PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 5: WAVES AND PARTICLE NATURE OF LIGHT

INTERFERENCE AND DIFFRACTION

SCORE	PERCENTAGE
/366	%

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Q1.

The photograph shows a guitar. The strings of the guitar are at the same tension.



When a string is plucked, a standing wave is set up on the string.

* Explain how a standing wave is set up on a string.

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(Total for question = 6 marks)

Q2.

For two waves of light to be coherent the waves must

(1)

☒ **A** always have a phase difference equal to 0.

☒ **B** oscillate in the same plane.

☒ **C** have a similar amplitude.

☒ **D** originate from one source.

(Total for question = 1 mark)

Q3.

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

(2)

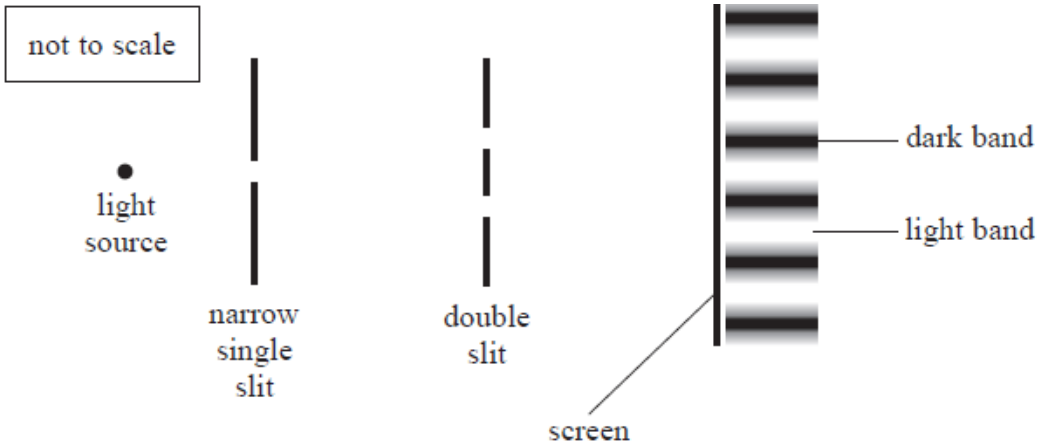
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(b) The arrangement in the diagram demonstrates the effect of superposition. When a monochromatic light source is used, a series of dark and light bands is formed on the screen.



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

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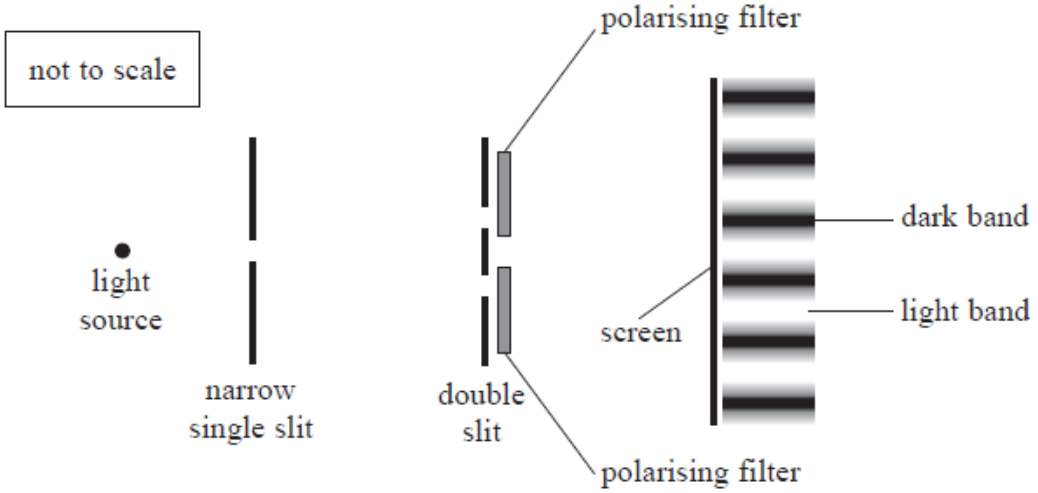
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(ii) Polarising filters are placed behind the slits as shown. When the planes of polarisation are parallel, the pattern of light and dark bands is still seen.



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

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

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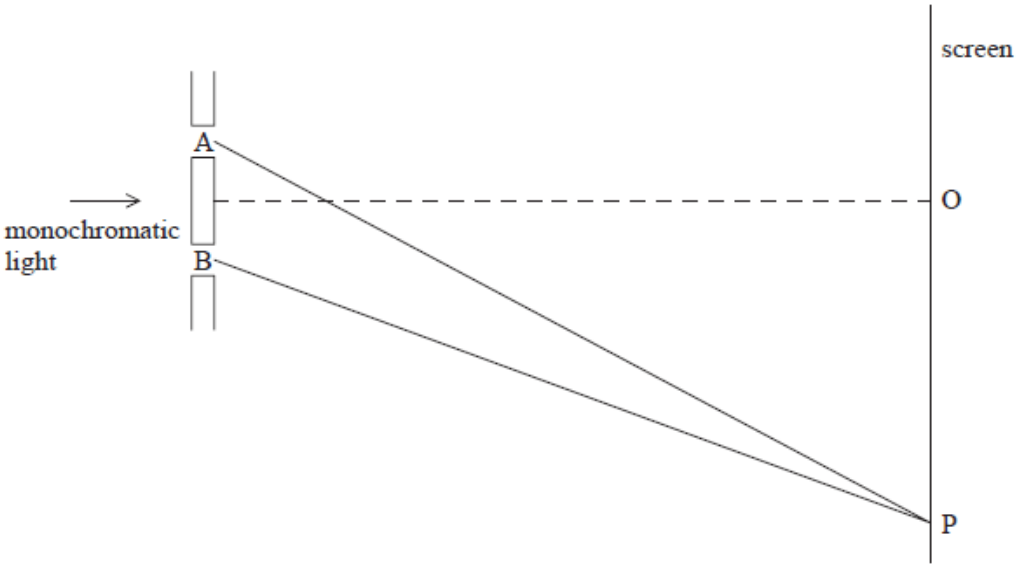
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Q4.

The experiment was carried out with laser light of wavelength 600 nm. The diagram below shows two paths taken by the light after it has passed through the two slits A and B. The diagram is not to scale.



(i) Point O is a point equidistant from the two slits.

Explain why there is a bright line at this point.

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(ii) The next bright line is observed on the screen at point P. Lines AP and BP show the path of the light from each slit to the screen at P.

State the difference in the lengths of the paths AP and BP.

(1)

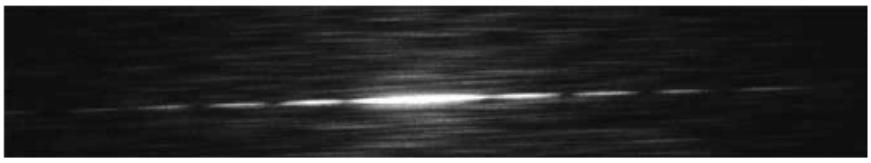
Difference in lengths of paths = ...

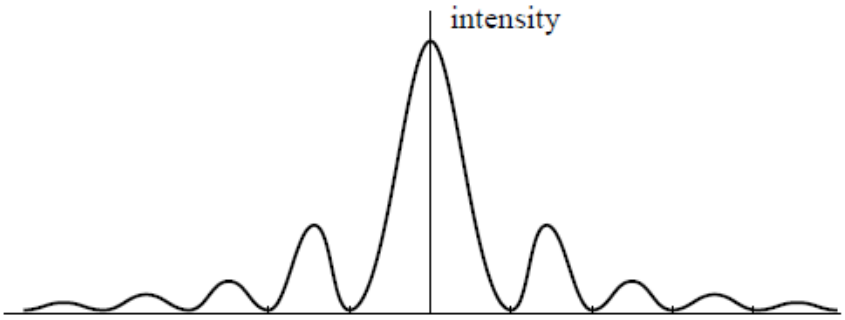
(Total for question = 4 marks)

Q5.

A student obtains the following diffraction pattern on a wall by shining a red laser beam through a single narrow slit.

The corresponding graph of intensity against position is shown below.





(a) Explain how the diffraction pattern is created.

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(b) Explain how the pattern would differ if green laser light were used instead of red laser light.

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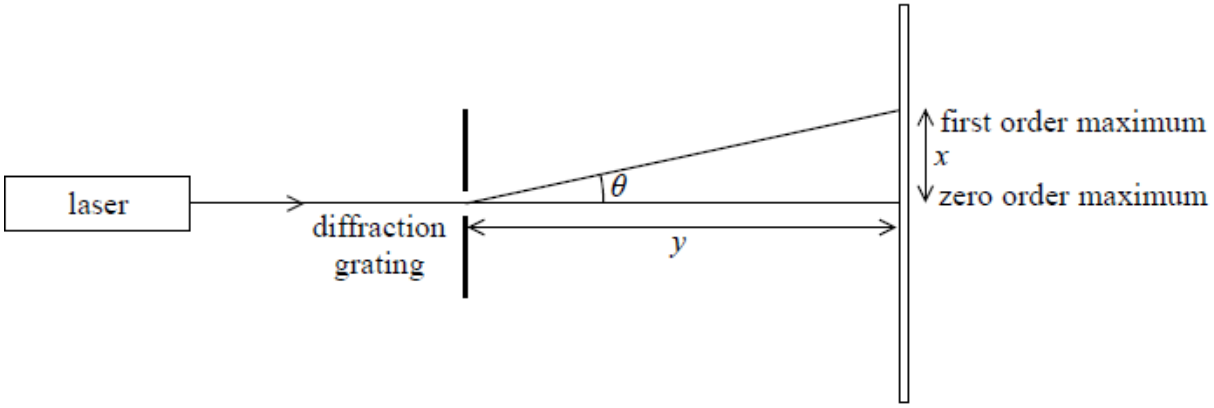
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(c) A student replaces the single slit with a diffraction grating and obtains the pattern shown in the photograph.



The photograph shows the zero order maximum and the first and second orders on either side.

The student takes measurements to determine the grating spacing.



The student measures x, the distance between the zero order maximum and the first order maximum, and y, the distance between the slit and the screen.

x = 23 cm
y = 1.5 m
Number of lines per millimetre = 300

Calculate the wavelength of light from the laser.

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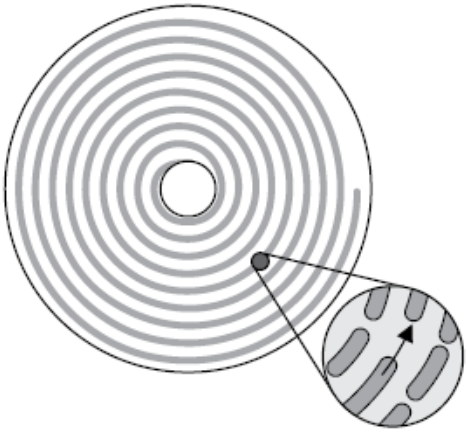
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Wavelength = ...

(Total for question = 9 marks)

Q6.

* The light from a lamp is reflected from the surface of a CD, which consists of a spiral track of elongated bumps.



CD surface showing spiral track of bumps with a smooth reflective surface in between.

(Source: http://gantisreerajiv.blogspot.co.uk/2012/04/you-cant-imagine-world-if-there-are.html:)

A physics student notices that although the light from the lamp is white, different colours are seen in the reflected light. He suggests that the colours are produced when diffraction occurs at the surface of the CD.

Discuss the extent to which the student's suggestion explains the presence of colours in the light reflected from the surface of the CD.

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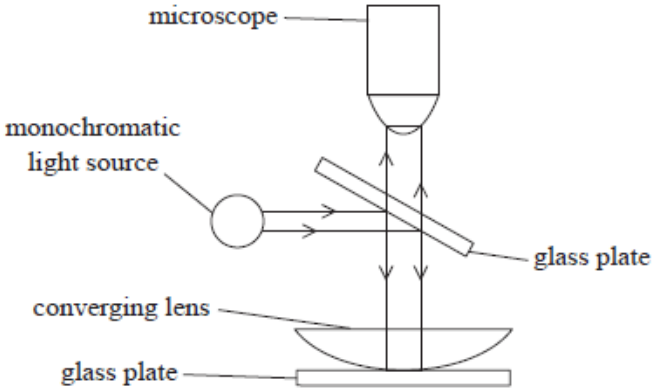
(Total for question = 6 marks)

Q7.

A method to determine the wavelength of light using a converging lens was first proposed by Sir Isaac Newton.

A converging lens is placed on a plane glass plate. The lens is illuminated from above with a parallel beam of monochromatic light, as shown.

Some of the light is reflected from the upper surface of the lower glass plate and some from the lower surface of the lens. Interference between these two reflected waves produces circular fringes. The pattern is viewed through a microscope.



Side view of apparatus



Pattern seen through microscope

When considering the principles of this experiment, a student suggests that interference fringes would only be produced with monochromatic light. This is because interference requires coherent light waves.

Discuss the validity of the student's suggestion.

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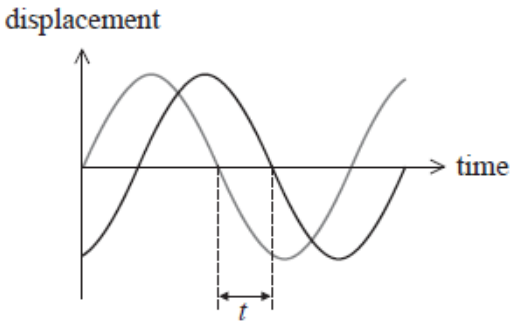
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(Total for question = 4 marks)

Q8.

Displacement-time graphs are shown for two waves, each of frequency f and period T.



The phase difference in radians between the two waves is given by

(1)

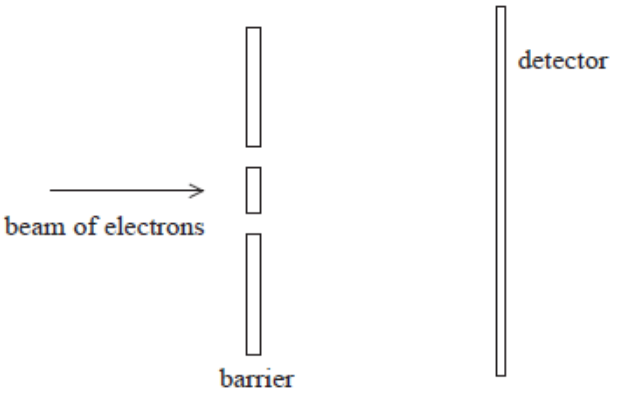
- ☒ **A** $\frac{2\pi t}{T}$
- ☒ **B** $\frac{\pi t}{T}$
- ☒ **C** $\frac{2\pi t}{f}$
- ☒ **D** $\frac{\pi t}{f}$

(Total for question = 1 mark)

Q9.

In 1965, Richard Feynman proposed a double slit experiment to investigate the wave properties of electrons.

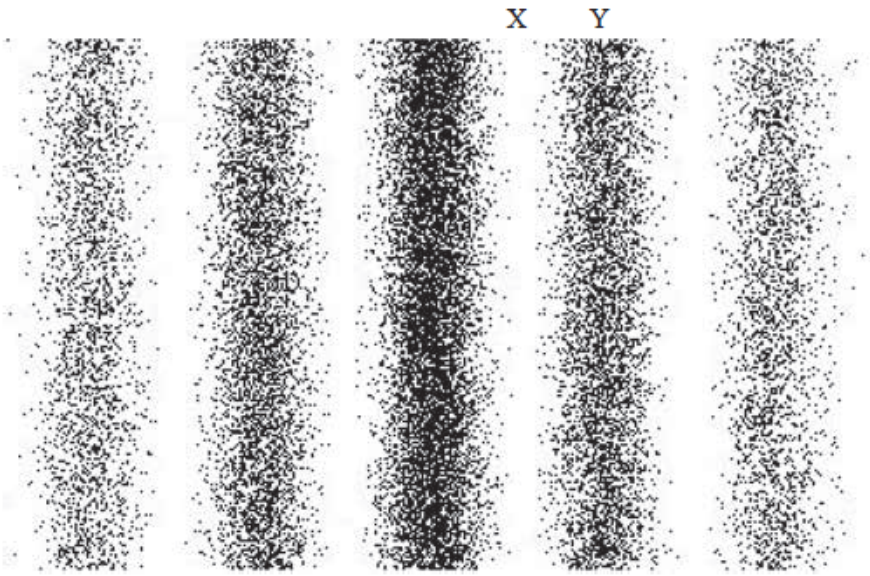
The experiment was later carried out using the arrangement shown.



