

8 A converging lens can be used to produce a real image on a screen.

- (a) A converging lens of focal length 15.0 cm is used to project an image of an illuminated object onto a screen. The object is a circle of diameter 4.0 mm and the image must be as large as possible on a screen of size 0.75 m by 1.25 m.

Calculate the distance between the lens and the screen for this image to be displayed.

(3)

Distance between lens and screen =

- (b) A magazine article includes the statement:

If the distance from the lens to the screen is doubled, the brightness of the image is halved.

Assess the validity of this statement.

(2)

(Total for Question 8 = 5 marks)

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9 A student has been learning about the photoelectric effect.

(a) The student was asked by his teacher to explain the photoelectric effect. He gave the following explanation:

Light above a certain threshold is able to free electrons from a metal, because the light gives energy to electrons in the metal.

Some of this energy is used to release the electrons from the metal and the rest becomes kinetic energy of the freed electron.

Discuss whether the student's answer fully explains the photoelectric effect.

(4)

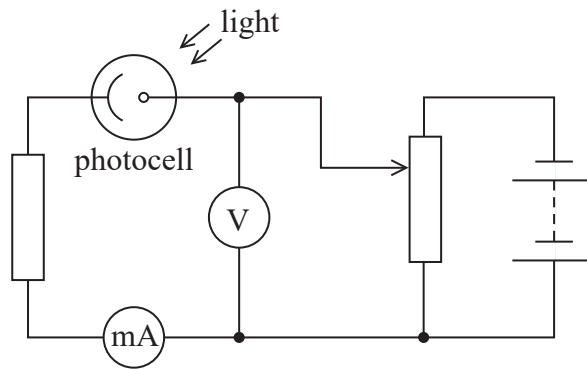
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(b) The student sets up a circuit to investigate the photoelectric effect.



The student illuminates the photocell with light of known frequency f . A current is produced in the circuit due to the emitted electrons. He adjusts the potential difference, using a potential divider, until the reading on the milliammeter is zero and records the corresponding reading V_s on the voltmeter. He repeats this procedure for other frequencies of light.

When the reading on the milliammeter is zero the maximum kinetic energy of the emitted electrons is given by eV_s .

Explain how the student can use his results to determine a value for the Planck constant h using a graphical method.

(5)

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(c) This experiment demonstrates the particle nature of light.

Explain what is meant by the particle nature of light.

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(Total for Question 9 = 11 marks)

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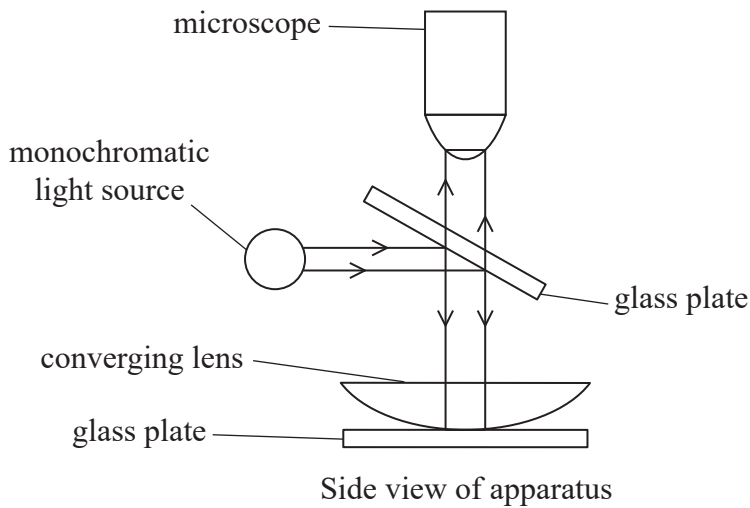
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- 13 A method to determine the wavelength of light using a converging lens was first proposed by Sir Isaac Newton.

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.



Pattern seen through microscope

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The diameter D of each circular fringe, numbered N from the centre, is measured using the microscope. The data obtained from such an experiment is shown.

N	D / mm		
1	5.13		
2	7.08		
3	8.71		
4	10.23		
5	11.48		

- (a) The relationship between N and D is of the form $D = pN^q$ where p and q are constants.

