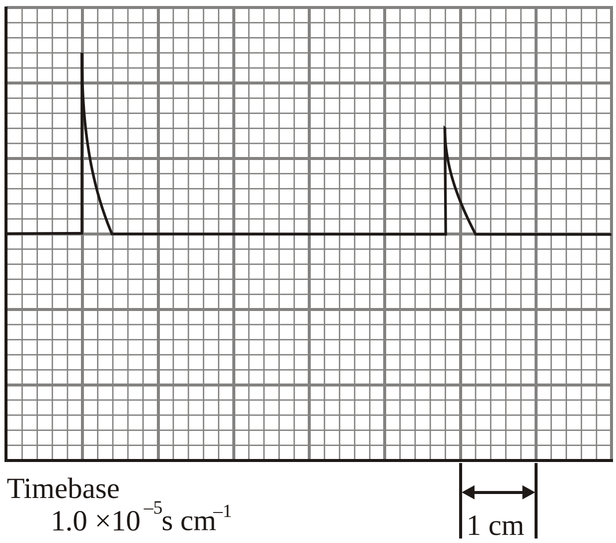
....

(2)
(Total 6 marks)

64. 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.

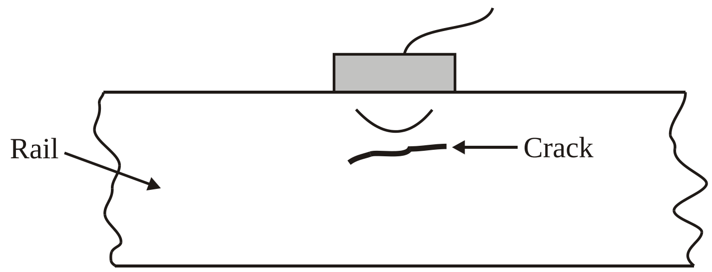
....

....

....

....
(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)
(Total 8 marks)

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

....

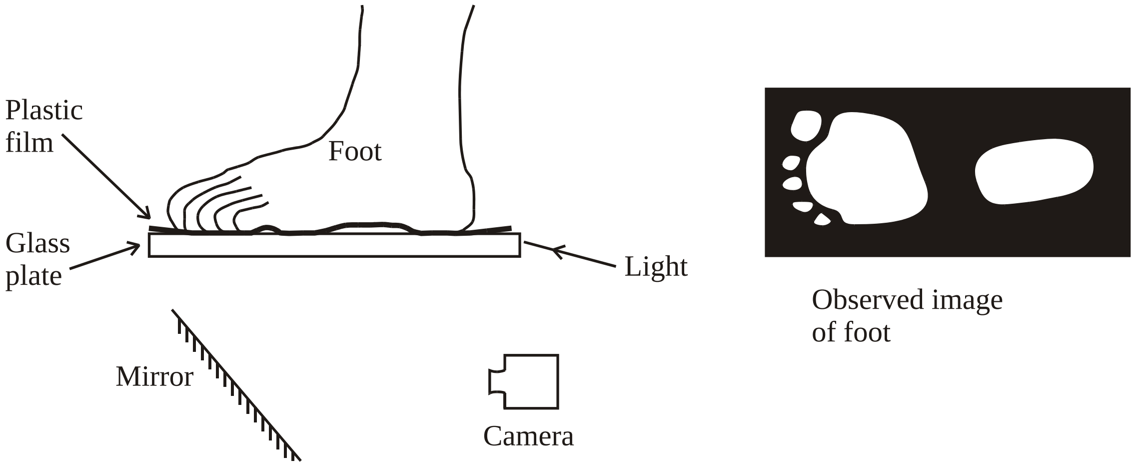
....

....

....

(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.



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

....

....

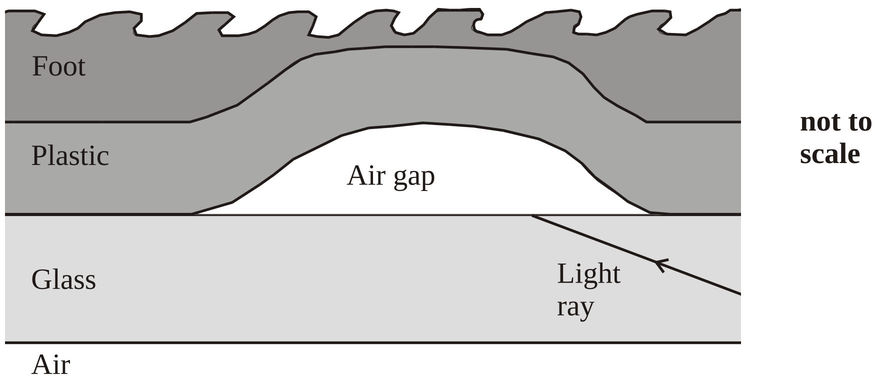
....

....

(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.

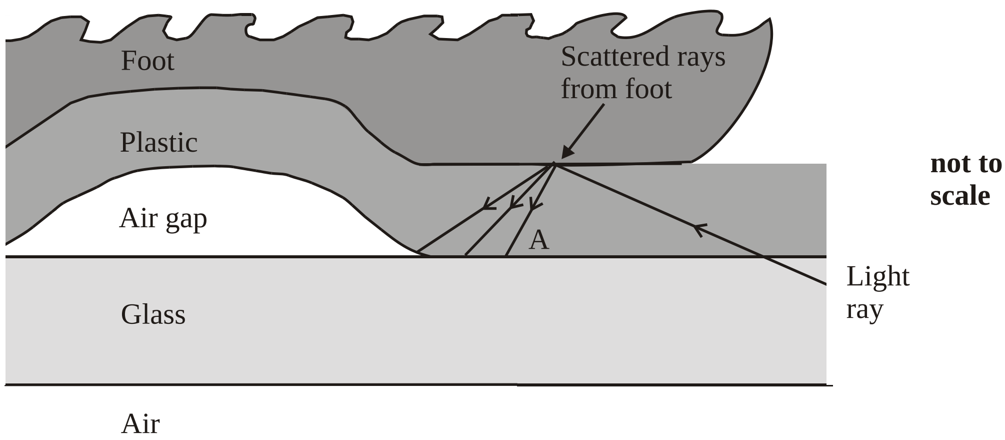
Complete the path of the ray in the diagram below.



(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.



(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)

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

....

....

....

....

(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.

....

....

....

....

....

....

....

....