A beam of electrons was directed at a barrier with two slits.

The detector recorded the positions where electrons arrived after passing through the slits.

The following pattern was obtained. Black dots represent points where electrons were detected. A band where electrons were not detected has been labelled X and a band where electrons were detected has been labelled Y.



The path difference for electrons arriving at band X from the separate slits was 2.5×10^{-1} m. For electrons arriving at band Y the path difference was 5.0×10^{-1} m.

Explain why this pattern is observed when the electron energy is 9.6×10^{-1} J.

The electrons are travelling at non-relativistic speeds.

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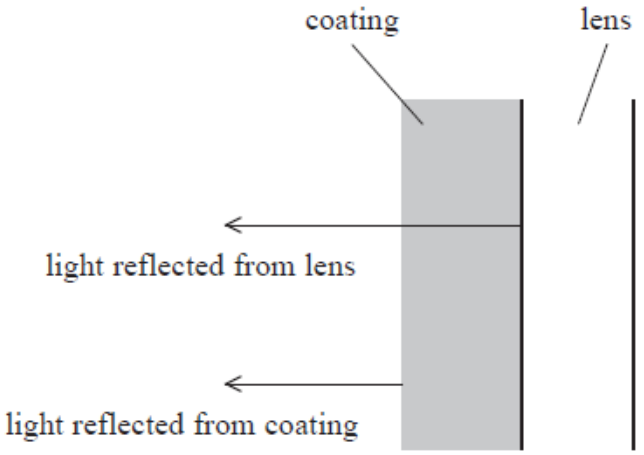
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(Total for question = 6 marks)

Q10.

Glass lenses used for optical instruments often have an anti-reflective coating. The coating is a thin layer of a transparent substance with refractive index n^c.

Light is reflected from the coating surface and from the lens surface as shown. The reflected light interferes destructively.



When a single-layer coating is used, the coating thickness is chosen to eliminate reflections for green light, which is in the middle of the visible spectrum.

(i) Calculate the minimum thickness d of the coating required for the reflection of green light to be eliminated.

frequency of green light = 6.00×10^{14} Hz
$n_c = 1.38$

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d = ...

(ii) State why white light reflected from coated lenses is seen as purple.

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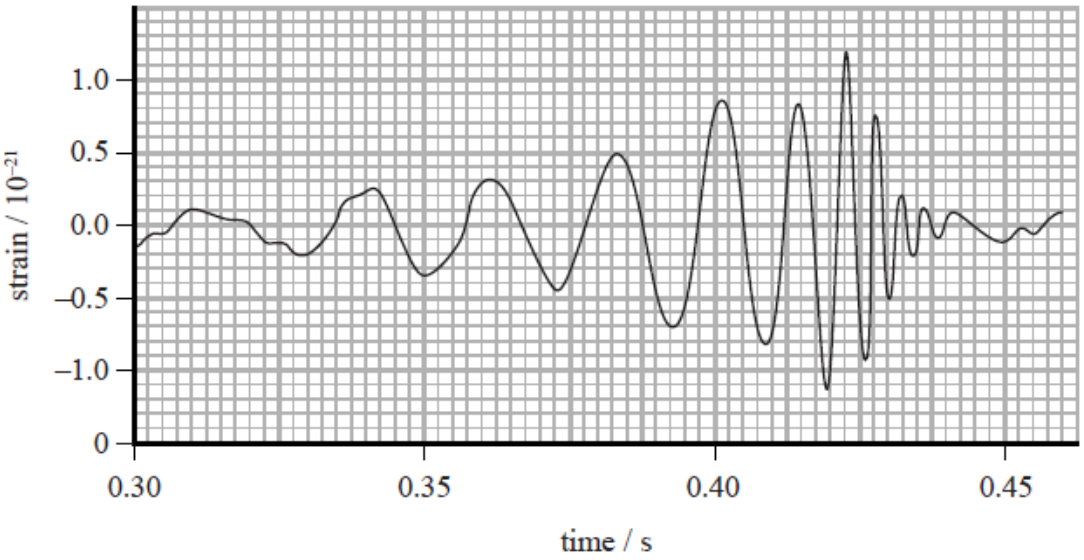
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(Total for question = 5 marks)

Q11.

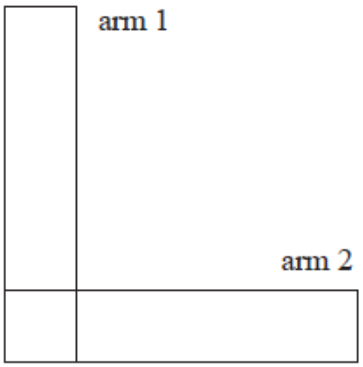
In 2016 scientists at the Laser Interferometer Gravitational-Wave Observatory (LIGO) announced that gravitational waves had been detected.

The signal they detected is shown on the graph.



Gravitational waves alternately compress and stretch matter by very small amounts as they pass through.

The LIGO detector has two arms, at 90° to each other, each 4 km long. As a gravitational wave passes the detector, the arms change length. The detector continuously compares the lengths of the two arms.



(i) An article states that 'the maximum change in the 4 km length of the arm is about 0.001 times the diameter of a proton'.

Determine whether this statement applies to the gravitational wave shown in the graph.

diameter of proton = 8.8×10^{-16} m

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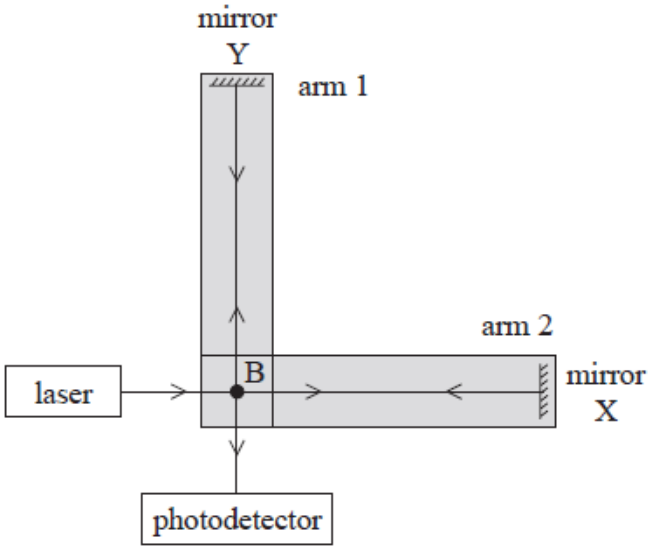
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(ii) In the LIGO detector, any change in the lengths of the arms is detected using a laser beam

and photodetector.



The laser beam is split into two at B, one beam travelling to one mirror and the other beam travelling to the other mirror. After reflection at the mirrors, the beams are recombined at B and reach the photodetector. The photodetector measures the intensity of the incident light.

The system is arranged so that when no gravitational waves are present, the beams have a path difference of half a wavelength at the photodetector.

Explain how the photodetector detects very small changes in the length of one arm, when the other arm stays the same length.

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(iii) The system could be arranged so that when no gravitational waves are present, the beams have zero path difference at the photodetector.

Explain whether using an initial path difference of half a wavelength is a more sensitive way of detecting changes in length than having an initial path difference of zero.

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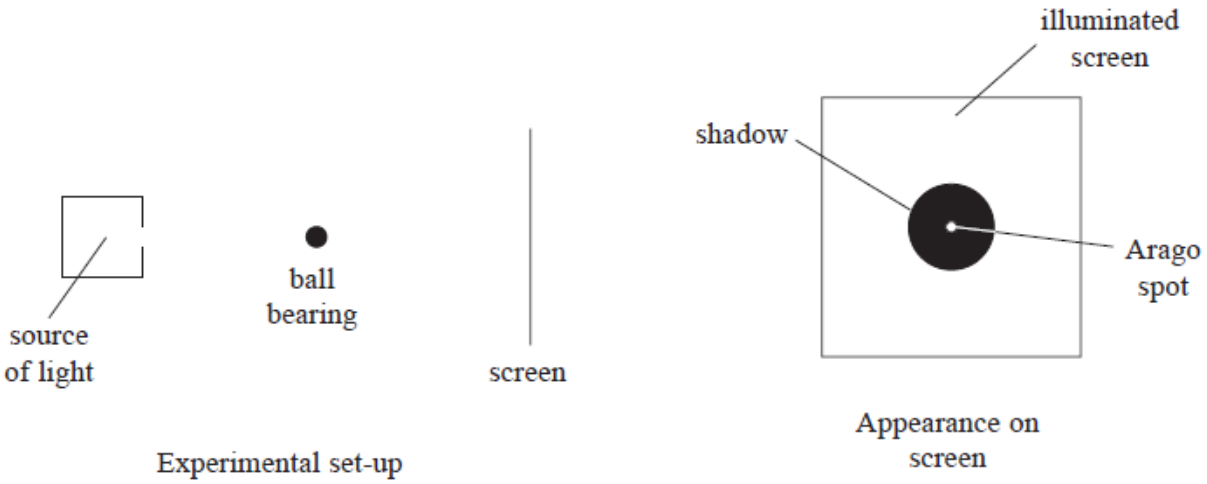
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(Total for question = 9 marks)

Q12.

The diagram shows a coherent beam of light incident on a metal ball bearing.

A dark shadow is seen on a screen behind the ball bearing. There is a small spot of light in the centre of the shadow. This spot of light is known as the Arago spot.



(a) Use Huygens' construction to explain the behaviour of light as it travels past the edge of the ball bearing.

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(b) Explain why a spot of light is produced at the centre of the shadow.

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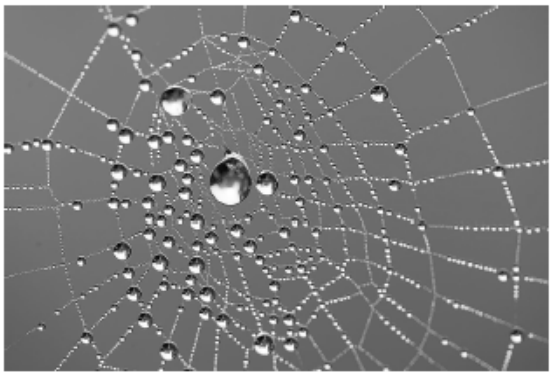
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(Total for question = 5 marks)

Q13.

The photograph shows part of a spider's web where water droplets have collected at certain points. The web is made from spider silk which is made by the spider.



Spiders are almost completely dependent on vibrations transmitted through their web for receiving information about the location of trapped insects. When the threads are disturbed by the insects, progressive waves are transmitted along sections of the silk.

It has been suggested that the droplets of water collect at certain points on the web because stationary waves are formed.

* Explain how stationary waves can be setup on a thread of spider silk, and how this can account for the collection of water droplets at certain points on the thread.

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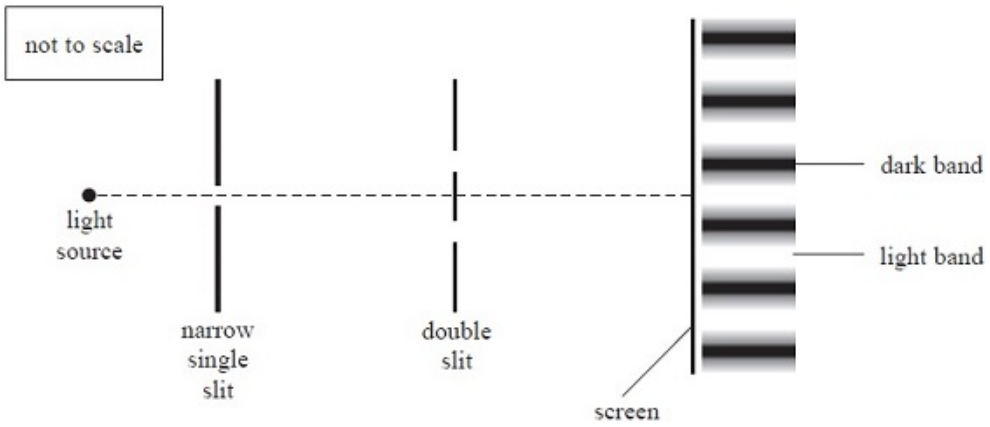
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Q14. In the 17th century, Isaac Newton suggested that light was made up of very small particles which he called corpuscles.

Newton's theory was favoured in England throughout the 18th century because of his great reputation although scientists elsewhere applied the wave theory.

In 1801 Thomas Young demonstrated his double slit experiment. Monochromatic light from a narrow single slit was passed through a double slit and a pattern of light and dark bands was seen on a screen, as shown in the diagram.



*(a) Explain how the light and dark bands are formed in the double slit experiment.

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(b) The observation of light and dark bands with the double slit experiment depends on the light from the slits being coherent.

Explain why coherence is necessary to observe the light and dark bands.

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(c) State why Young's experiment disproved Newton's corpuscular theory.

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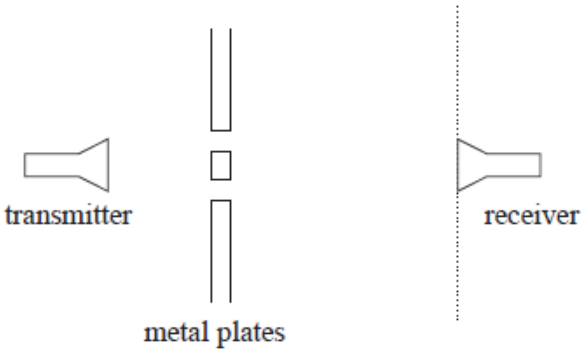
(Total for Question = 7 marks)

Q15.

Details supplied with a school microwave transmitter and receiver include the following information:

Transmitter supplies a 10 GHz polarised EM wave. Receiver detects EM waves in a single plane containing the direction of propagation, producing an audible output proportional to the microwave intensity.

A student uses the microwave transmitter and receiver to investigate interference using the set-up shown.



As the receiver is moved along the dotted line, alternate points of maximum and minimum intensity are detected.

Explain why points of maximum and minimum intensity are detected.

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(Total for question = 4 marks)

Q16.

A stationary interference pattern is created by the superposition of waves from two sources which are close together.

For this to occur the waves must

☒ **A** be in phase with each other.

☒ **B** be transverse.

☒ **C** have the same amplitude.

☒ **D** have the same frequency.

(Total for question = 1 mark)

Q17.

Huygens' principle states that every point on a wavefront is a source of wavelets which spread out at the same speed.

State what is meant by a wavefront.

(1)

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(Total for question = 1 mark)

Q18.

The photograph shows an ultrasonic mouse repeller used in a house.



The mouse repeller produces ultrasound that repels mice but cannot be heard by humans.

The mouse hears ultrasound directly and by reflection from the walls.

The mouse repeller produces ultrasound of frequency 26.0 kHz.

speed of sound = 340 m s^{-1}

A student makes the following suggestion.

"If the ultrasound reflects off a wall directly opposite the mouse repeller a standing wave is formed, so there will be areas in the room where the mice will not hear the ultrasound."

Evaluate this suggestion.

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(Total for question = 6 marks)

Q19.

A book entitled *Interesting Projects with a Microwave Oven* suggests using chocolate to measure the speed of light. The chocolate is placed on a non-metallic tray in the oven.
The oven is switched on and a pattern is observed in the melting chocolate.