Determine p and q for this data using a graphical method. Use the additional columns for your processed data.

(8)

$p =$

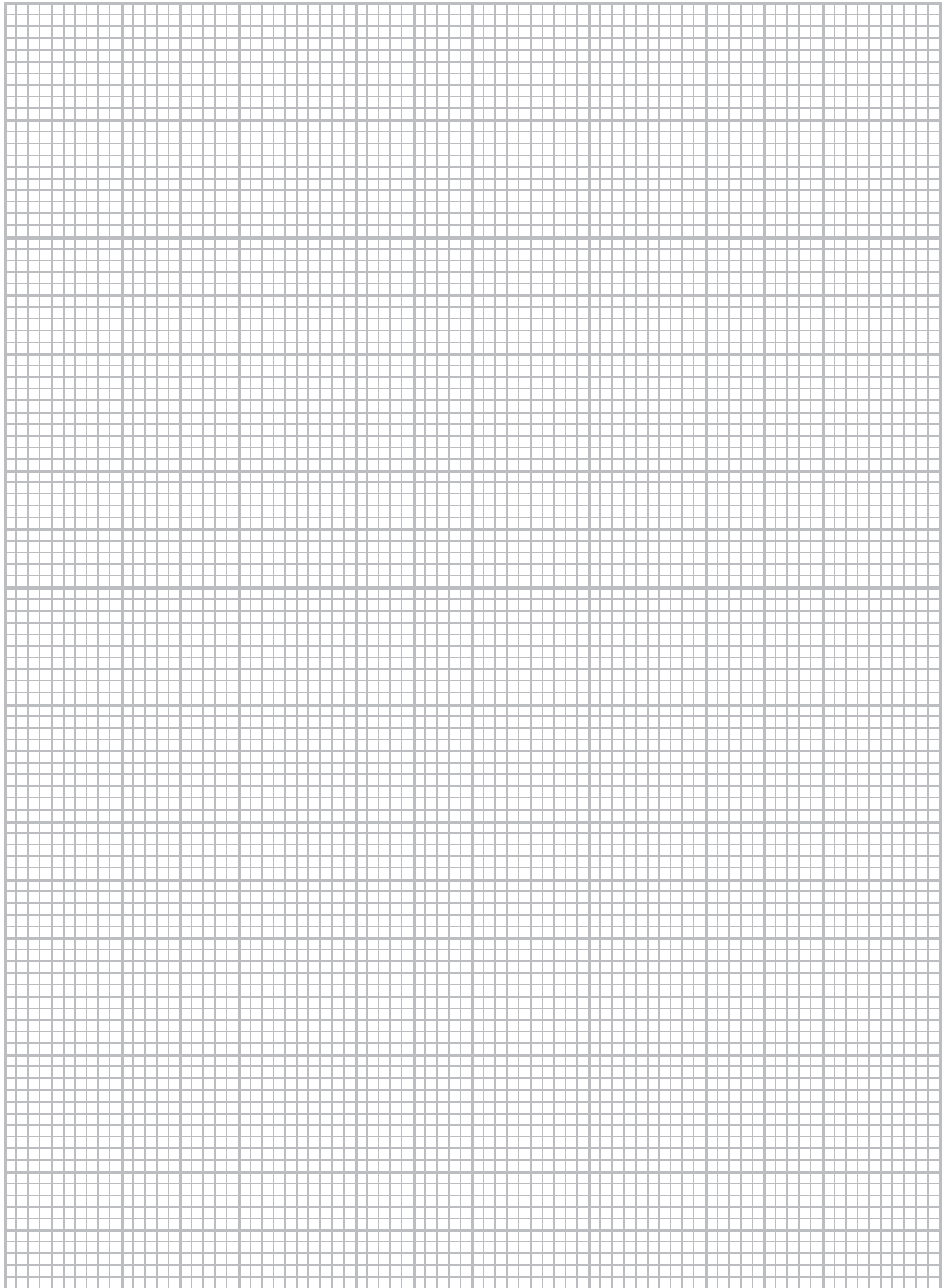
$q =$



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- (b) The table below shows the readings from which the diameter of the first dark circle was calculated.