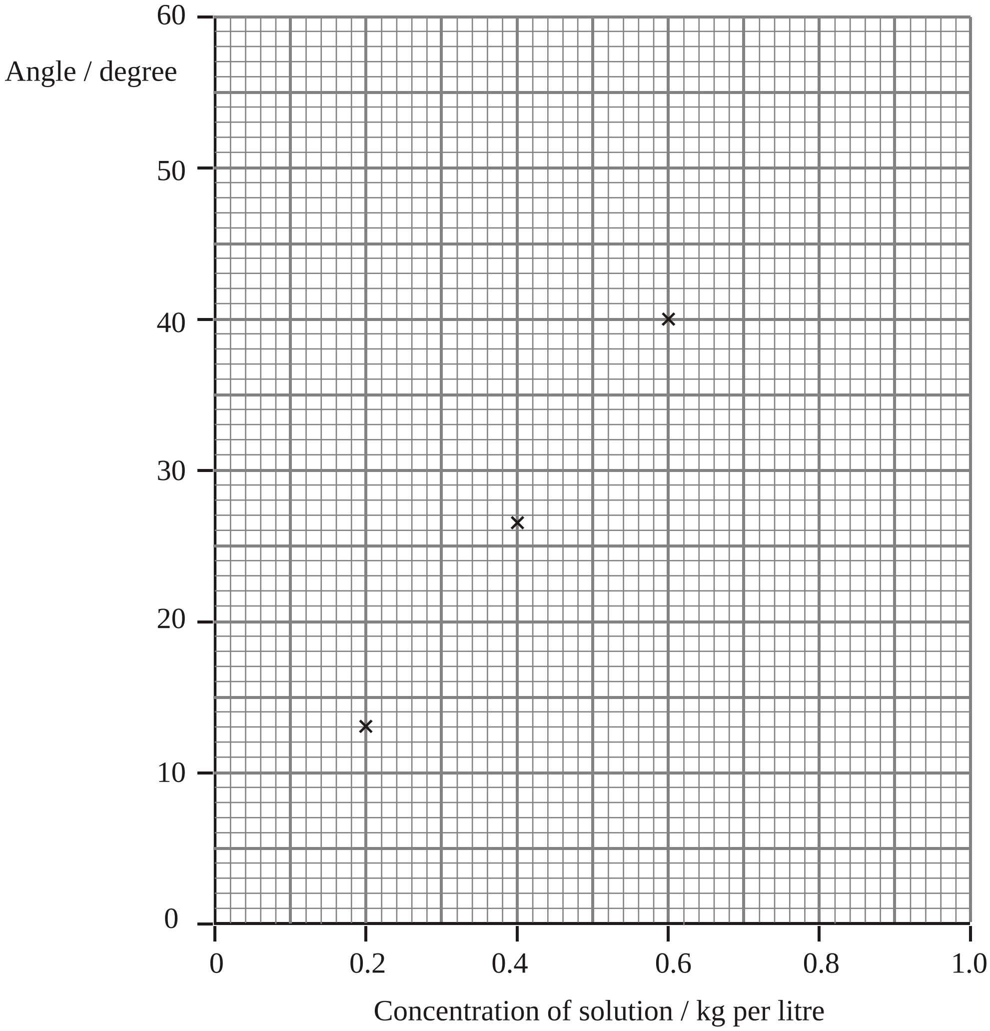
(4)

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)

(Total 10 marks)

67. 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.

....

....

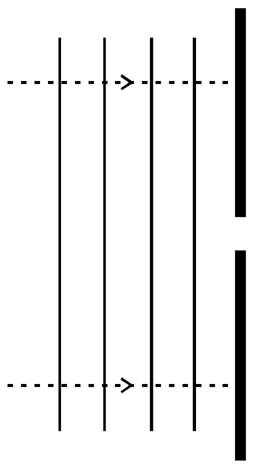
....

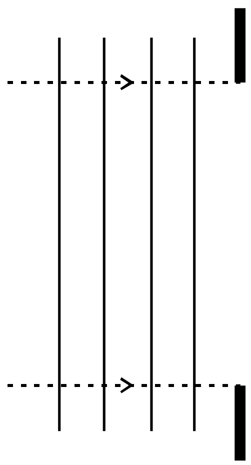
....

....

(Total 2 marks)

68. Each of the diagrams below shows a series of wavefronts, one wavelength apart, approaching a gap between two barriers in a ripple tank.





What is a wavefront?

....

....

(1)

Add further wavefronts to each diagram to show what happens as the waves pass through each gap.

(3)

The station BBC Radio 4 broadcasts both on the Long Wave band at 198 kHz and on VHF at approximately 94 MHz. In mountainous parts of the country, reception is better on Long Wave than on VHF. Suggest why.

....

....

....

....

(2)
(Total 6 marks)

69. 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

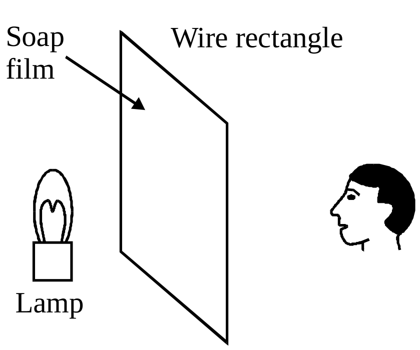


Figure 2

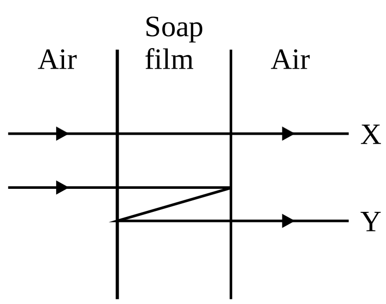


Figure 2 represents two possible paths for light to pass through the film from the lamp to the student. One path (labelled X) shows light passing straight through the film. The light following path Y is reflected twice, once at each side of the film, during its passage from the lamp to the student.

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.

....

....

....

....

(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.

....

....

....

....

(2)

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

....

....

....

....

(2)

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

....

....

....

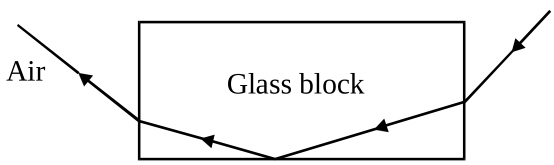
(2)

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

(1)
(Total 11 marks)

70. 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?

....

....

(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?

....

....

(1)

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

....

....

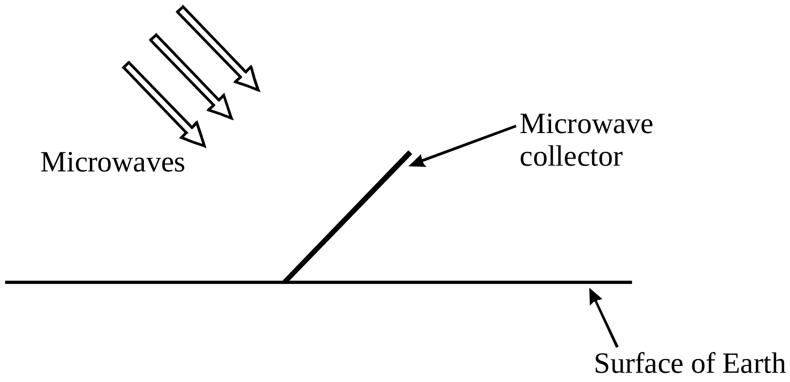
(1)
(Total 6 marks)

71. Radio waves and sound waves are sometimes confused by the general public.
Complete the table to give **three** ways in which they differ.