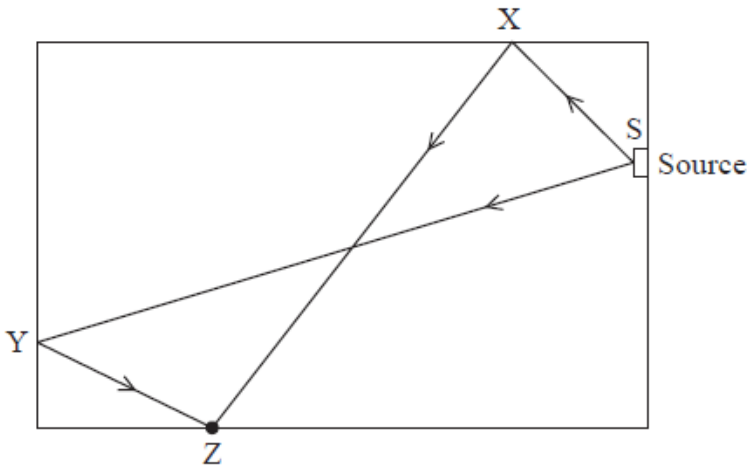
The photograph shows some lighter areas where the chocolate is melting and some darker areas where the chocolate remains hard.

The book states that microwaves are emitted from the source in the oven. The microwaves reflect off the metal walls so that the microwaves reaching any point arrive from different directions. The microwaves produce a standing wave pattern causing hot and cold areas in the oven.

The wavelength was determined to be 12 cm by measuring the distance between adjacent hot and cold areas.

(a) The diagram shows two different paths by which microwaves can reach the point Z.

Not to scale



SX = 9 cm, XZ = 23 cm, SY = 36 cm, YZ = 8 cm

Calculate the phase difference between microwaves from the source at S reaching point Z by the two different paths.

(2)

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Phase difference = ...

(b) Explain how a pattern of hot and cold areas is produced in the chocolate. You should assume that each point of the chocolate is reached by microwaves following two different paths only.

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(c) Explain why the microwaves reaching a point in the chocolate must be coherent for this effect to occur.

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(d) The microwave frequency is stated on the oven as 2450 MHz.

Evaluate the success of this experiment at determining the speed of light.

(3)

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(Total for question = 11 marks)

Q20.

Read the following press release and then answer the question that follows.

"Lockheed Martin Demonstrates Weapons Grade High Power Fiber Laser

BOTHELL, Wash., Jan. 28, 2014 – Lockheed Martin has demonstrated a 30-kilowatt electric fiber laser, the highest power ever documented while retaining beam quality and electrical efficiency.

The internally funded research and development program culminated in this demonstration, which was achieved by combining many fiber lasers into a single, near–perfect quality beam of light – all while using approximately 50 percent less electricity than alternative solid–state laser technologies. The unique process, called Spectral Beam Combining, sends beams from multiple fiber laser modules, each with a unique wavelength, into a combiner that forms a single, powerful, high quality beam."

(Source: Lockheed Martin Demonstrates Weapons Grade High Power Fiber Laser Wash Bothell, Jan 28, 2014)

Traditional solid state lasers convert about 20% of electrical input energy to light output.

The high power laser uses Spectral Beam Combining involving several beams with different wavelengths instead of a system using coherent beams.

Explain how combining coherent beams could lead to zero intensity in some parts of the combined beam.

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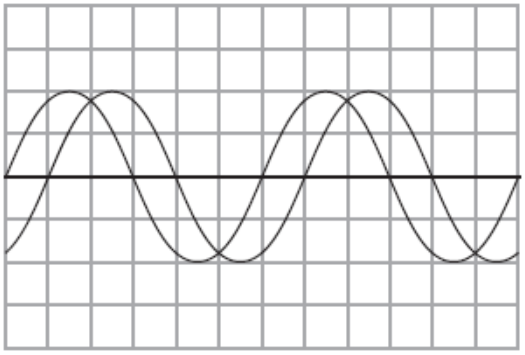
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(Total for question = 3 marks)

Q21.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A two-beam oscilloscope is used to display signals from two microphones as shown.



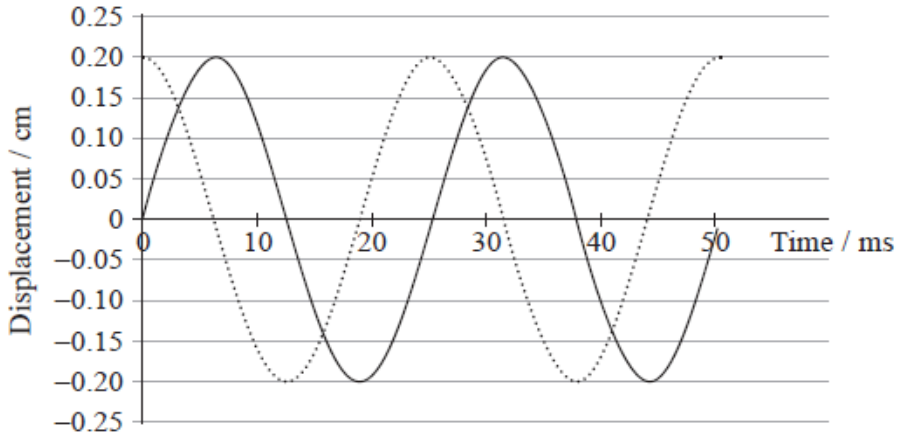
Which of the following could be the phase difference in radians between the traces?

- ☐ **A** $\frac{\pi}{6}$
- ☐ **B** $\frac{\pi}{4}$
- ☐ **C** $\frac{\pi}{3}$
- ☐ **D** $\frac{\pi}{2}$

(Total for question = 1 mark)

Q22.

The graph shows the variation of displacement with time for two waves.



What is the phase difference between these two waves?

(1)

☒ **A** 6 ms

☒ **B** 0.20 cm

☒ **C** π radians

☒ **D** 90 degrees

(Total for question = 1 mark)

Q23.

* The photograph shows a pipe organ in a concert hall.



(Source: www.yucatanliving.com/article-photos/news/01042010/pipe-organ.jpg)

When the organ is played, sound travels through the air to a person in the audience as a wave. It is found that there are some positions in the concert hall where particular frequencies are quieter than others.

Explain why this might be the case and give an action that could be taken to eliminate this problem.

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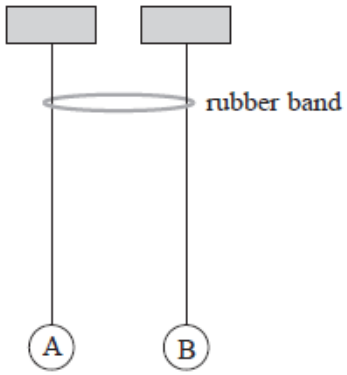
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(Total for question = 6 marks)

Q24.

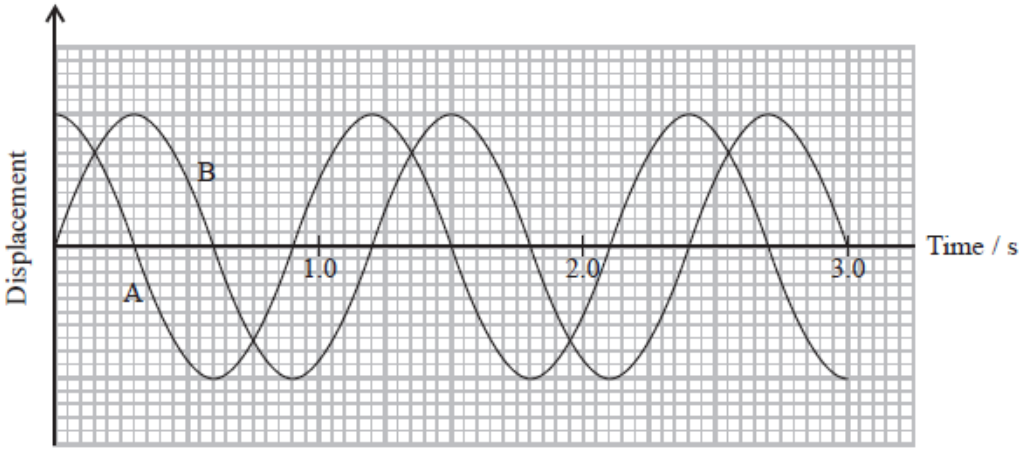
The diagram shows two identical pendulums, A and B, side by side with a rubber band placed over both strings.



Pendulum A is displaced and starts to oscillate. As pendulum A oscillates, pendulum B starts to oscillate with the same time period, its amplitude increasing as the amplitude of pendulum A decreases. At one stage pendulum A is no longer oscillating and pendulum B has its maximum amplitude. Then pendulum A starts to oscillate again with increasing amplitude, as the amplitude of pendulum B decreases.

The apparatus is adjusted so that the pendulums do not have the same length as each other. When the first pendulum is set into oscillation, the second pendulum starts to oscillate, but with very small amplitude; the first pendulum does not stop oscillating.

The graph shows how the displacement of each pendulum varies with time at one stage in the motion.



(i) State the phase relationship between the two pendulums.

(1)

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(ii) Determine the length of pendulums A and B.

(3)

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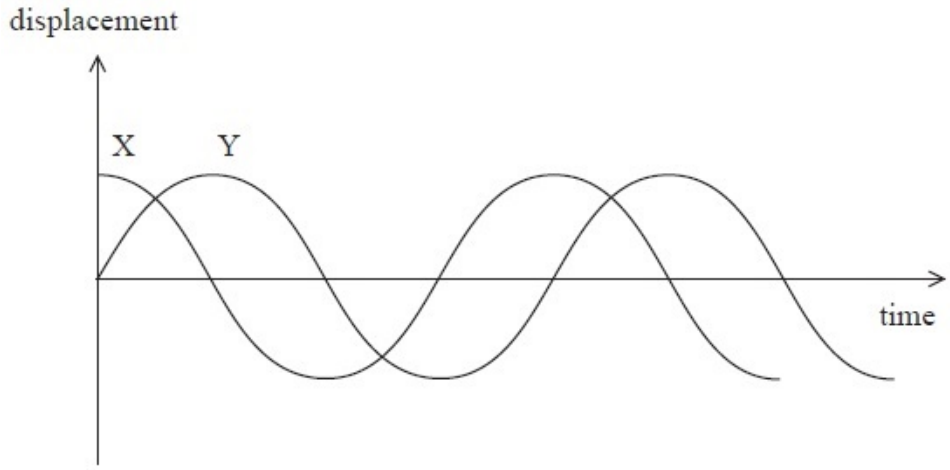
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Length = ...

(Total for question = 4 marks)

Q25. The diagram shows displacement-time graphs for two oscillations, X and Y.



Which of the following statements correctly describes their phase relationship?

- ☒ **A** X and Y are in antiphase
- ☒ **B** X and Y are in phase
- ☒ **C** X is π/2 radians ahead of Y
- ☒ **D** Y is π/2 radians ahead of X

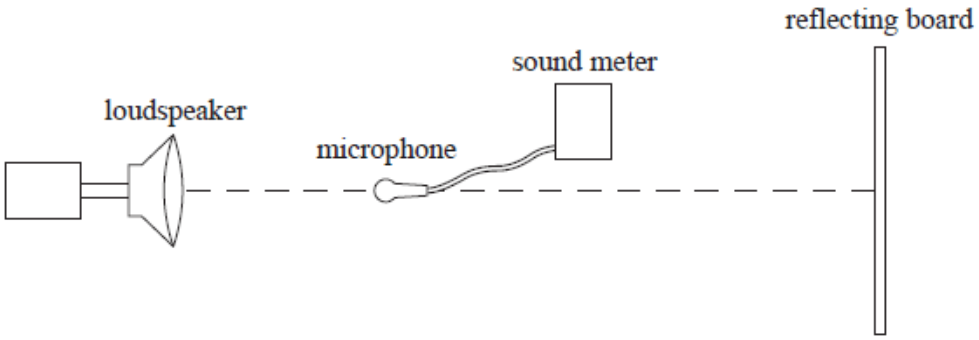
(Total for Question = 1 mark)

Q26.

Two students are carrying out an investigation to determine a value for the speed of sound in air.

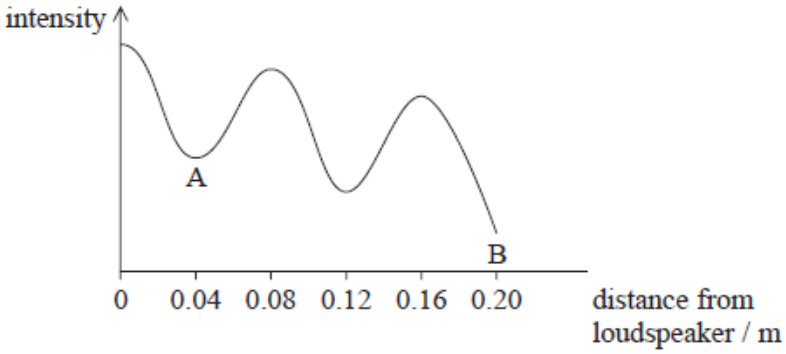
They stand 80 m from a building. One student hits two pieces of wood together to make a loud sound and a short time later an echo is heard. The other student uses a stopwatch to measure the time interval *t* between the two pieces of wood being hit and the echo being heard. The procedure is repeated. The students also measure the air temperature.

A method to determine a value for the speed of sound is shown in the diagram.



A loudspeaker is placed at a distance from a vertical reflecting board. Sound waves reflect off the board and set up a standing wave between the loudspeaker and the board. A microphone connected to a sound meter is moved in a straight line from the loudspeaker to the board. As the microphone is moved, the sound meter records the varying intensity of the standing wave.

The sketch graph shows how the intensity varies with distance from the loudspeaker.



(i) Explain why the intensity at point B is less than the intensity at point A.

(3)

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(ii) Use the graph to determine a value for the speed of sound.

frequency of sound wave = 2.0 kHz

(3)

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Speed of sound = ...

(Total for question = 6 marks)

Q27.

If certain crystals are subjected to a mechanical stress, a potential difference is generated across them. This is called the piezoelectric effect. These crystals can be produced as very thin films.

Below is a photograph of a T-shirt with a built-in phone charger, which is being tested at a music festival. The white rectangle is a piezoelectric film.



(a) By considering how a sound wave travels through the air, explain how sound can cause a piezoelectric film to generate a potential difference.

(4)

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(b) Explain why the crystals used in the T-shirt need to be in the form of a large, thin film.

(3)

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(c) When the T-shirt is used at a music festival the sound levels are sufficient to generate about 20 kJ over ten hours. This is enough to charge one phone.

Calculate the electrical power output.

(3)

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Power output = ...

(d) Give **one** advantage and **one** disadvantage of this charger compared with a conventional charger.

(2)

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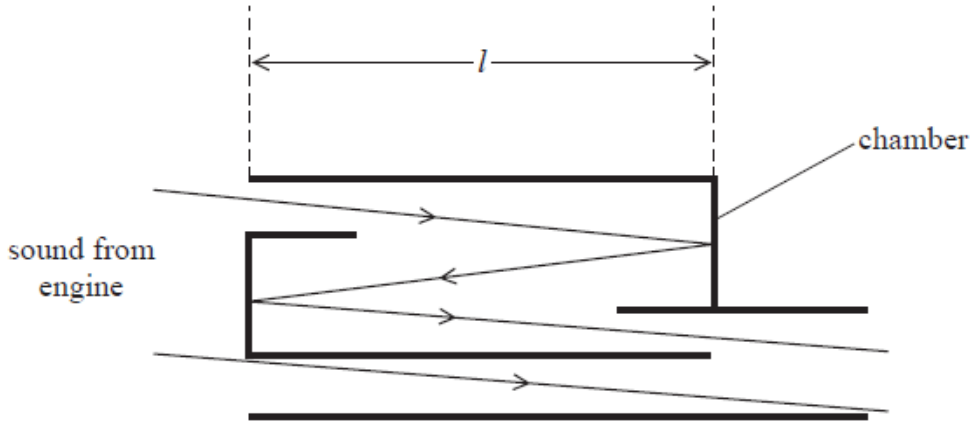
(Total for question = 12 marks)

Q28.