Position of left-hand side of circle / mm	Position of right-hand side of circle / mm	Diameter / mm
54.79	49.66	5.13

- (i) Use these readings to estimate the percentage uncertainty in the diameter due to the resolution of the instrument.

(2)

Percentage uncertainty =

- (ii) State why the actual percentage uncertainty would have been greater than the value calculated in (b)(i).

(1)



- (c) 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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(Total for Question 13 = 15 marks)

TOTAL FOR PAPER = 120 MARKS

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- 4 A student carried out an experiment to determine the focal length of a converging lens.

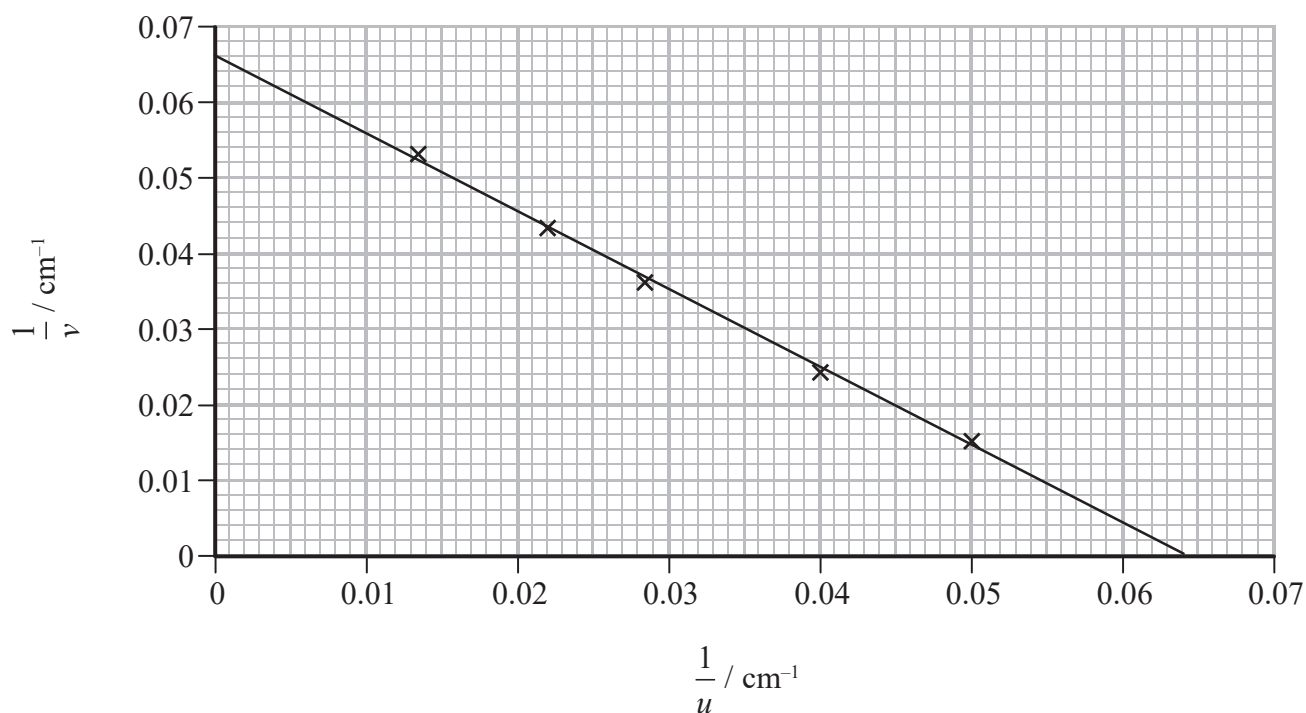
He placed the lens a distance u from an illuminated object. He placed a screen on the other side of the lens and moved the screen until a sharp image of the object was produced. He measured the corresponding image distance v .

The student repeated the procedure for four more values of u .

In his lab report he wrote:

"I made an initial determination of the focal length of the lens and concluded that it was about 15 cm. When I plotted a graph it confirmed my initial determination of the lens focal length."

The student's graph is shown.