Radio waves	Sound waves

(3)

It is proposed to place a solar power station in orbit around the Earth. The solar power station will convert sunlight to microwave energy. Microwave collectors on Earth will convert the microwaves into electricity.



The solar power station orbits the Earth at a constant distance from the surface of 36 000 km. The total area of the collectors is equivalent to a rectangle with dimensions of 120 m by 250 m.

The collectors are used to generate 600 kW of power. Calculate the intensity of the microwaves at the collectors. State any assumption that you make.

....

....

....

....

Intensity = ...

(3)

Calculate the total power which the orbiting station would have to emit if it transmitted microwaves equally in all directions. State any assumption that you make.

....

....

....

....

....

Power = ...

(3)

Suggest a more efficient method of transmitting the microwave energy to the collectors on Earth.

....

(1)
(Total 10 marks)

72. Describe with the aid of a diagram how you could produce stationary waves on a string.

....

....

....

....

(3)

Explain how you could use a stationary wave to determine the speed of travelling waves on the string. You may be awarded a mark for the clarity of your answer.

....

....

....

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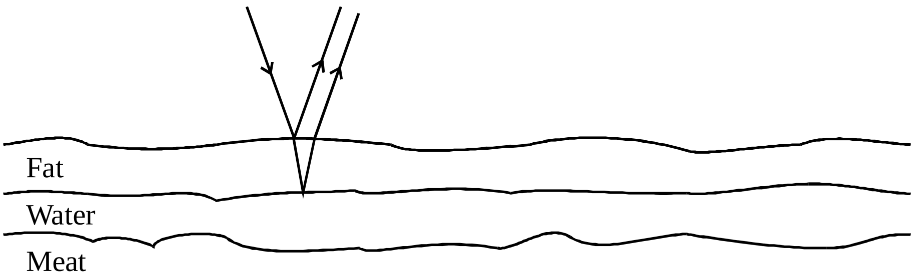
....

....

(4)
(Total 7 marks)

73. 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.

....

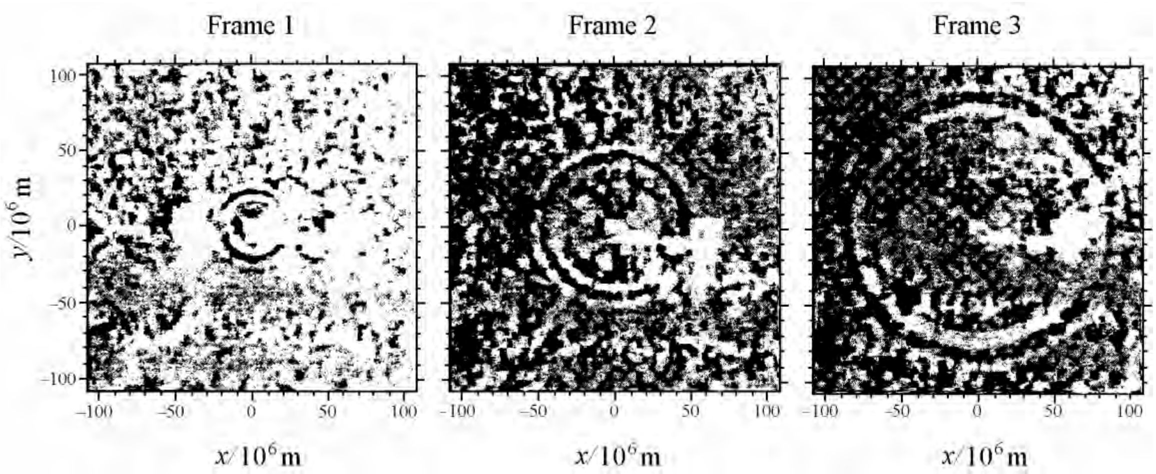
....

....

....

(2)
(Total 9 marks)

74. 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)

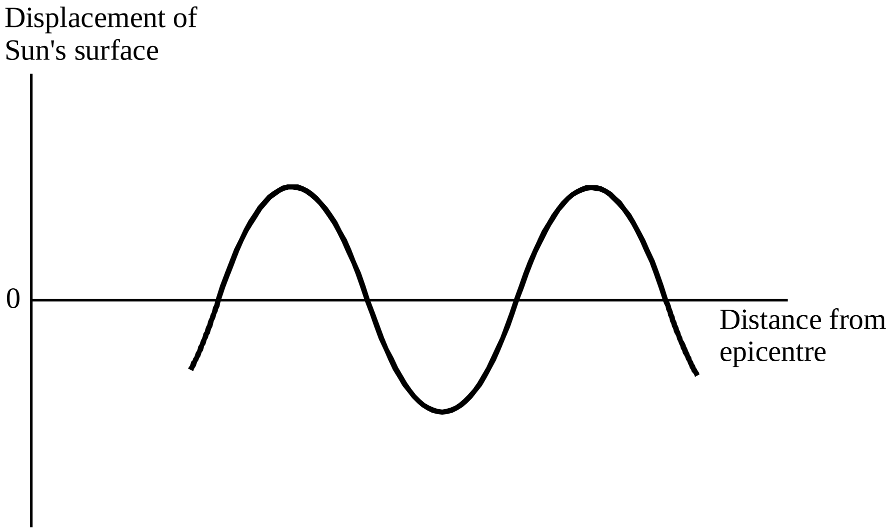
How could a physicist check whether the speed of the ripple was constant?

....

....

(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)
(Total 11 marks)

75. 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.

....

....

(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.

....

....