Vibrations of a car engine cause a sound wave in air.

A silencer is a device fitted to a car to reduce the sound from the engine.
Some sound passes through the silencer chamber and is reflected twice. Some sound passes straight through the chamber without being reflected.

The simplified diagram shows the paths of the sound as it travels through the chamber. Sound leaving the chamber is a combination of sound waves from the two paths. The sound waves are in phase as they enter the chamber.



An engine produces sound with a frequency of about 140 Hz.

Explain why, to reduce this sound, the length *l* of the chamber should be about 60 cm.

speed of sound in air = 340 m s^{-1}

(4)

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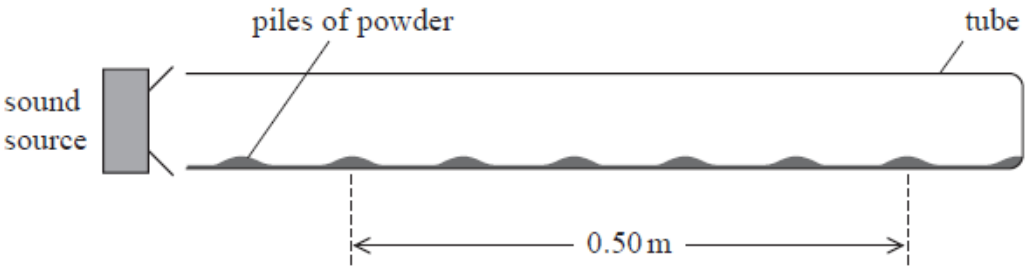
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(Total for question = 4 marks)

Q29.

In an experiment to determine the speed of sound in air, a powder is sprinkled over the base of a horizontal glass tube. One end of the tube is closed. A sound source is placed at the open end of the tube, as shown.



Soundwaves travel along the tube and reflect from the closed end.

Explain why the powder forms into small piles at regular intervals along the length of the tube.

(5)

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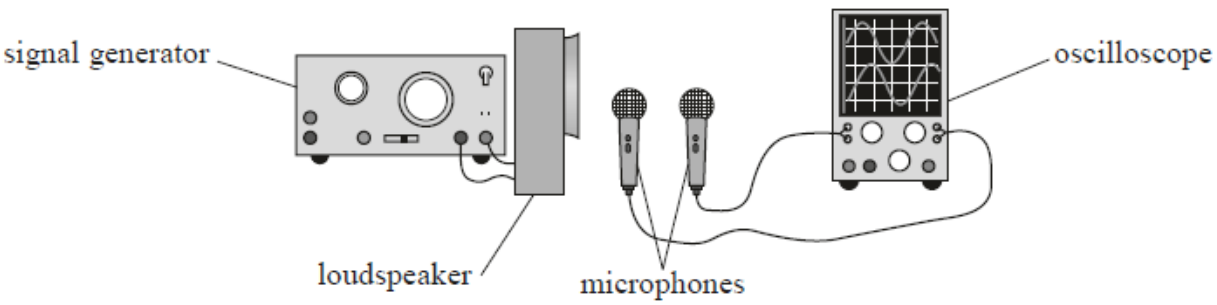
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(Total for question = 5 marks)

Q30.

In an experiment to determine the speed of sound in air, a 2-beam oscilloscope is used to display the signals from two microphones. The microphones are placed in front of a loudspeaker that is connected to a signal generator.



The loudspeaker emits a sound of frequency *f*.

The microphones are placed at different distances from the loudspeaker. The time taken for the sound to travel from the first microphone to the second is t.

Which of the following expressions gives the phase difference between the two signals?

☒ **A** πtf

☒ **B** $2\pi tf$

☒ **C** $\frac{\pi f}{t}$

☒ **D** $\frac{2\pi f}{t}$

(Total for question = 1 mark)

Q1.

The photograph shows a guitar. The strings of the guitar are at the same tension.



When a string is plucked, a standing wave is set up on the string.

* Explain how a standing wave is set up on a string.

(6)

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(Total for question = 6 marks)

Q2.

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

(2)

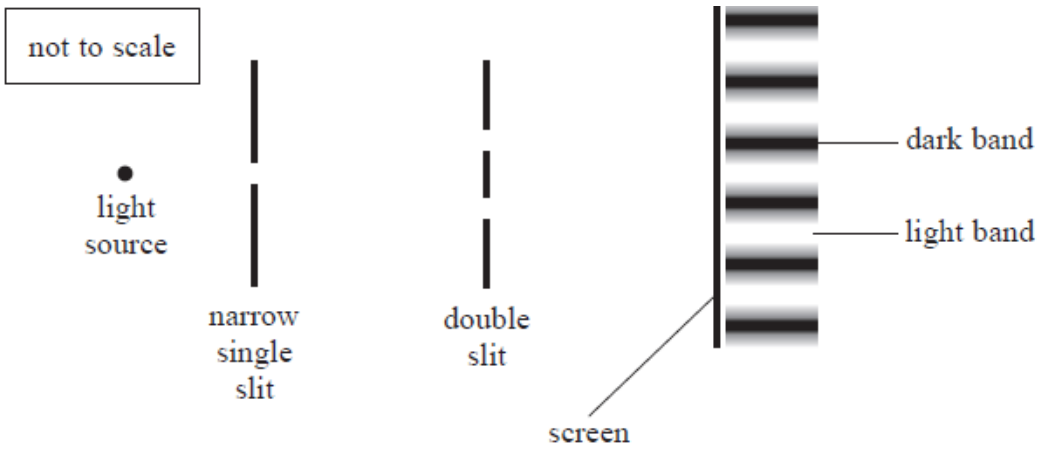
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(b) The arrangement in the diagram demonstrates the effect of superposition. When a monochromatic light source is used, a series of dark and light bands is formed on the screen.



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

(3)

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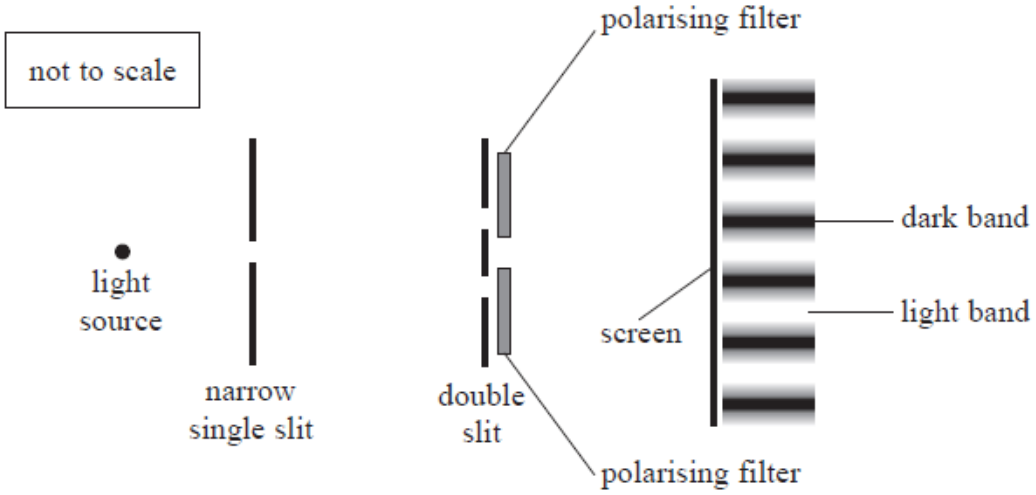
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(ii) Polarising filters are placed behind the slits as shown. When the planes of polarisation are parallel, the pattern of light and dark bands is still seen.



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

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

(3)

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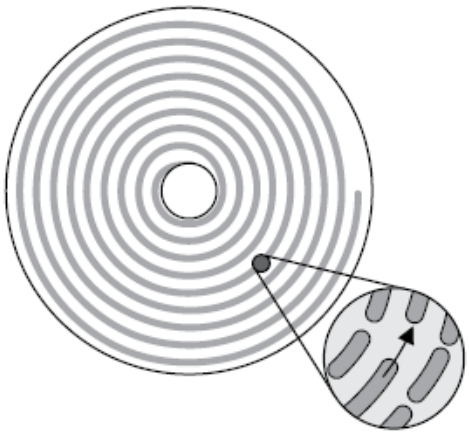
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Q3.

* The light from a lamp is reflected from the surface of a CD, which consists of a spiral track of elongated bumps.



CD surface showing spiral track of bumps with a smooth reflective surface in between.

(Source: http://gantisreerajiv.blogspot.co.uk/2012/04/you-cant-imagine-world-if-there-are.html:)

A physics student notices that although the light from the lamp is white, different colours are seen in the reflected light. He suggests that the colours are produced when diffraction occurs at the surface of the CD.

Discuss the extent to which the student's suggestion explains the presence of colours in the light reflected from the surface of the CD.

(6)

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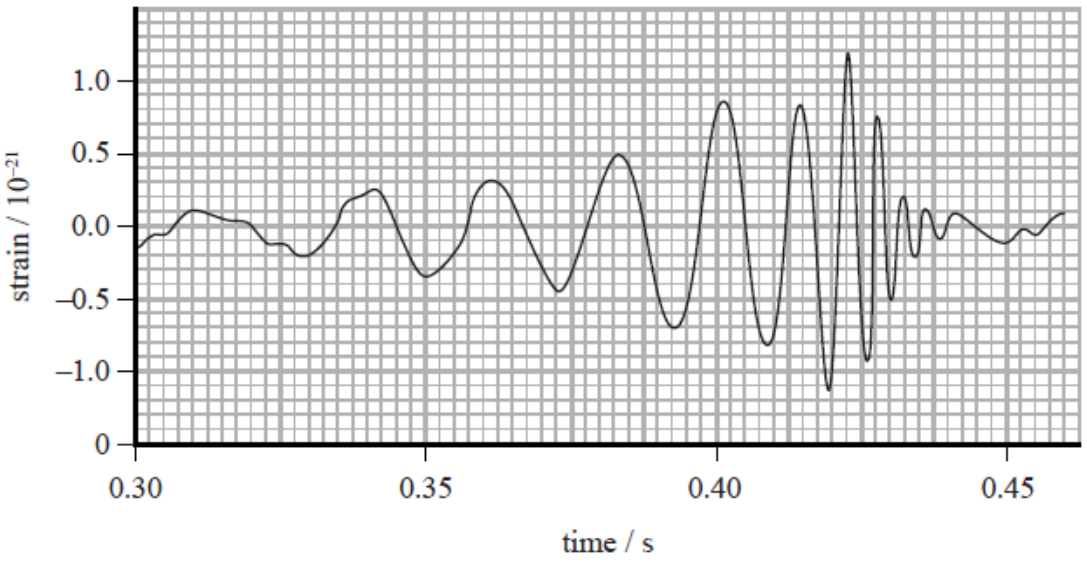
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(Total for question = 6 marks)

Q4.

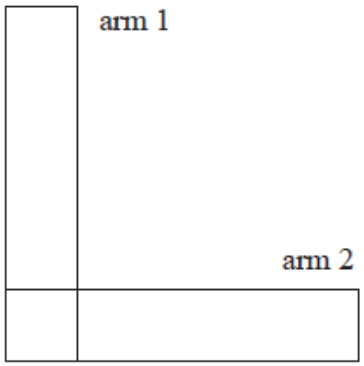
In 2016 scientists at the Laser Interferometer Gravitational-Wave Observatory (LIGO) announced that gravitational waves had been detected.

The signal they detected is shown on the graph.



Gravitational waves alternately compress and stretch matter by very small amounts as they pass through.

The LIGO detector has two arms, at 90° to each other, each 4 km long. As a gravitational wave passes the detector, the arms change length. The detector continuously compares the lengths of the two arms.



(i) An article states that 'the maximum change in the 4 km length of the arm is about 0.001 times the diameter of a proton'.

Determine whether this statement applies to the gravitational wave shown in the graph.

diameter of proton = 8.8×10^{-16} m

(3)

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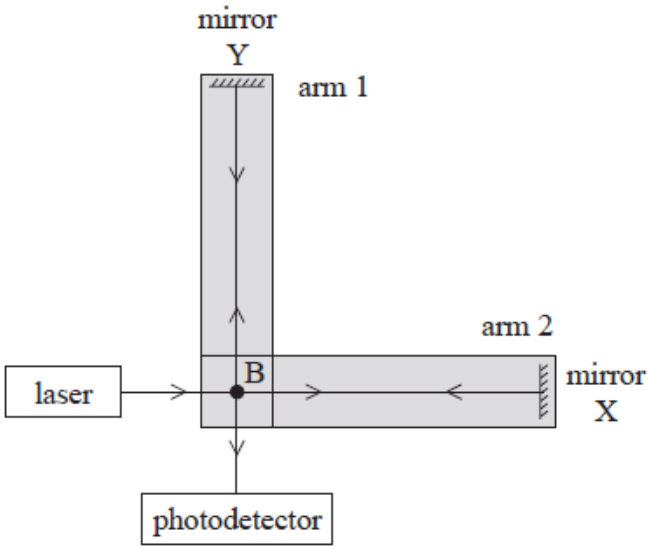
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(ii) In the LIGO detector, any change in the lengths of the arms is detected using a laser beam and photodetector.



The laser beam is split into two at B, one beam travelling to one mirror and the other beam travelling to the other mirror. After reflection at the mirrors, the beams are recombined at B and reach the photodetector. The photodetector measures the intensity of the incident light.

The system is arranged so that when no gravitational waves are present, the beams have a path difference of half a wavelength at the photodetector.

Explain how the photodetector detects very small changes in the length of one arm, when the other arm stays the same length.

(4)

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(iii) The system could be arranged so that when no gravitational waves are present, the beams have zero path difference at the photodetector.

Explain whether using an initial path difference of half a wavelength is a more sensitive way of detecting changes in length than having an initial path difference of zero.

(2)

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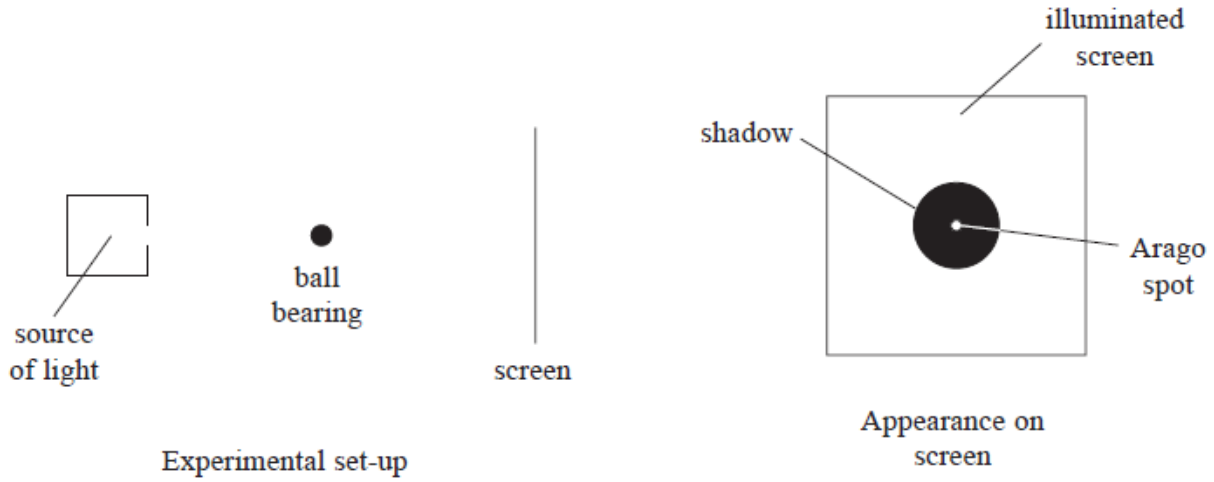
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(Total for question = 9 marks)

Q5.