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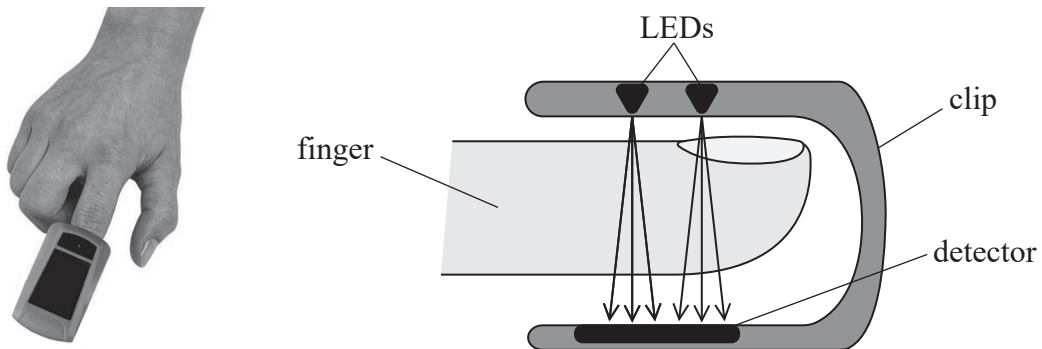
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- 5 An oximeter is a device used in hospitals to monitor the oxygen level in a patient's blood.

In an oximeter, two light-emitting diodes (LEDs) are mounted opposite light sensors in a clip and attached to the patient's finger. One of the LEDs produces red light and the other produces infrared.



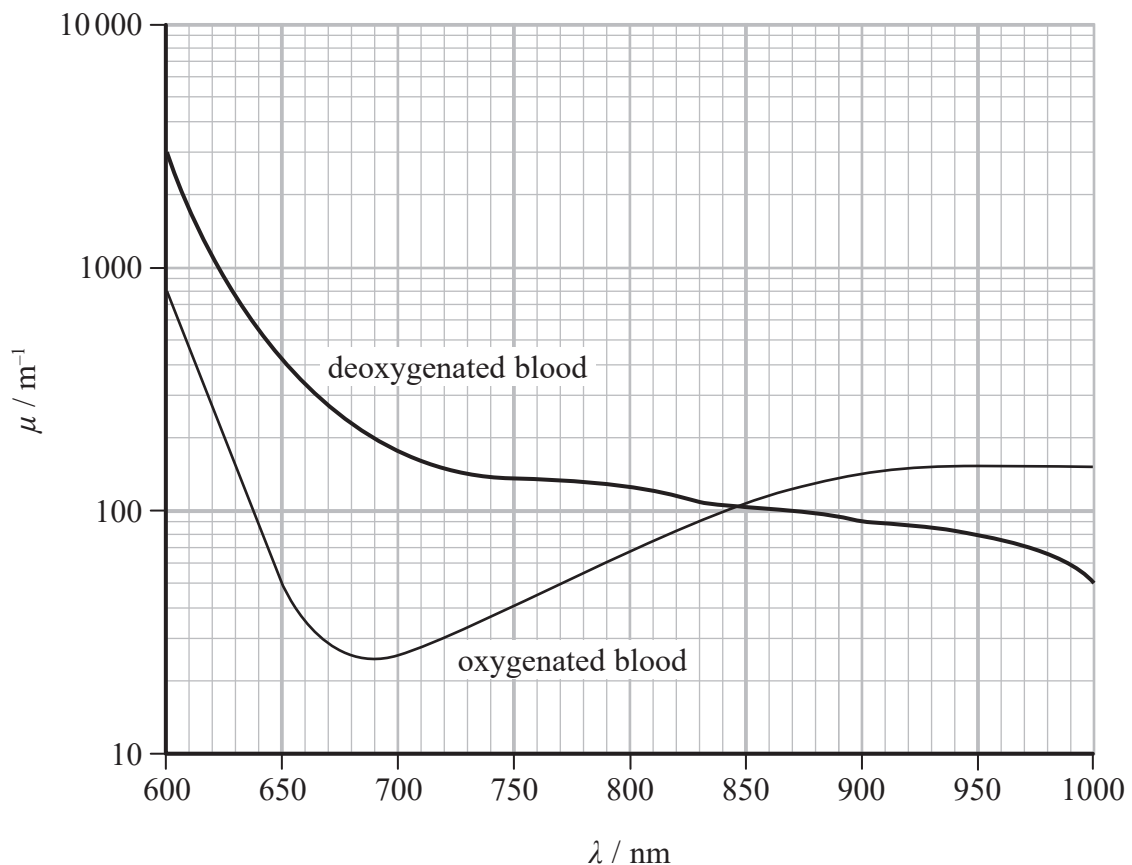
The intensity I of electromagnetic radiation received by the detector, after passing through a thickness x of blood, is given by