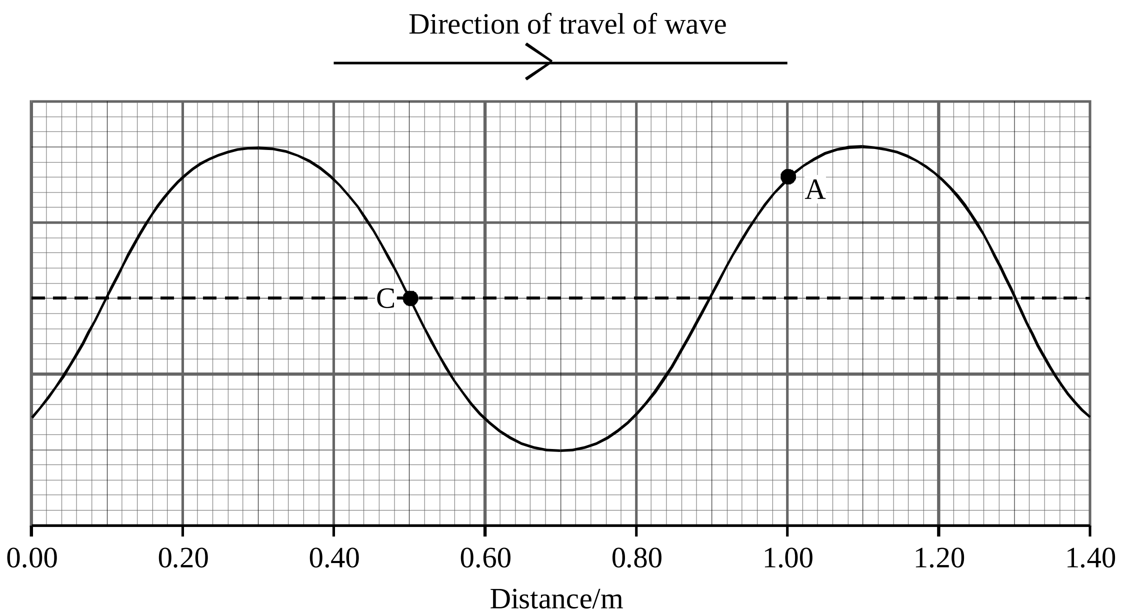
....

....

....

(3)
(Total 8 marks)

76. The diagram shows the shape of a wave on a stretched rope at one instant of time. The wave is travelling to the right.



Determine the wavelength of the wave.

Wavelength = ...

Mark on the diagram a point on the rope whose motion is exactly out of phase with the motion at point A. Label this point X.

Mark on the diagram a point on the rope which is at rest at the instant shown. Label this point Y.

Draw an arrow on the diagram at point C to show the direction in which the rope at C is moving at the instant shown.

(4)

The wave speed is 3.2 m s^{-1}. After how long will the rope next appear exactly the same as in the diagram above?

....

....

Time = ...

(2)
(Total 6 marks)

77. Describe how you would demonstrate experimentally that electromagnetic waves can be polarised, using **either** light **or** microwaves. Include a diagram of the apparatus you would use.

....

....

....

....

....

....

....

....

(4)

What does the experiment tell you about the nature of electromagnetic waves?

....

....

(1)
(Total 5 marks)

78. 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? ....

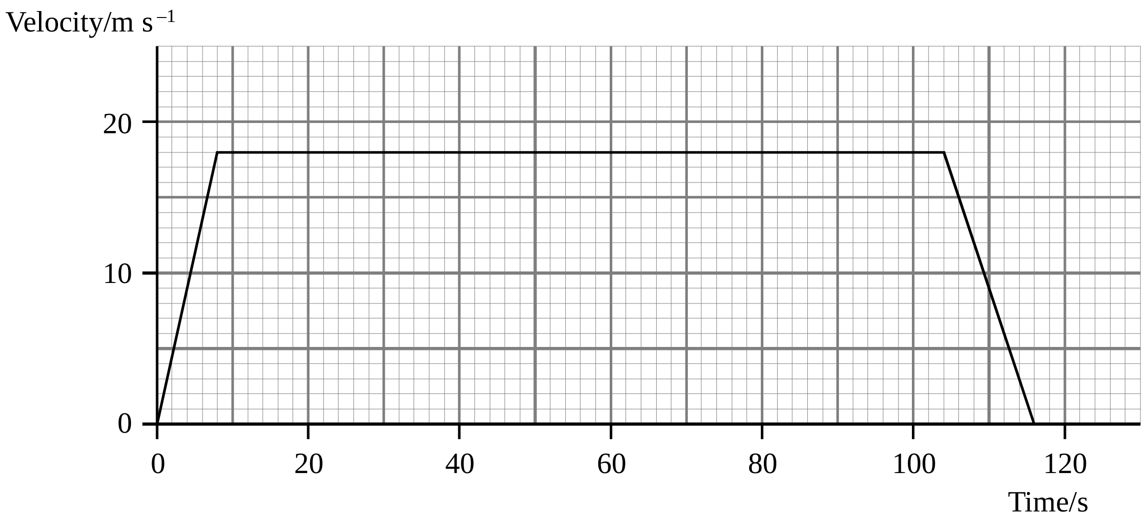
....

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)

79. 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.

....

....

....

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....

....

(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)

80. 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

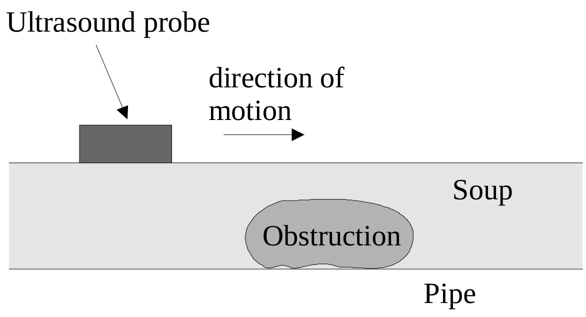
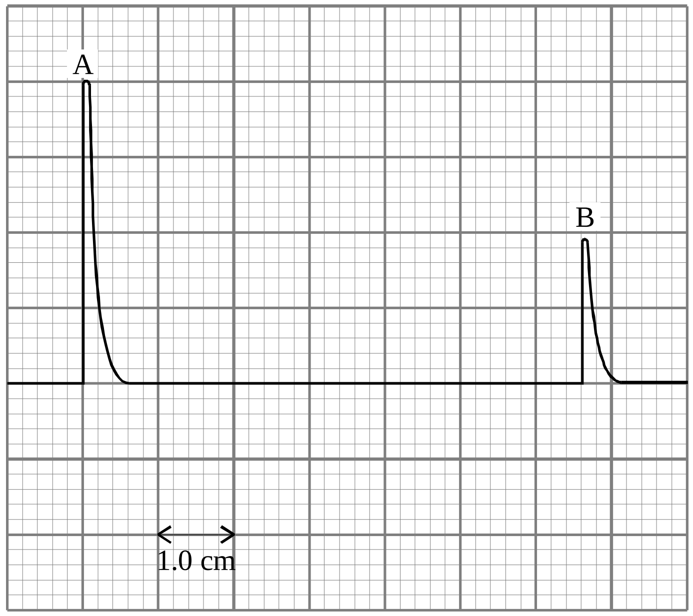


Figure 2



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.

....

....

....

....

....

....

....

....

(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.