The diagram shows a coherent beam of light incident on a metal ball bearing.

A dark shadow is seen on a screen behind the ball bearing. There is a small spot of light in the centre of the shadow. This spot of light is known as the Arago spot.



(a) Use Huygens' construction to explain the behaviour of light as it travels past the edge of the ball bearing.

(2)

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(b) Explain why a spot of light is produced at the centre of the shadow.

(3)

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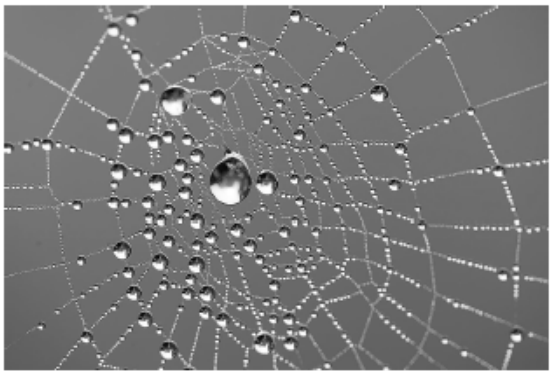
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(Total for question = 5 marks)

Q6.

The photograph shows part of a spider's web where water droplets have collected at certain points. The web is made from spider silk which is made by the spider.



Spiders are almost completely dependent on vibrations transmitted through their web for receiving information about the location of trapped insects. When the threads are disturbed by the insects, progressive waves are transmitted along sections of the silk.

It has been suggested that the droplets of water collect at certain points on the web because stationary waves are formed.

* Explain how stationary waves can be setup on a thread of spider silk, and how this can account for the collection of water droplets at certain points on the thread.

(6)

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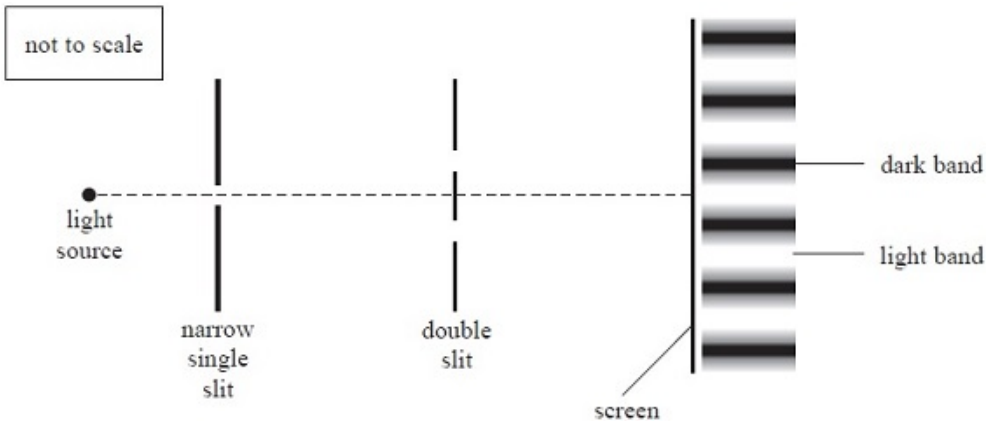
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Q7. In the 17th century, Isaac Newton suggested that light was made up of very small particles which he called corpuscles.

Newton's theory was favoured in England throughout the 18th century because of his great reputation although scientists elsewhere applied the wave theory.

In 1801 Thomas Young demonstrated his double slit experiment. Monochromatic light from a narrow single slit was passed through a double slit and a pattern of light and dark bands was seen on a screen, as shown in the diagram.



*(a) Explain how the light and dark bands are formed in the double slit experiment.

(4)

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(b) The observation of light and dark bands with the double slit experiment depends on the light from the slits being coherent.

Explain why coherence is necessary to observe the light and dark bands.

(2)

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(c) State why Young's experiment disproved Newton's corpuscular theory.

(1)

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(Total for Question = 7 marks)

Q8.

In a concert hall, sound waves produced by an instrument are reflected from different parts of the hall. Two coherent sound waves meet at a point where their phase difference is π.

What is the smallest possible path difference to produce this phase difference?

☒ **A** λ / 4

☒ **B** λ / 2

☒ **C** 3 λ / 4

☒ **D** λ

(Total for question = 1 mark)

Q9.

The photograph shows an ultrasonic mouse repeller used in a house.



The mouse repeller produces ultrasound that repels mice but cannot be heard by humans. The mouse hears ultrasound directly and by reflection from the walls.

The mouse repeller produces ultrasound of frequency 26.0 kHz.

speed of sound = 340 m s^{-1}

A student makes the following suggestion.

"If the ultrasound reflects off a wall directly opposite the mouse repeller a standing wave is formed, so there will be areas in the room where the mice will not hear the ultrasound."

Evaluate this suggestion.

(6)

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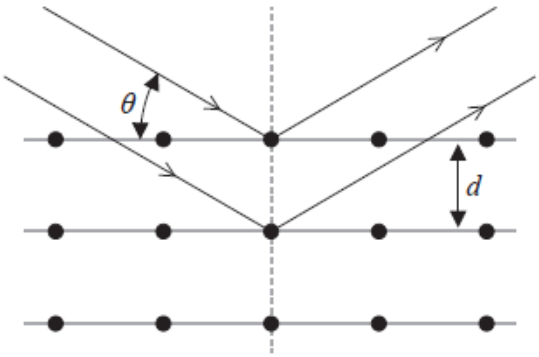
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(Total for question = 6 marks)

Q10.

An electron beam can be used to explore the structure of solid materials. The diagram shows an electron beam reflected by the top two layers of atoms within a material. The two layers are separated by a distance *d*.



(i) Show that the extra distance travelled by the electron beam reflecting off the second layer of atoms is given by $2d\sin\theta$.

θ is the angle between the beam and each layer of atoms.

You may add to the diagram.

(2)

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(ii) Give one reason why there is more than one ring shown in both Figure 1 and Figure 2.

(1)

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(Total for question = 3 marks)

Q11.

Waves from a point light source follow separate paths and recombine at a point after travelling different distances.

When the waves recombine the path difference is $\lambda/2$. The corresponding phase difference is

☒ **A** 360°

☒ **B** π/2 radians

☒ **C** 180°

☒ **D** 2π radians

(Total for question = 1 mark)

Q12.

A book entitled *Interesting Projects with a Microwave Oven* suggests using chocolate to measure the speed of light. The chocolate is placed on a non-metallic tray in the oven.
The oven is switched on and a pattern is observed in the melting chocolate.



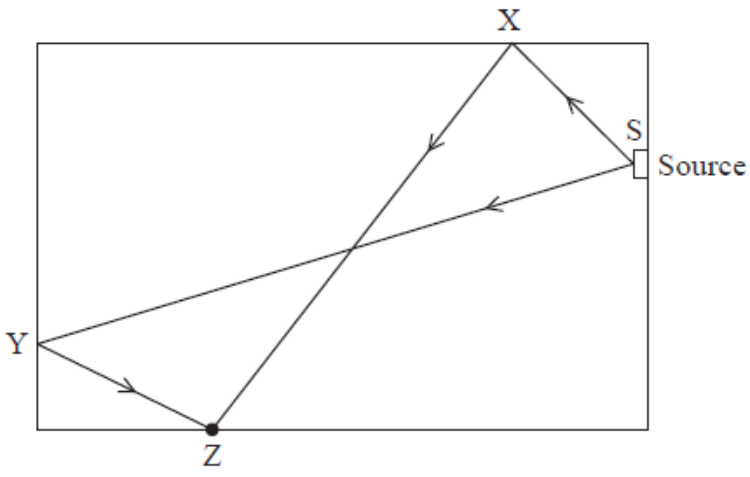
The photograph shows some lighter areas where the chocolate is melting and some darker areas where the chocolate remains hard.

The book states that microwaves are emitted from the source in the oven. The microwaves reflect off the metal walls so that the microwaves reaching any point arrive from different directions. The microwaves produce a standing wave pattern causing hot and cold areas in the oven.

The wavelength was determined to be 12 cm by measuring the distance between adjacent hot and cold areas.

(a) The diagram shows two different paths by which microwaves can reach the point Z.

Not to scale



SX = 9 cm, XZ = 23 cm, SY = 36 cm, YZ = 8 cm

Calculate the phase difference between microwaves from the source at S reaching point Z by the two different paths.

(2)

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Phase difference = ...

(b) Explain how a pattern of hot and cold areas is produced in the chocolate. You should assume that each point of the chocolate is reached by microwaves following two different paths only.

(4)

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(c) Explain why the microwaves reaching a point in the chocolate must be coherent for this effect to occur.

(2)

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(d) The microwave frequency is stated on the oven as 2450 MHz.

Evaluate the success of this experiment at determining the speed of light.

(3)

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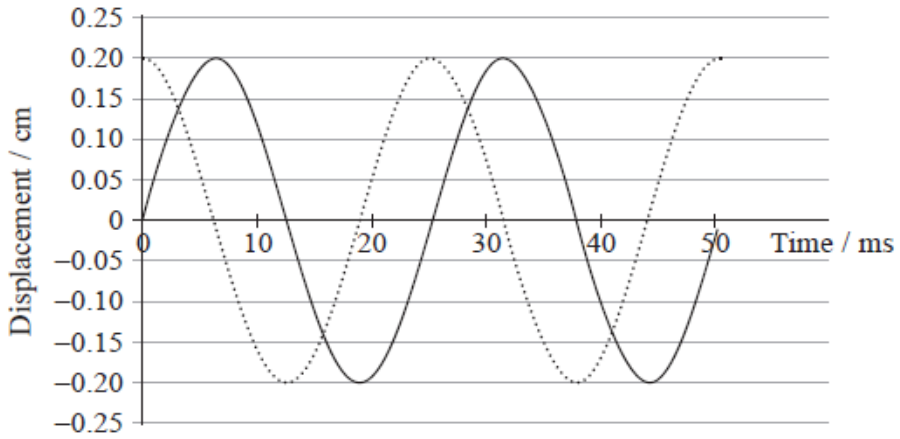
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(Total for question = 11 marks)

Q13.

The graph shows the variation of displacement with time for two waves.



What is the phase difference between these two waves?

(1)

☒ **A** 6 ms

☒ **B** 0.20 cm

☒ **C** π radians

☒ **D** 90 degrees

(Total for question = 1 mark)

Q14.

* The photograph shows a pipe organ in a concert hall.



(Source: www.yucatanliving.com/article-photos/news/01042010/pipe-organ.jpg)

When the organ is played, sound travels through the air to a person in the audience as a wave. It is found that there are some positions in the concert hall where particular frequencies are quieter than others.

Explain why this might be the case and give an action that could be taken to eliminate this problem.

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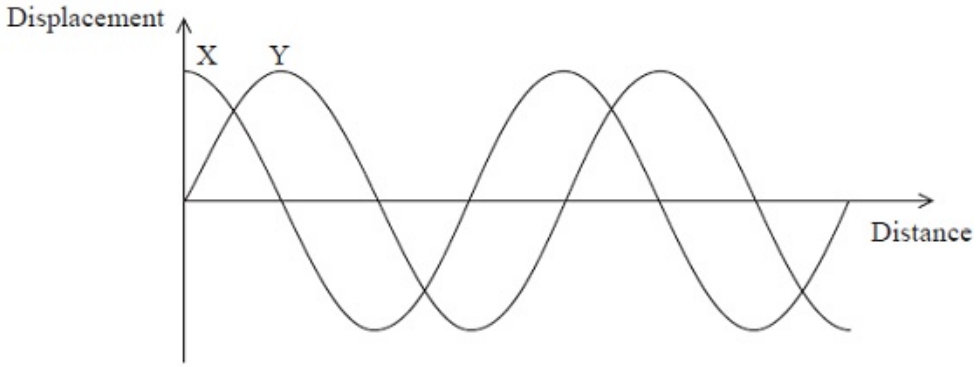
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(Total for question = 6 marks)

Q15. The diagram shows a displacement-distance graph at an instant for two waves, X and Y, travelling to the right.



Which of the following statements correctly describes the phase relationship between the two waves?

☒ **A** X and Y are in antiphase

☒ **B** X and Y are in phase

☒ **C** X is π/2 radians ahead of Y

☒ **D** Y is π/2 radians ahead of X

(Total for Question = 1 mark)

Q16.

Two coherent sources emit waves of wavelength λ which are in phase. The two waves meet at a point, having travelled slightly different distances. The waves now have a phase difference of 180º (π radians).

Which of the following could be the path difference at this point?

$\frac{3\lambda}{4}$ **A** $\frac{\lambda}{4}$

$\frac{3\lambda}{4}$ **B** $\frac{\lambda}{2}$

$\frac{3\lambda}{4}$ **C** $\frac{3\lambda}{4}$

$\frac{3\lambda}{4}$ **D** $\frac{P_O}{P_I}$

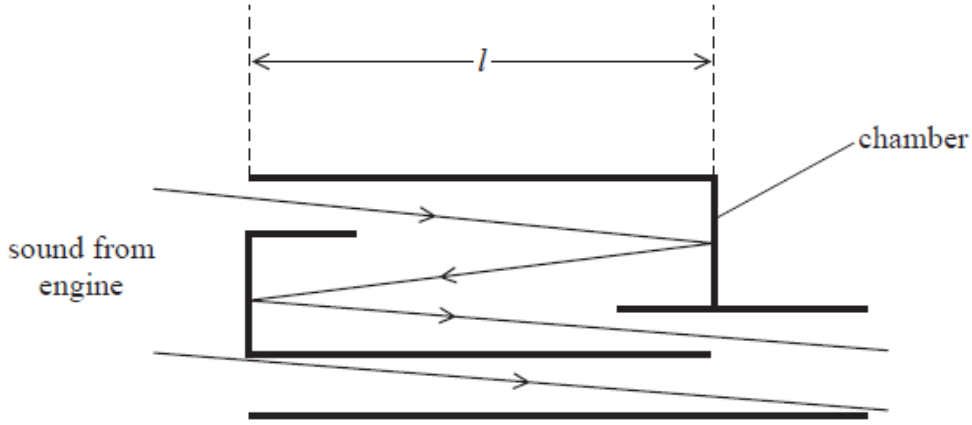
(Total for question = 1 marks)

Q17.

Vibrations of a car engine cause a sound wave in air.

A silencer is a device fitted to a car to reduce the sound from the engine.
Some sound passes through the silencer chamber and is reflected twice. Some sound passes straight through the chamber without being reflected.

The simplified diagram shows the paths of the sound as it travels through the chamber. Sound leaving the chamber is a combination of sound waves from the two paths. The sound waves are in phase as they enter the chamber.



An engine produces sound with a frequency of about 140 Hz.

Explain why, to reduce this sound, the length *l* of the chamber should be about 60 cm.

speed of sound in air = 340 m s^{-1}

(4)

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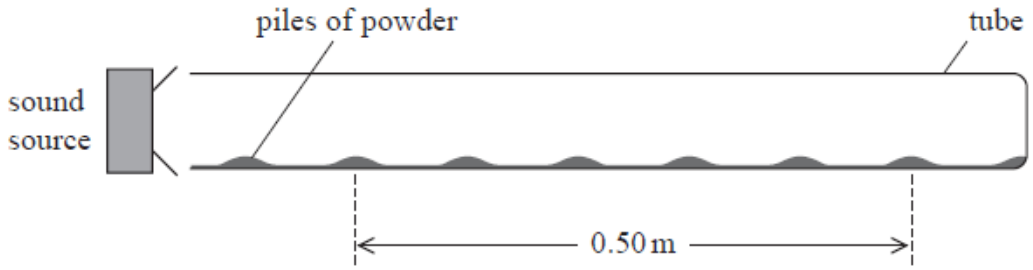
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(Total for question = 4 marks)

Q18.