$$I = I_0 e^{-\mu x}$$

where I_0 is the intensity that would have been received if the blood were not present and μ is the attenuation coefficient of blood.

The red LED emits visible light of wavelength 650 nm and the infrared LED emits infrared of wavelength 950 nm.

The graph shows how μ varies with wavelength λ for oxygenated blood and deoxygenated blood.



(a) I_0 for the infrared LED is 1.8 W m^{-2} .

Calculate I for the infrared after passing through 1.4 mm of oxygenated blood.

(3)

$I = \dots\dots\dots$

(b) The oximeter determines I/I_0 the fraction of radiation transmitted at each wavelength.

Deduce whether I/I_0 will be smaller for the red or the infrared radiation if the blood is deoxygenated.

(3)

It is suggested that ambient light could affect the readings produced by the oximeter.

Halogen lamps have a filament temperature of 3200 K.

(c) Deduce whether the light from such a lamp would have a significant effect on the oximeter readings.

(3)

(Total for Question 5 = 9 marks)

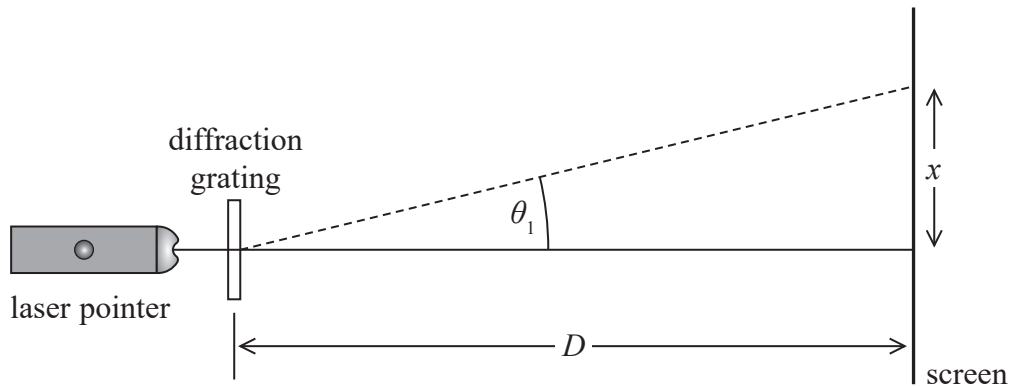


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- 11 Light from a laser pointer was passed through a diffraction grating. The light was perpendicular to the diffraction grating as shown. A diffraction pattern was produced on a screen.



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 .

- (a) 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.

$$D = 1.45 \text{ m}$$

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

(5)

$$\lambda_2 = \dots\dots\dots$$

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(b) Explain one modification to this method that would decrease the uncertainty in the calculated value of λ_2 . (2)

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(c) In another experiment, the light from the laser pointer was not quite perpendicular to the screen.
Explain how this would change the diffraction pattern produced on the screen. (3)

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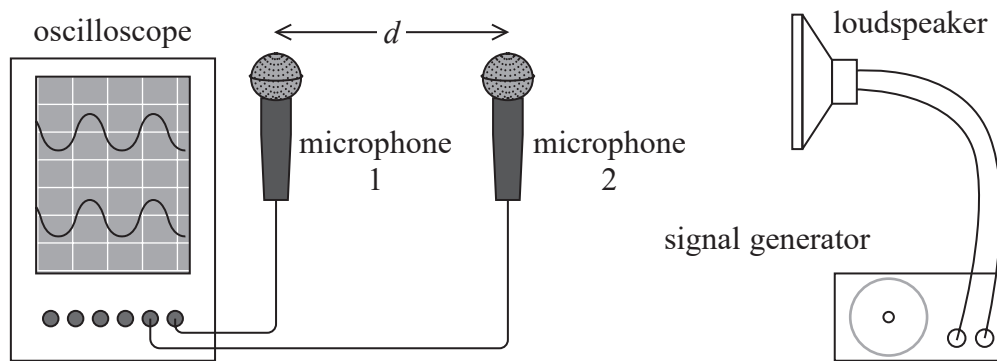
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(Total for Question 11 = 10 marks)