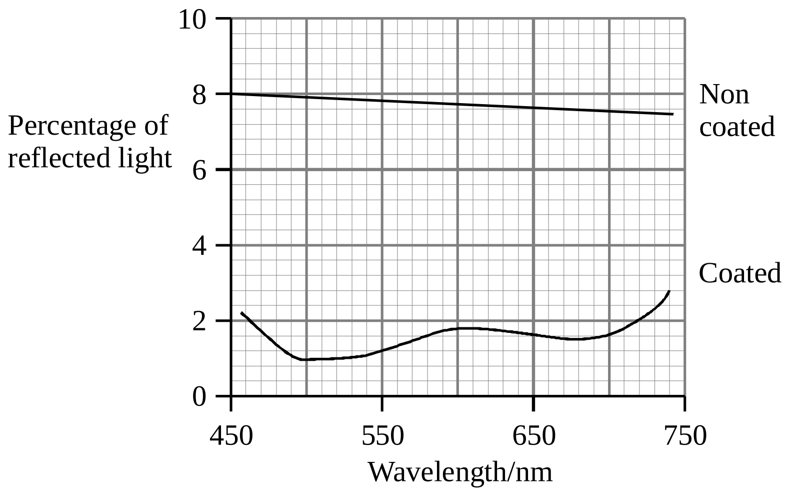
....

....

....
(1)
(Total 8 marks)

81. 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.

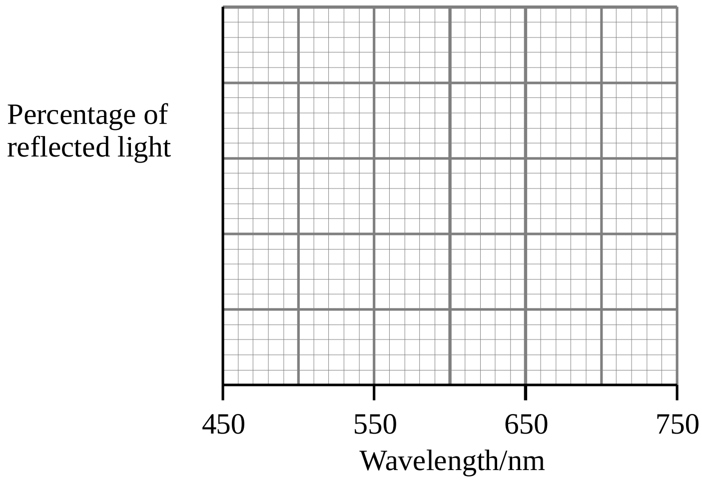


State the wavelength range for which the coated glass reflects less than 2% of the incident light.

....

(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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....

....

....

(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)

82. The possibility of nuclear fusion experiments in your living room is getting closer! Lasers could be used to deliver a huge pulse of energy in a very short time to a small volume of deuterium (an isotope of hydrogen) to produce the conditions for fusion for just an instant.

A neodymium laser produces 40 J of coherent light of wavelength 1050 nm for a period of 400 fs (1 fs = 10^{-15} s).

Explain the meaning of the word **coherent.**

....

....

....

(1)

Calculate the power delivered by this laser.

....

....

....

....

Power = ...

(2)

Calculate the energy level change taking place in atoms of neodymium when emitting light of the above wavelength.

....

....

....

....

....

....

(3)
(Total 6 marks)

83. Listed below are four types of wave:

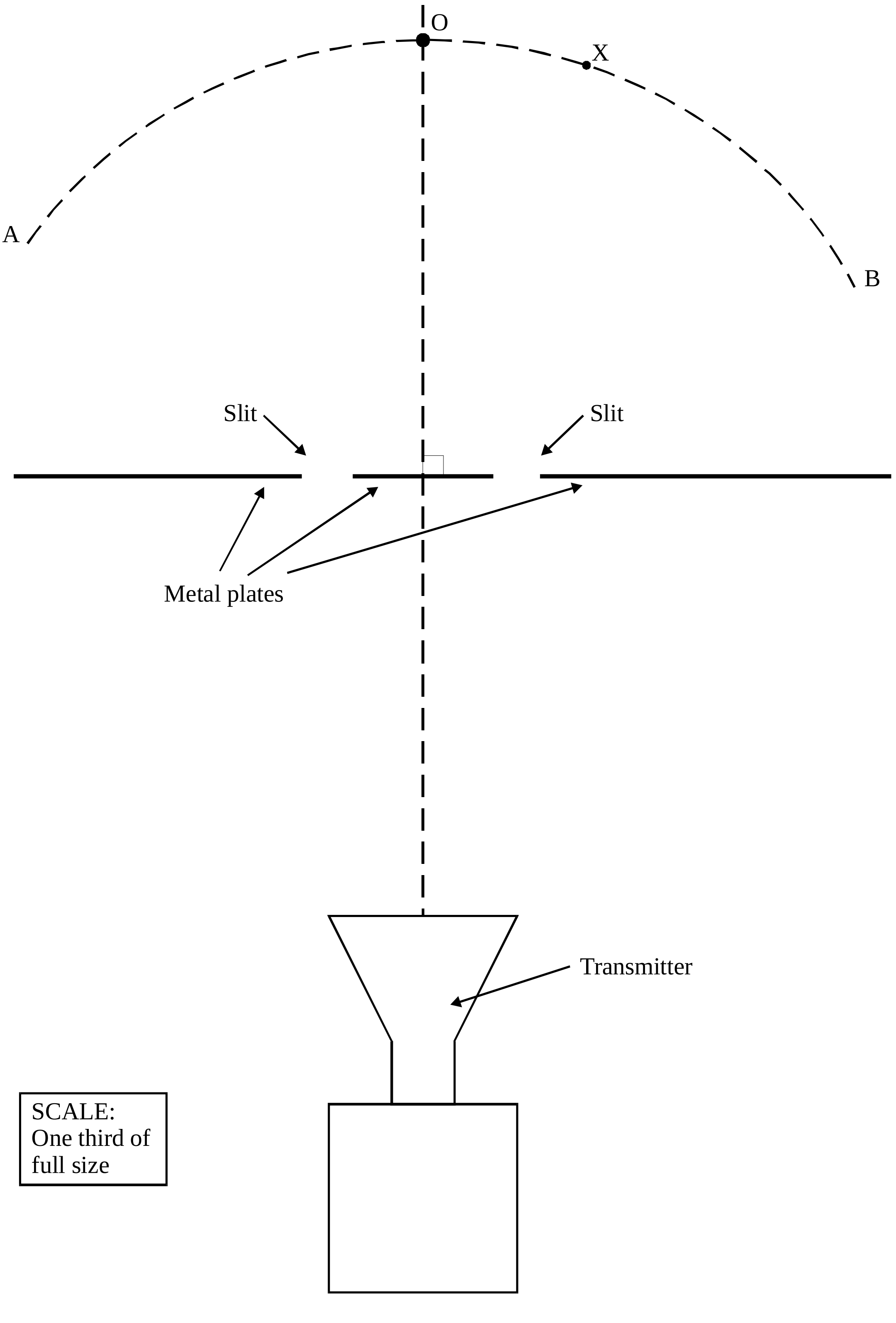
microwave sound ultraviolet infrared

From this list, choose the wave which matches each description in the table below, and write it in the space provided. (You may choose a type of wave once, more than once or not at all.)