In an experiment to determine the speed of sound in air, a powder is sprinkled over the base of a horizontal glass tube. One end of the tube is closed. A sound source is placed at the open end of the tube, as shown.



Soundwaves travel along the tube and reflect from the closed end.

Explain why the powder forms into small piles at regular intervals along the length of the tube.

(5)

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(Total for question = 5 marks)

Q19.

The photograph shows a guitar.



When a guitar string is plucked, a standing wave is created.

Explain how a standing wave is created on the string.

(3)

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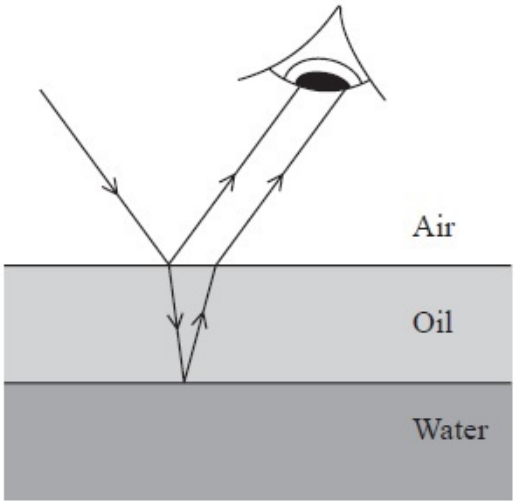
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(Total for question = 3 marks)

Q20. The diagram shows a ray of white light striking a thin layer of oil on water. Light reflects from the upper and lower surfaces of the oil, so that two rays reach the eye of an observer. With the eye in different positions the observer sees different colours from the oil.



Which of the following phenomena is not involved in the production of the colours seen?

☒ **A** polarisation

☒ **B** reflection

☒ **C** refraction

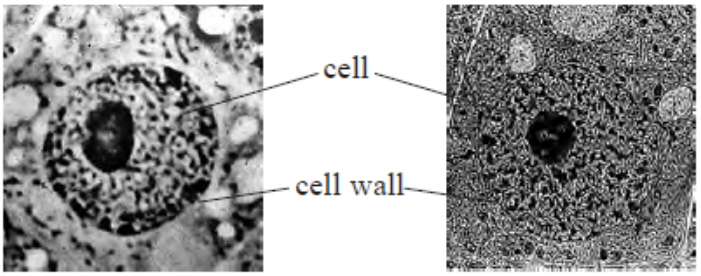
☒ **D** superposition

(Total for Question = 1 mark)

Q1.

An optical microscope uses a beam of visible light. An electron microscope uses a beam of electrons.

A biologist looked at an animal cell using both microscopes. The two images are shown; both have the same magnification.



using optical microscope using electron microscope

www.udel.edu

The image of the animal cell produced by the electron microscope is less blurred than the image produced by the optical microscope.

Explain why.

(2)

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(Total for question = 2 marks)

Q2.

The effect of diffraction is more noticeable, in everyday life, with sound than with light. This is because

☒ **A** sound has a much longer wavelength than light.

☒ **B** sound is a longitudinal wave, light is a transverse wave.

☒ **C** sound is a mechanical wave, light is an electromagnetic wave.

☒ **D** sound travels more slowly in air than light does.

(Total for question = 1 marks)

Q3.

When food is cooked in a microwave oven, microwave radiation is absorbed by water molecules, increasing the internal energy of the food.

(a) The photograph shows a microwave leakage detector.



The detector is held next to the microwave oven to see if any microwave radiation is leaking to the surroundings.

Suggest why microwave radiation leaking to the surroundings could be dangerous to people.

(2)

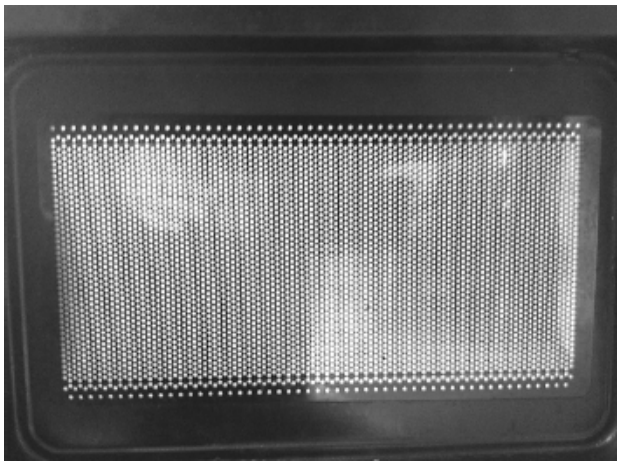
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(b) The internal walls of the microwave oven are solid metal. The photograph shows the door of a microwave oven.



The door consists of two sheets of glass with a layer of metal between. The layer of metal has many small holes in it, so that food inside the microwave oven may be seen while it is being heated without exposing the user to dangerous levels of microwave radiation. It has been suggested that, due to diffraction effects, light can pass through the holes but microwaves

cannot.

(i) Explain what is meant by diffraction.

(2)

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(ii) Calculate the wavelength of the microwave radiation used in the oven.

microwave frequency = 2.5 GHz.

(2)

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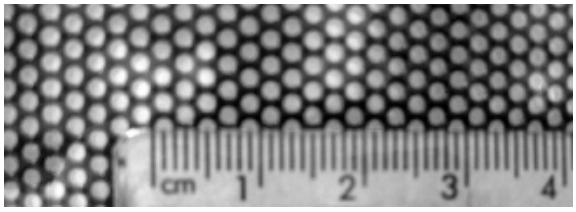
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Wavelength = ...

(iii) The photograph shows a section of the microwave oven door. Use the photograph to determine the diameter of the holes.



(1)

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Diameter = ...

*(iv) Discuss the suggestion that, due to diffraction effects, light can pass through the holes but microwaves cannot.

(3)

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Q4.

In everyday life the effect of diffraction is more significant for sound than for light.

This is because

☒ **A** light has a much shorter wavelength than sound.

☒ **B** light is a transverse wave but sound is a longitudinal wave.

☒ **C** light is an electromagnetic wave but sound is a mechanical wave.

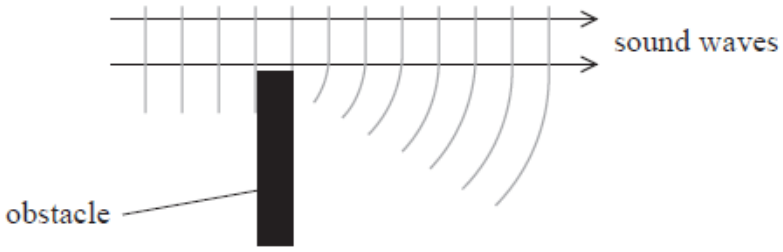
☒ **D** the speed of light in air is much higher than the speed of sound.

(Total for question = 1 mark)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Sound waves can diffract around obstacles as shown in the diagram.



The diffraction effect is

☒ **A** greater for large amplitude sound waves.

☒ **B** greater for low frequency sound waves.

☒ **C** independent of the frequency of the sound waves.

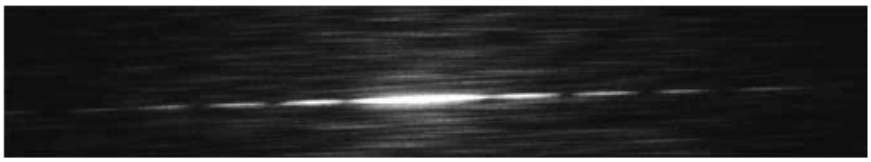
☒ **D** independent of the speed of the sound waves.

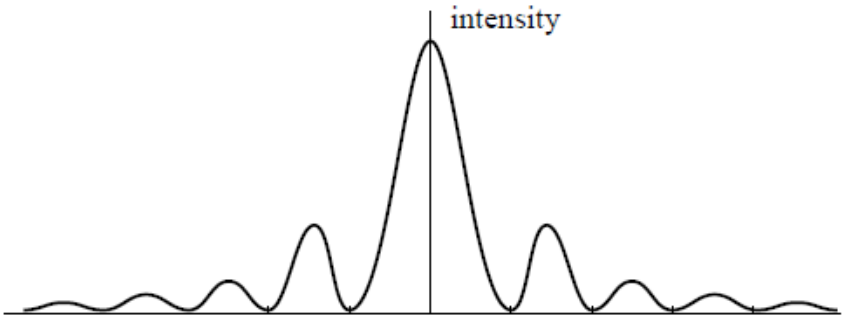
(Total for question = 1 mark)

Q6.

A student obtains the following diffraction pattern on a wall by shining a red laser beam through a single narrow slit.

The corresponding graph of intensity against position is shown below.





(a) Explain how the diffraction pattern is created.

(3)

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(b) Explain how the pattern would differ if green laser light were used instead of red laser light.

(3)

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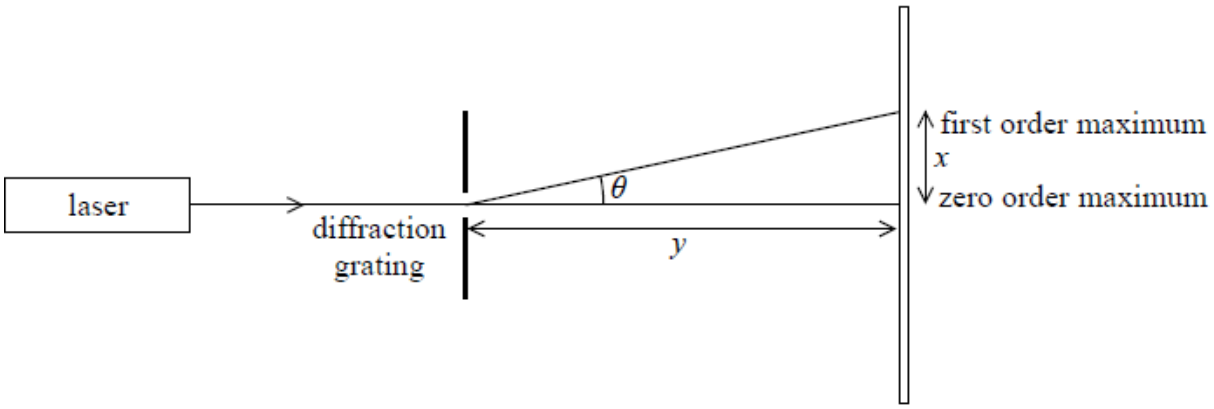
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(c) A student replaces the single slit with a diffraction grating and obtains the pattern shown in the photograph.



The photograph shows the zero order maximum and the first and second orders on either side.

The student takes measurements to determine the grating spacing.



The student measures x, the distance between the zero order maximum and the first order maximum, and y, the distance between the slit and the screen.

x = 23 cm
y = 1.5 m
Number of lines per millimetre = 300

Calculate the wavelength of light from the laser.

(3)

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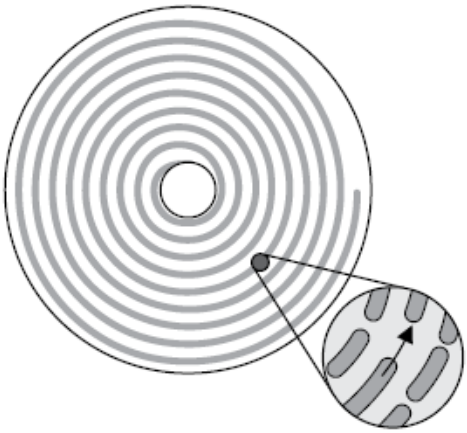
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Wavelength = ...

(Total for question = 9 marks)

Q7.

* The light from a lamp is reflected from the surface of a CD, which consists of a spiral track of elongated bumps.



CD surface showing spiral track of bumps with a smooth reflective surface in between.

(Source: http://gantisreerajiv.blogspot.co.uk/2012/04/you-cant-imagine-world-if-there-are.html:)

A physics student notices that although the light from the lamp is white, different colours are seen in the reflected light. He suggests that the colours are produced when diffraction occurs at the surface of the CD.

Discuss the extent to which the student's suggestion explains the presence of colours in the light reflected from the surface of the CD.

(6)

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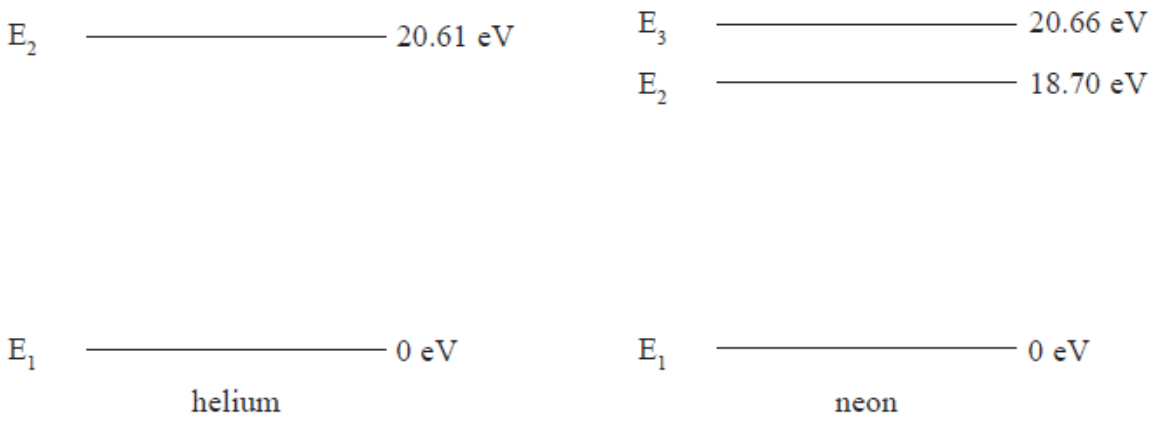
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(Total for question = 6 marks)

Q8.

A helium-neon gas laser is often used in the laboratory as a source of high intensity, coherent, monochromatic light.

The diagram shows some of the energy levels above the ground level E_3 for helium atoms and for neon atoms. The highest shown levels for helium atoms and neon atoms are almost identical.



Helium atoms in the gas are excited to level E_2 by the current passing through the laser. They collide at high speed with neon atoms. Because the energies are so similar, the energy is transferred from the helium atoms to the neon atoms. The neon atoms become excited in turn to level E_3. As the neon atoms subsequently drop to level E_2 they emit photons.

(a) Explain what is meant by a photon.

(2)

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(b) Calculate the frequency of the photons produced as the neon atoms drop from level E_3 to level E_2.

(3)

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Frequency = ...

(c) An electron in level E_3 of neon has 0.05 eV more energy than an electron in level E_2 of helium.

Suggest the source of the energy to make up this difference.

(1)

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(d) The photograph shows a device for making a vertical slit with variable width.



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When the slit is fully open a laser beam is shone through it and a single point of light is seen on a screen.

As the slit is reduced in width the point of light becomes a horizontal line that gets longer as the slit gets narrower.

Explain this observation

(3)

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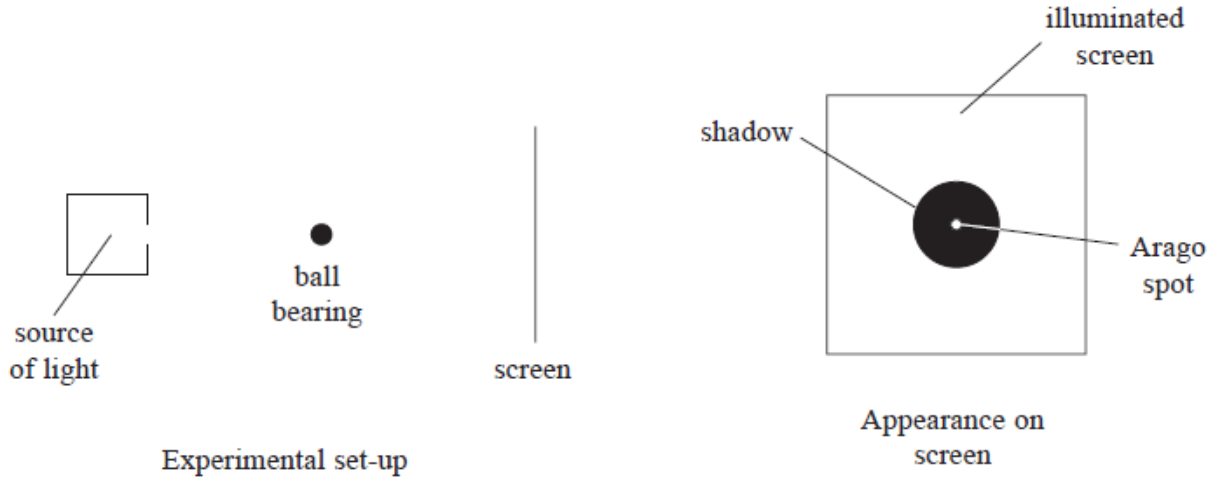
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(Total for question = 9 marks)

Q9.