Description	Type of wave
A wave capable of causing photoelectric emission of electrons	
A wave whose vibrations are parallel to the direction of propagation of the wave	
A transverse wave of wavelength 5×10^{-6} m	
The wave of highest frequency	

(Total 4 marks)

84. The diagram is a plan view of an experiment to measure the wavelength of microwaves. The diagram is to scale but **one third of full size**.



As a microwave detector is moved around the arc from A to B, alternate maxima and minima of intensity are observed. Explain why.

....

....

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....

(4)

A maximum is observed at point O, and the next maximum at point X. By means of suitable measurements on the diagram determine the wavelength of the microwaves.

....

....

....

....

....

Wavelength = ...

(3)

A teacher demonstrating this experiment finds that, even at the maxima, the wave intensity is small. A student suggests making the slits wider to let more energy through. Explain why this might not be a good idea.

....

....

....

....

(2)

For an interference pattern to be observed between waves from two sources, the sources must be coherent. Explain what is meant by **coherent**, and what makes the two sources in this experiment coherent.

....

....

....

....

....

(2)
(Total 11 marks)

85. **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?

....

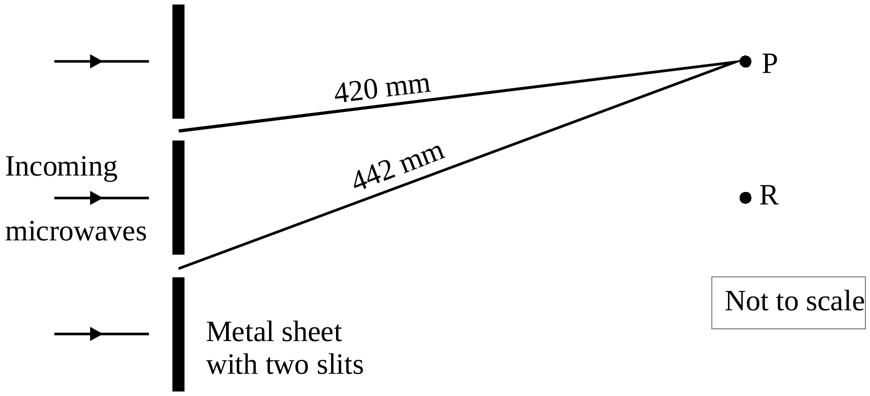
....

....

....

(2)
(Total 7 marks)

86. A beam of microwaves is directed at two slits in a metal sheet. The diagram below shows two adjacent positions P and R where a microwave detector would register maximum readings.



Use the diagram to determine the wavelength of the microwaves.

....

....

Wavelength = ...

Calculate the frequency of the microwaves.

....

....

Frequency = ...

(4)

On the diagram mark with a Q a position where another maximum reading would occur. On the diagram mark with a D a position where a minimum reading would occur.

(2)

In a similar experiment, sound waves were directed at the same metal sheet. The speed of sound is 330ms^{-1} and the frequency of the sound waves was 1100Hz. Explain why a maximum reading would *not* be detected at P in this experiment.

....

....

....

....

(2)
(Total 8 marks)

87. 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

$\boxed{=2*B3*D3}$

....

....

....

....

(2)

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

....

....

....

....

(2)

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

....

....

....

Value = ………………………..

(2)

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

....

....

....

....

(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

....

....

....

....

....

....

(3)
(Total 11 marks)

88. *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.

....

....

....

....

(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.

....

....

....

....

....

....

(3)
(Total 8 marks)

89. 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?

....

....

(1)

Explain the change in intensity as the filter is rotated.

....

....

....

....

(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.

....

....

....

(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.

....

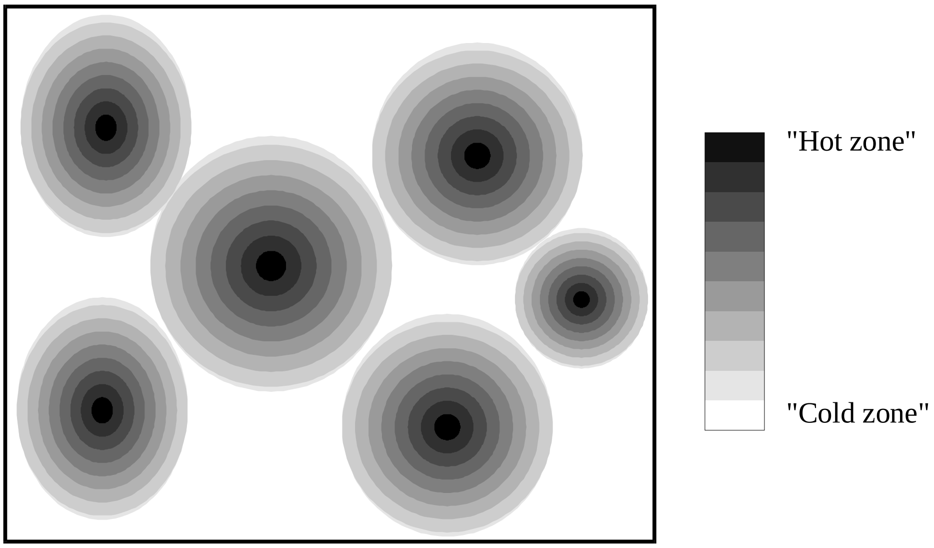
....

(1)
(Total 6 marks)

90. 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 ……………………………………………………………………………

....

....

....

(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.

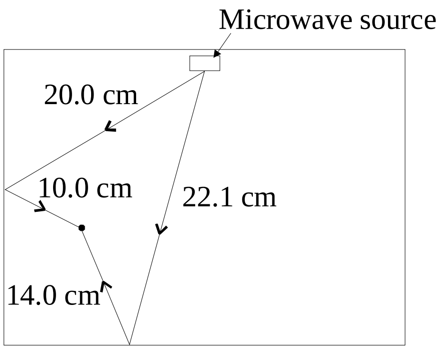
Show that the wavelength of the microwave radiation is about 12 cm.

....

....

(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.

....

....

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.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

(3)

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

....

....

....

....