The diagram shows a coherent beam of light incident on a metal ball bearing.

A dark shadow is seen on a screen behind the ball bearing. There is a small spot of light in the centre of the shadow. This spot of light is known as the Arago spot.



(a) Use Huygens' construction to explain the behaviour of light as it travels past the edge of the ball bearing.

(2)

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(b) Explain why a spot of light is produced at the centre of the shadow.

(3)

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(Total for question = 5 marks)

Q10.

Light can be modelled as a wave.

Diffraction provides evidence for the wave nature of light.

Use Huygens' construction to describe what happens to light waves after passing through a narrow gap.

(3)

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(Total for question = 3 marks)

Q1.

In an experiment to determine the wavelength of light, a diffraction grating is illuminated with light from a monochromatic source. A series of bright spots is observed.

The experiment is repeated and the distance between consecutive bright spots increases.

Select the row of the table that gives two changes to the experimental set up which would both cause the distance between consecutive bright spots to increase.

(1)

	Number of slits per mm in the diffraction grating	Wavelength of the light source
☐ **A**	Increased	Increased
☐ **B**	Increased	Decreased
☐ **C**	Decreased	Increased
☐ **D**	Decreased	Decreased

(Total for question = 1 mark)

Q2.

In 1905 Einstein published his equation for the photoelectric effect.

In 1916 Millikan demonstrated that the maximum kinetic energy of photoelectrons is consistent with Einstein's equation.

Millikan used a device known as a monochromator to ensure that a single wavelength of light was used to illuminate the surface of the lithium.

A monochromator separates wavelengths using a diffraction grating.

Calculate the angle at which a diffraction grating would produce the most intense line at a single wavelength of 6.1×10^{-7} m.

number of lines per mm for grating = $600\,\text{mm}^{-1}$

(3)

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Angle = ...

(Total for question = 3 marks)

Q3.

Read the extract and answer the question that follows.

In the 17th century there were two proposed theories to explain the refraction of light. Using a wave model, Huygens stated that light slows down when it passes from air to water. Using a particle model, Newton stated that light speeds up when it passes from air to water. Newton's theory was more readily accepted until the speed of light in water was measured in the 19th century.

In the early 20th century, Einstein used observations from the photoelectric effect to provide evidence for the particle model of light.

Nowadays, both the wave model of light and the particle model of light are accepted, as each can be used to explain different aspects of the behaviour of light.

Diffraction and interference can be explained using the wave model of light.

In an investigation to determine the wavelength of light from a laser, the light passed through a diffraction grating with 300 lines per millimetre.
A diffraction pattern consisting of a series of bright dots was observed on a screen.

The following data were recorded:

distance between grating and screen = 2.00 m
distance from central maximum to 2^{nd} order maximum = 89.0 cm.

Calculate the wavelength of light from the laser.

(3)

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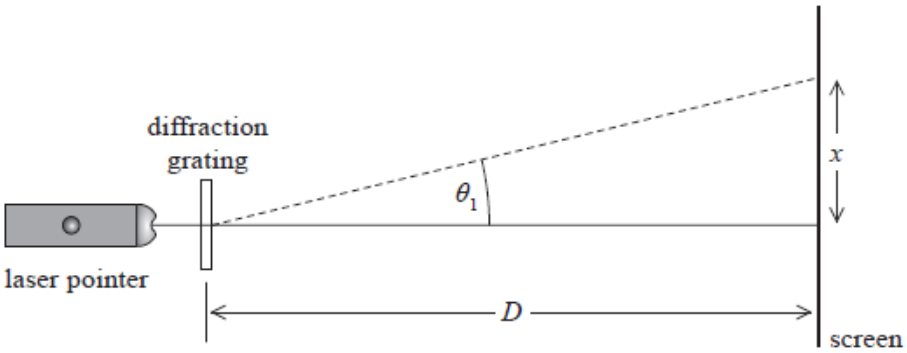
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Wavelength = ...

(Total for question = 3 marks)

Q4.

Light from a laser pointer was passed through a diffraction grating. The light was perpendicular to the diffraction grating as shown. A diffraction pattern was produced on a screen.



The distance between the first order maximum and the central maximum of the diffraction pattern was x. The distance between the diffraction grating and the screen was D.

Distance x was measured to be 0.500 m with a metre rule. The wavelength of light λ_1 from the laser pointer was 650 nm.

The laser pointer was replaced with one that produced light of a different wavelength. The new distance x was measured to be 0.400 m.

D = 1.45 m

Calculate the wavelength λ_2 of the light emitted by the replacement laser pointer.

(5)

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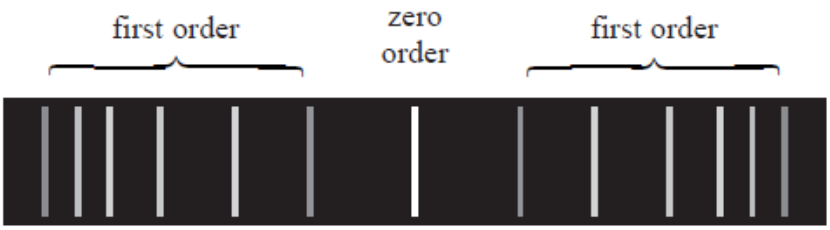
λ_2 = ...

(Total for question = 5 marks)

Q5.

In a spectrometer, light from a tube of hot gas is passed through a diffraction grating.

The diagram shows the zero order and the first order maxima for the line spectrum produced.



(a) The spectrometer measures the angles between the different lines and the zero order. One of the lines has a wavelength of 650 nm and is observed, in the first order spectrum, at an angle of 19.9° from the zero order.

Calculate the number of lines per metre of the diffraction grating.

(3)

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Number of lines per metre = ...

(b) Explain one precaution that could be taken to ensure the accuracy of the measurement of the angle.

(2)

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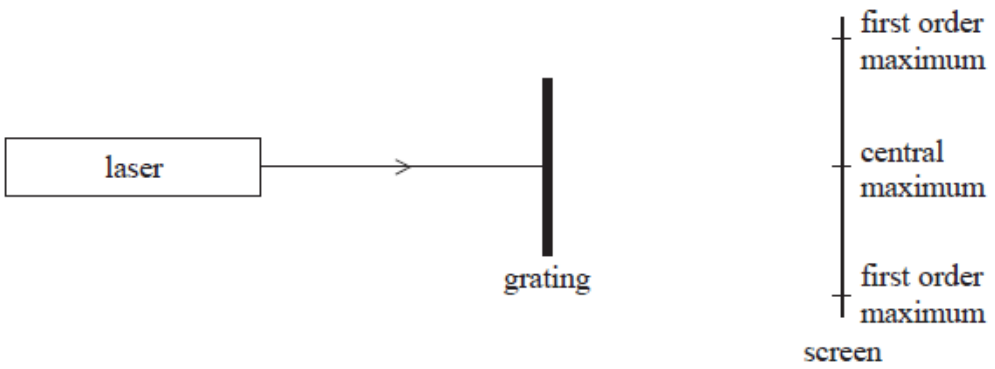
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Q6.

A beam of light from a laser is directed at a diffraction grating.

The diagram shows the positions of the central maximum and the first order maxima on a screen.



Which of the following would cause the first order maxima to be closer to the central maximum on the screen?

(1)

☒ **A** moving the laser closer to the grating

☒ **B** moving the screen further from the grating

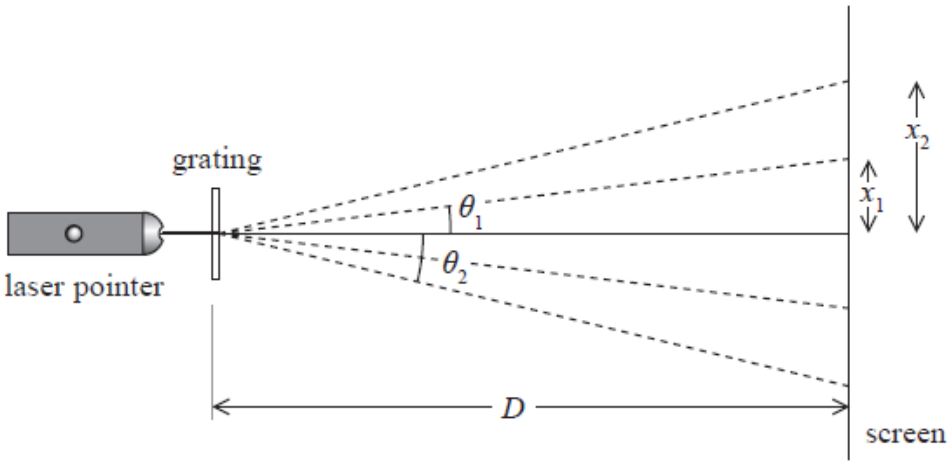
☒ **C** using a grating with more lines per metre

☒ **D** using laser light with a higher frequency

(Total for question = 1 mark)

Q7.

A student is using a diffraction grating to determine the wavelength of the light emitted by a laser pointer. The light from the laser pointer is directed so that it is normal to the plane of the grating. The diffracted light is viewed on a screen a distance *D* from the grating.



The diagram shows the first two diffracted orders where x_1 and x_2 are the distances of the maxima for these orders from the central maximum of the diffraction pattern.

(a) Before carrying out the experiment, the student carries out a risk assessment to ensure that the experimental procedure is safe.

Explain one precaution that should be taken.

(2)

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(b) The student measures the distances from the central maximum of the diffraction pattern for various diffracted orders *n*, using a metre rule.

n	x_n / cm	θ / °	sin θ
0	0	0.00	0.000
1	35.5	11.4	0.20
2	74		
3	126.5	35.9	0.586
4	211	50.4	0.771

(i) Criticise the results that are recorded.

(1)

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(ii) Complete the data for the 2nd order maximum.

D = 1.750 m

(2)

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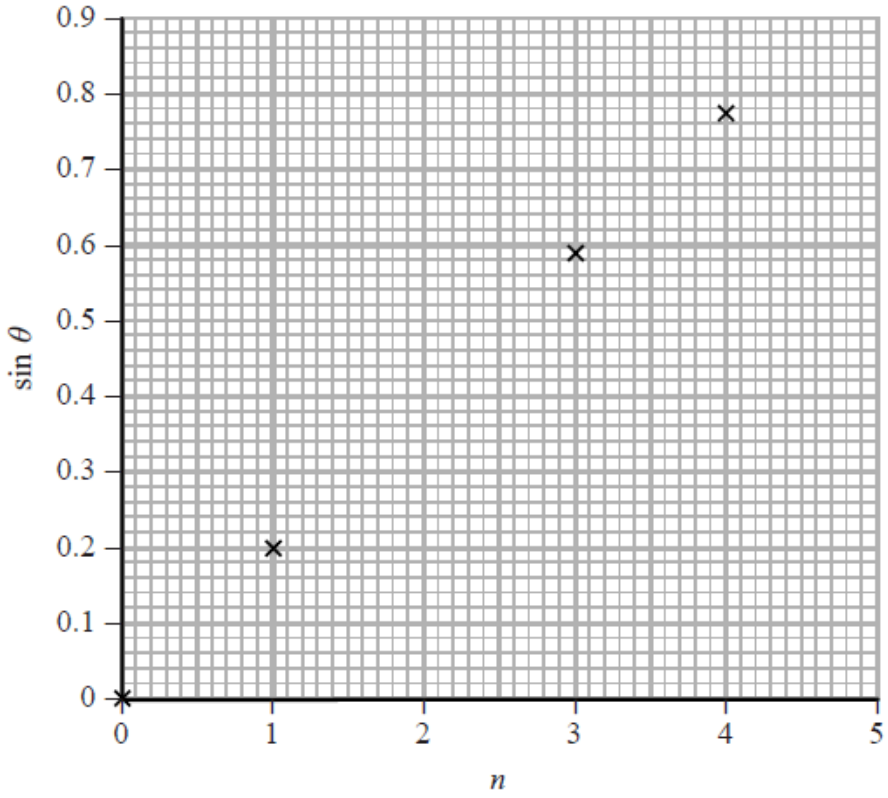
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(iii) Add your data to the axes and draw a line of best fit.

(1)



(iv) Use your graph to determine a value for the wavelength of the laser light.
The grating has 300 lines per mm

(5)

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Wavelength = ...

(c) State and justify two modifications to the experimental method which would have improved the accuracy of the value obtained for the wavelength.

(4)

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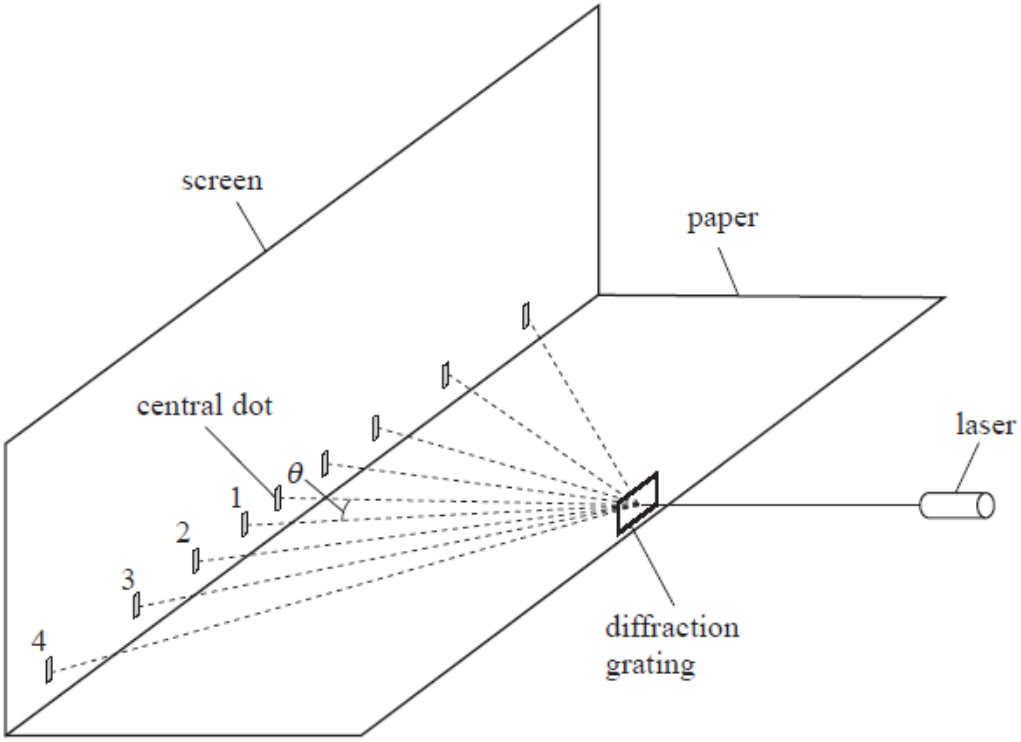
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(Total for question = 15 marks)

Q8.

The arrangement shown was used to determine the wavelength of light emitted by a laser.



A laser light beam was shone at a diffraction grating. A series of dots of light was produced on a screen. The angles θ between the light ray to the central dot and the light rays to the dots labelled 1 to 4 were measured with a protractor.

n	θ / °	$\sin\theta$
1	12	0.21
2	23	0.39
3	34	0.56
4	51	0.78

(a) Describe how the angle θ could be determined without using a protractor.

(2)

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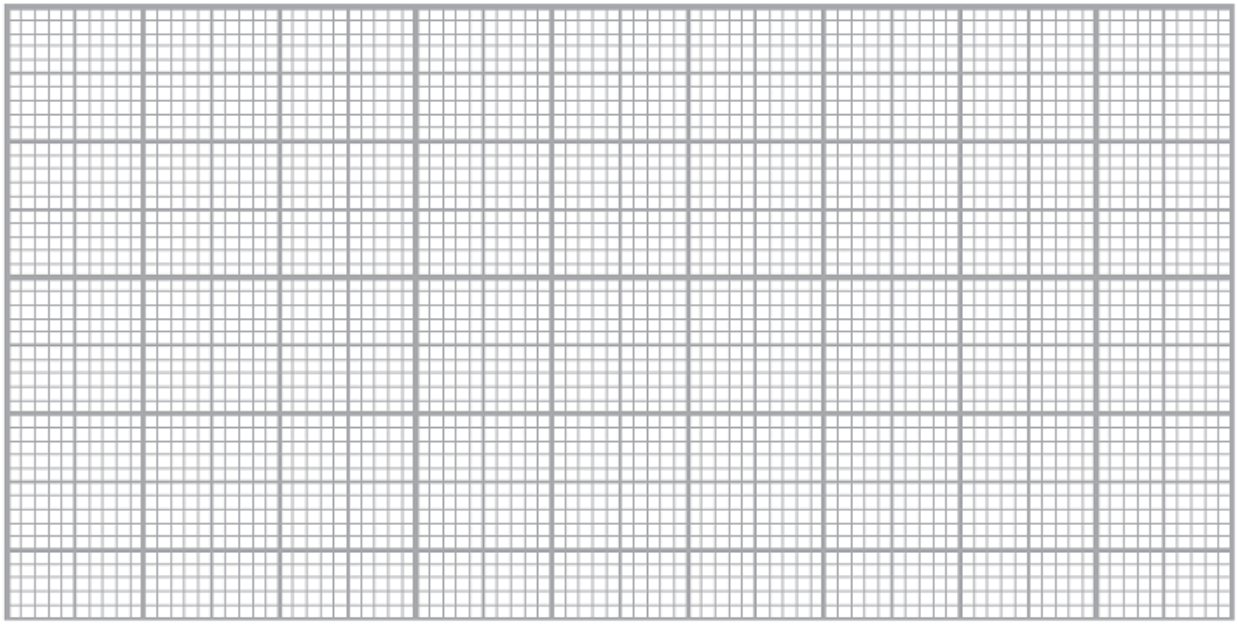
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(b) Plot a graph of n against $\sin\theta$ on the grid below.

(4)



(c) The diffraction grating has 300 lines mm^{-1}.

Determine the wavelength of the laser light.

(4)

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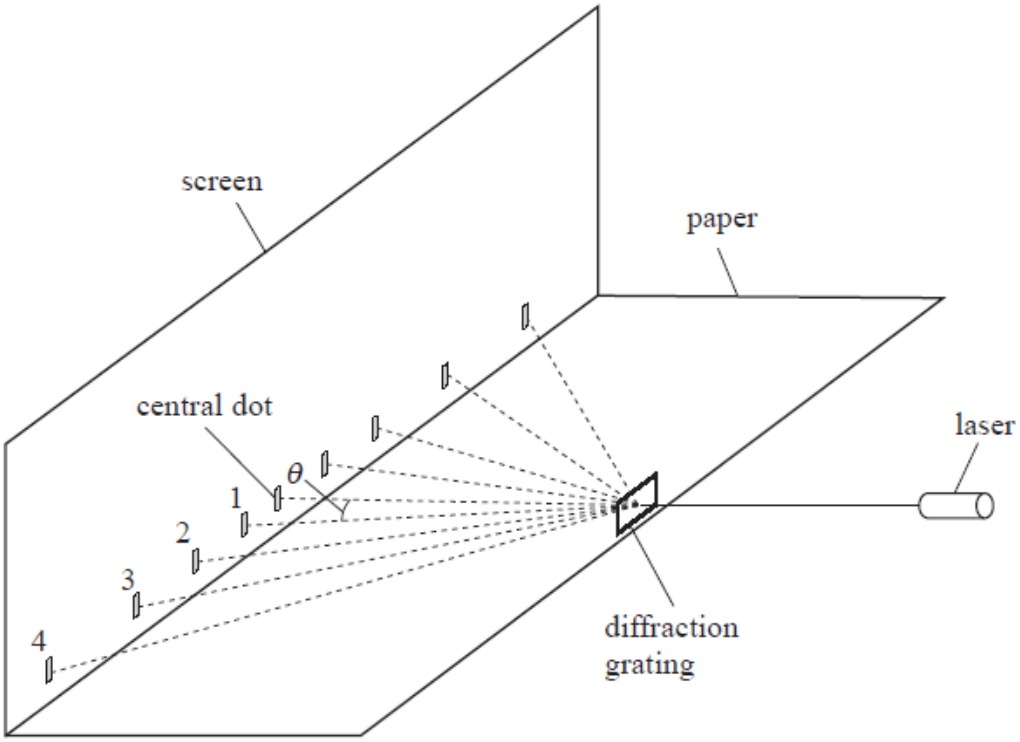
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Wavelength = ...

(Total for question = 10 marks)

Q9.

The arrangement shown was used to determine the wavelength of light emitted by a laser.



A laser light beam was shone at a diffraction grating. A series of dots of light was produced on a screen. The angles θ between the light ray to the central dot and the light rays to the dots labelled 1 to 4 were measured with a protractor.

n	θ / °	$\sin\theta$
1	12	0.21
2	23	0.39
3	34	0.56
4	51	0.78

The diffraction grating has 300 lines mm^{-1}.

Determine the wavelength of the laser light.

(4)

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Wavelength = ...

(Total for question = 4 marks)

Q10.

Barnard's star is a red dwarf star in the vicinity of the Sun. The wavelength of a line in the spectrum of light emitted from Barnard's star is measured to be 656.0 nm. The same light produced by a source in a laboratory has a wavelength of 656.2 nm.

A diffraction grating can be used to analyse the radiation emitted by a variety of sources.

(i) A diffraction grating of known grating spacing is used in a school laboratory to analyse the light emitted by a laser.

Describe how the diffraction grating is used and the measurements that should be taken.

(3)

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(ii) A diffraction grating with grating spacing of 2.2×10^{-6} m is used to determine the difference in wavelength for the spectral line emitted by Barnard's star.

Comment on the suitability of using a diffraction grating with this spacing. You should include appropriate calculations.

(4)

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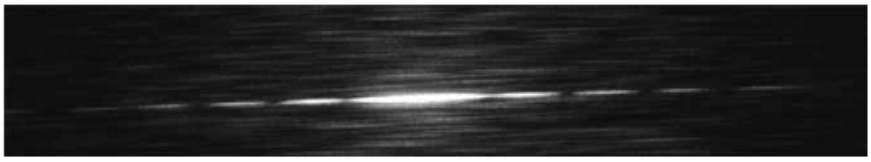
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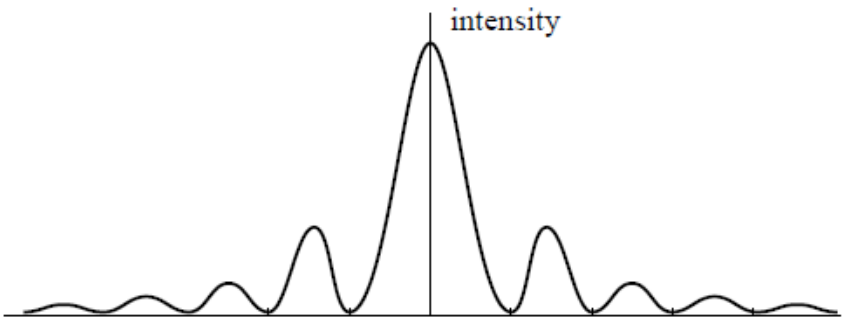
(Total for question = 7 marks)

Q11.

A student obtains the following diffraction pattern on a wall by shining a red laser beam through a single narrow slit.

The corresponding graph of intensity against position is shown below.





(a) Explain how the diffraction pattern is created.

(3)

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(b) Explain how the pattern would differ if green laser light were used instead of red laser light.

(3)

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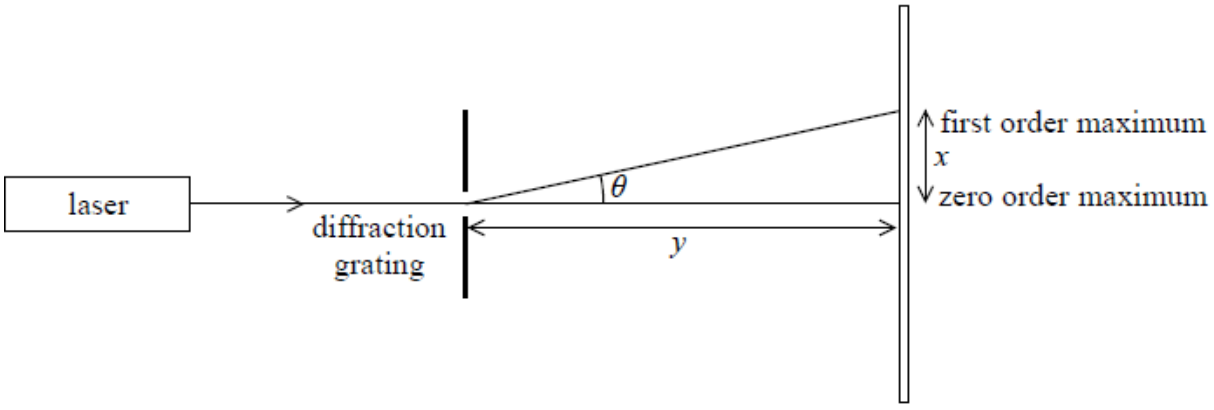
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(c) A student replaces the single slit with a diffraction grating and obtains the pattern shown in the photograph.



The photograph shows the zero order maximum and the first and second orders on either side.

The student takes measurements to determine the grating spacing.



The student measures x, the distance between the zero order maximum and the first order maximum, and y, the distance between the slit and the screen.

x = 23 cm
y = 1.5 m
Number of lines per millimetre = 300

Calculate the wavelength of light from the laser.

(3)

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Wavelength = ...

(Total for question = 9 marks)

Q12.

The diffraction of light provides evidence for the wave theory of light.

A student carried out an investigation to determine the wavelength of the light emitted from a laser pen.

He shone the light from the laser pen so that it was incident perpendicularly on a diffraction grating. The diffraction grating had 200 lines per mm. He observed the diffraction pattern on a screen 3.00 m away from the grating. The pattern consisted of a series of bright dots.



(i) Give a reason why a laser is a suitable source of light to produce a diffraction pattern.

(1)

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(ii) The student measured a distance of 102 cm between the central maximum and the centre of a third order maximum.

The table shows the range of wavelengths for each colour of the visible spectrum.

Colour	Range of wavelength / nm
violet	380 – 450
blue	450 – 495
green	495 – 570
yellow	570 – 590
orange	590 – 620
red	620 – 750

Deduce the colour of the light emitted from the laser pen.

(5)

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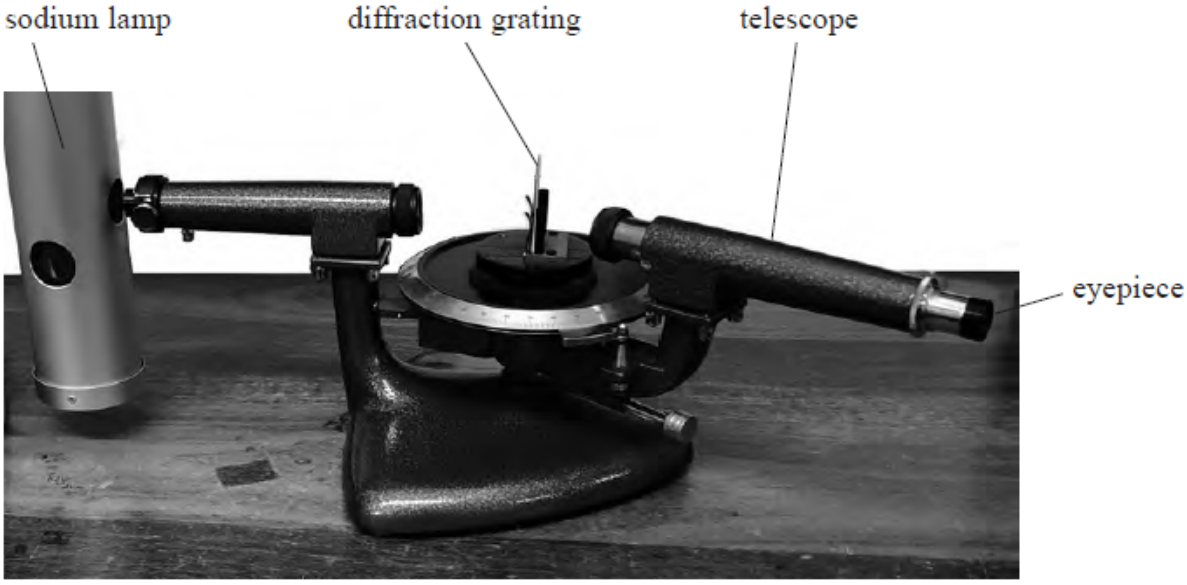
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(Total for question = 6 marks)

Q13.

The photograph shows a school spectrometer.



The spectrometer allows parallel rays of light to be passed through a diffraction grating and the resulting angles of diffraction to be measured.

The spectrometer and diffraction grating are used to analyse the light from a sodium lamp. In the sodium lamp, sodium is heated until it becomes a vapour and an electric current is passed through it. The vapour then emits light.

After the light passes through the diffraction grating a line spectrum is observed.

(i) Explain why only certain wavelengths are observed.

(6)

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(ii) Diffraction gratings with the following spacings are available:

$d / 10^{-6}$ m	1.0	1.7	2.0	3.3

Explain which would be the best spacing to use to measure the diffraction angle for the third order maximum for yellow light of wavelength 589 nm.

(3)

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(Total for question = 9 marks)

Q14.

An electron beam is directed onto crystalline graphite. A fluorescent screen on the other side of the crystal shows the pattern in Figure 1. The brighter areas correspond to higher electron intensity.

The speed of the electrons is increased and the resulting pattern is shown in Figure 2.

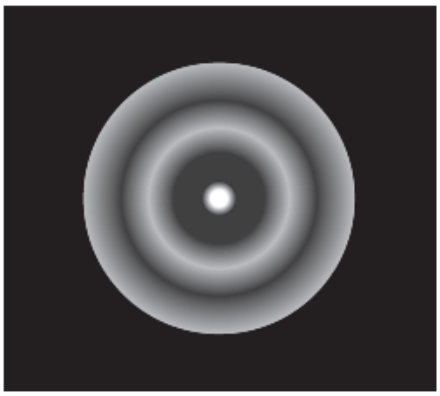


Figure 1



Figure 2

* Discuss the conclusions that can be drawn from this information about the behaviour of electrons and the structure of graphite.

(6)

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(Total for question = 6 marks)

Q15.

A monochromatic beam of light of wavelength λ from a laser is directed at a diffraction grating of line spacing *d*.

A student calculates the value of d/λ in order to determine the expected number of visible maxima.

The calculated value of d/λ is 4.7

How many maxima are visible?

☒ **A** 4

☒ **B** 5

☒ **C** 9

☒ **D** 11

(Total for question = 1 mark)