(2)
(Total 11 marks)

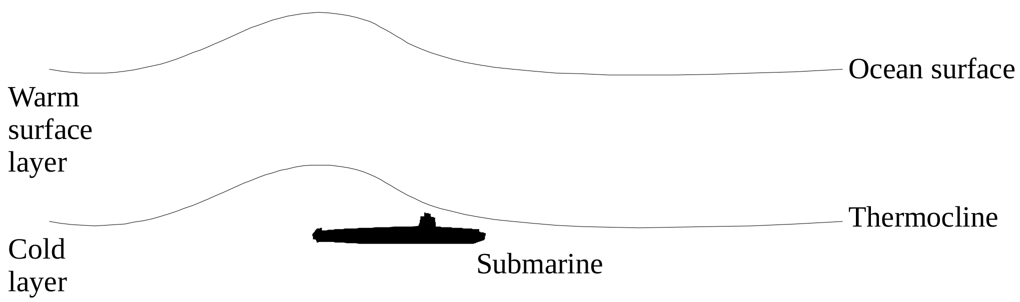
91. An ocean can be considered to be made up of two layers: a layer of warm water and a layer of cold water. The interface between them is called a thermocline.

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

....

....

(1)



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

....

....

(1)

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

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(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.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Minimum change = ………………………..

(2)

Suggest a possible problem in detecting submarines in this way.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

(1)
(Total 10 marks)

92. 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.

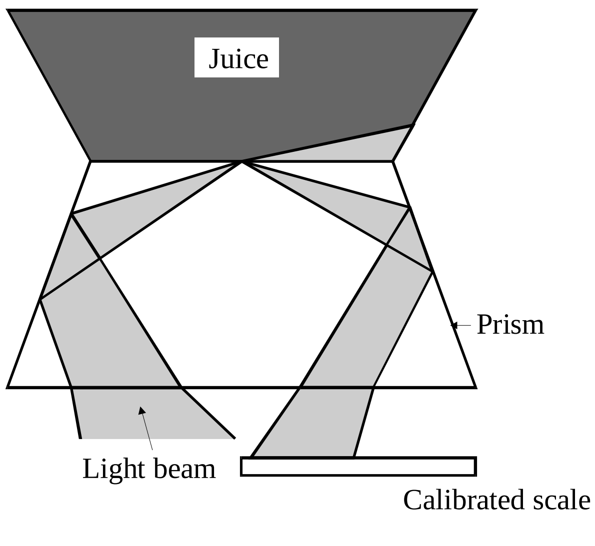


Figure 1

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

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(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.

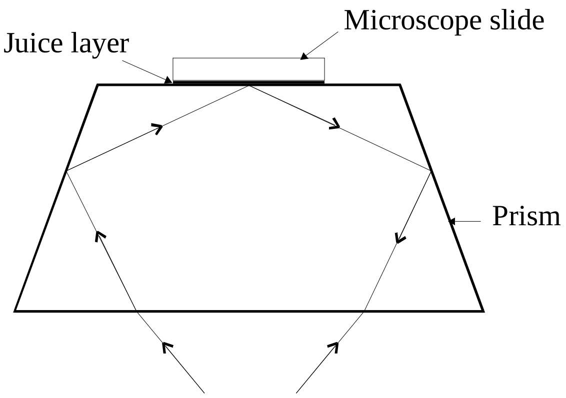


Figure 2

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.*

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(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)

93. Under what circumstances could two progressive waves produce a stationary (standing) wave?

....

....

....

....

(2)

Describe with the aid of a diagram an experiment using microwaves to produce stationary (standing) waves.

....

....

....

How would you show that a stationary wave had been produced?

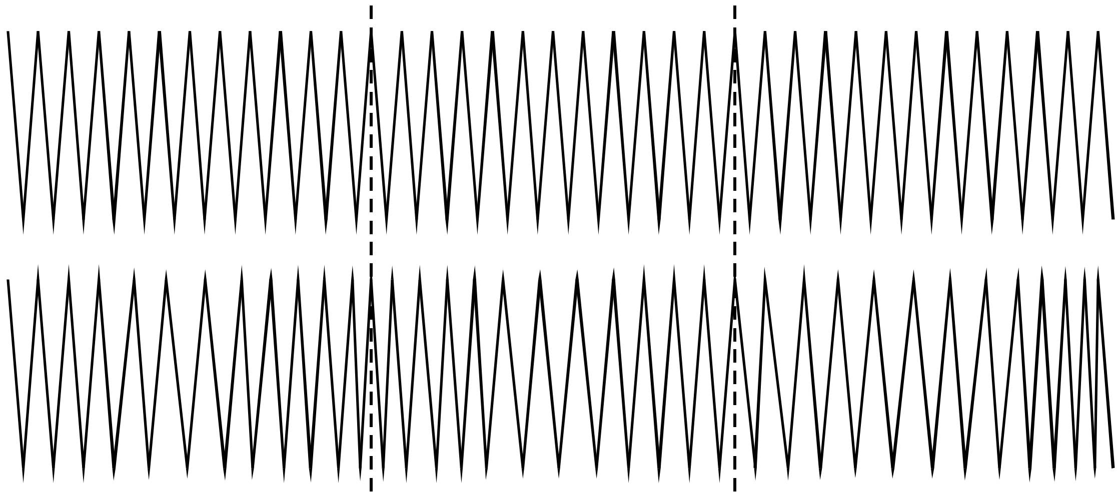
....

....

....

(3)
(Total 5 marks)

94. The diagram shows part of a stretched slinky spring and the same section of the spring when a longitudinal wave is travelling along it.



The dotted vertical lines show the positions of two coils which at this moment are undisplaced.

Mark on the lower diagram a compression C and a rarefaction R

Measure the wavelength of the wave

Wavelength ....

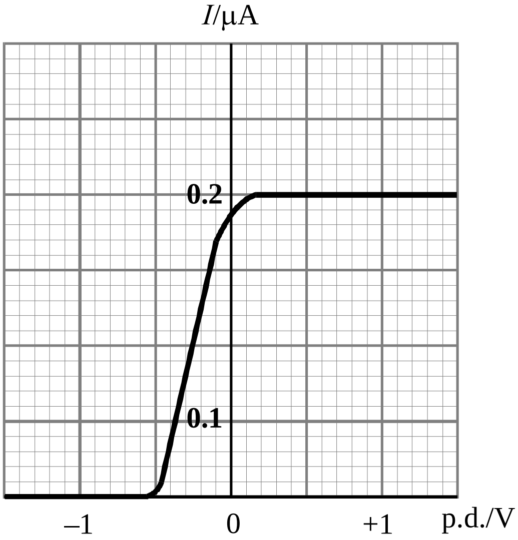
Mark on the lower diagram a coil with maximum displacement, M.

Measure the amplitude of the wave, i.e. the displacement of coil M.

Amplitude ....

(Total 4 marks)

95. Monochromatic light of constant intensity falls on a photocell. The graph shows how the current in the photocell varies with the potential difference applied across it.



The frequency of the incident light is 6.0×10^{14} Hz. Use the graph to estimate the work function of the metal which forms the cathode of the photocell.

....

....

....

....

....

Work function = ………........……...............

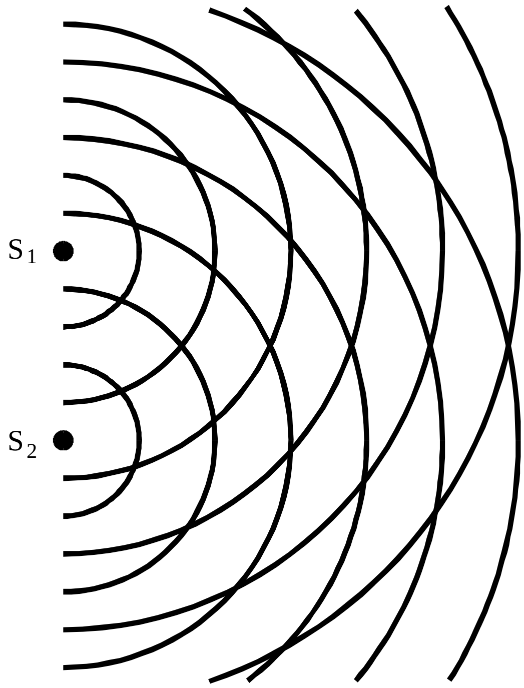
(3)

Add to the axes above the graph obtained when only the intensity of the light is increased. Label this graph A.

Add to the axes above the graph obtained when only the frequency of the light is increased. Label this graph B.

(4)
(Total 7 marks)

96. The diagram shows wavefronts spreading out from two identical sources, S_1 and S_2.



Describe how such a pattern could be produced and observed using a ripple tank.

....

....

....

....

....

(5)

On the diagram draw the following:

(i) a line labelled A joining points where the waves from S_1 and S_2 have travelled equal distances,

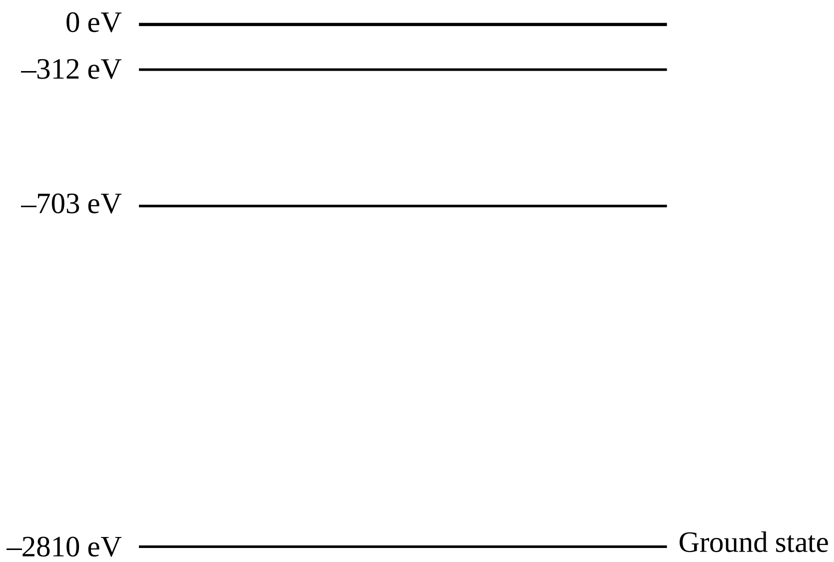
(ii) a line labelled B joining points where the waves from S_1 have travelled one wavelength further than the waves from S_2,

(iii) a line labelled C joining points where the waves from S_2 have travelled half a wavelength further than the waves from S_1.

(4)
(Total 9 marks)

97. A muon is a particle which has the *same charge* as an electron but its *mass* is 207 times the mass of an electron.

An unusual atom similar to hydrogen has been created, consisting of a muon orbiting a single proton. An energy level diagram for this atom is shown.



State the ionisation energy of this atom.

....

Calculate the maximum possible wavelength of a photon which, when absorbed, would be able to ionise this atom.

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

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

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

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

Maximum wavelength =...

To which part of the electromagnetic spectrum does this photon belong?

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

(5)

Calculate the de Broglie wavelength of a muon travelling at 11% of the speed of light.

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

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

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

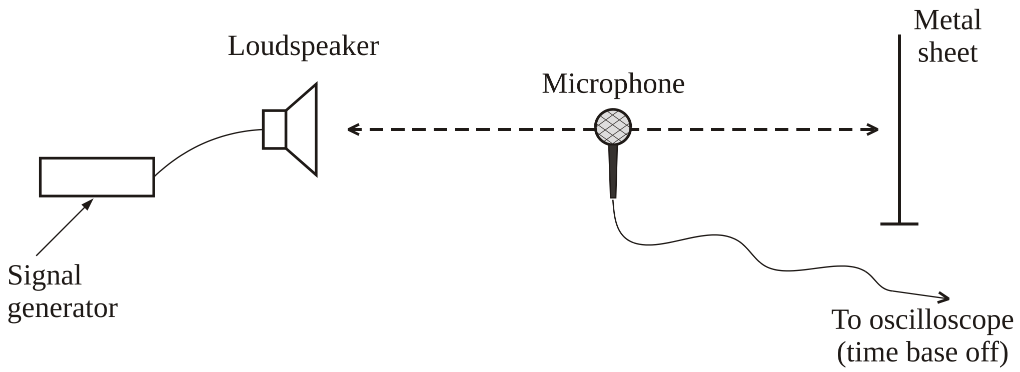
..............................……………………………………………………………………

Wavelength =...

(3)

(Total 8 marks)

98. The diagram below shows a loudspeaker which sends a note of constant frequency towards a vertical metal sheet. As the microphone is moved between the loudspeaker and the metal sheet the amplitude of the vertical trace on the oscilloscope continually changes several times between maximum and minimum values. This shows that a stationary wave has been set up in the space between the loudspeaker and the metal sheet.



How has the stationary wave been produced?

....

....

....

(2)

State how the stationary wave pattern changes when the frequency of the signal generator is doubled. Explain your answer.

....

....

....

(2)

What measurements would you take, and how would you use them, to calculate the speed of sound in air?

....

....

....

....

....

(4)

Suggest why the minima detected near the sheet are much smaller than those detected near the loudspeaker.

....

....

....

(2)
(Total 10 marks)