TOTAL FOR PAPER = 120 MARKS



- 6 In an experiment to determine the speed of sound in air a student connected two microphones to an oscilloscope, as shown.



The microphones detect sound from the loudspeaker, converting it to an electrical signal. The signal is displayed on the oscilloscope screen.

Both microphones were initially positioned the same distance from the loudspeaker. The two signals were in phase on the oscilloscope screen. The student slowly moved microphone 2 towards the loudspeaker, until the two signals on the oscilloscope were in phase again. He then measured the distance d between the microphones to determine the wavelength λ of the sound waves.

$$d = 20.5 \text{ cm}$$

- (a) Comment on the student's experimental technique to determine λ .

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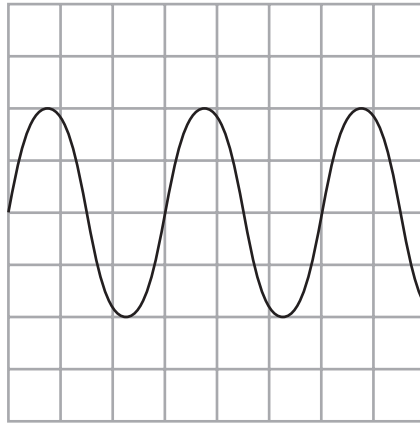
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(b) The oscilloscope trace for the signal from microphone 1 is shown below.



The time base of the oscilloscope was set to 0.20 ms div^{-1} .

Determine a value for the speed of sound in air.

(5)

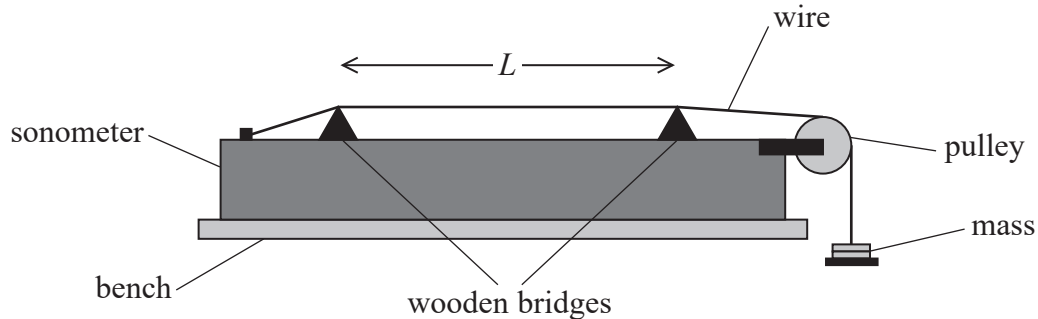
Speed of sound =

(Total for Question 6 = 7 marks)



- 13 A student used a sonometer to investigate the properties of a stretched wire. The sonometer is a long hollow wooden box.

A steel wire is attached to one end of the box and rests on two wooden bridges. The wire is placed under tension T by hanging a mass from the end of the wire, as shown.



The student placed the base of a vibrating tuning fork in contact with the wire, at one of the bridges. This set the wire into oscillation. He adjusted the position of the other bridge until a single-loop standing wave was produced on the wire between the bridges.

- (a) Explain how an antinode is produced at the mid-point of the wire between the bridges.

(3)

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- (b) The student repeated this for a series of tuning forks with different frequencies f .
For each fork he measured the distance L between the bridges.

The steel wire, of mass per unit length μ , was placed under tension T by hanging a mass of 2.10 kg from the end of the wire.

- (i) State one safety precaution that should be taken when carrying out the investigation.

(1)

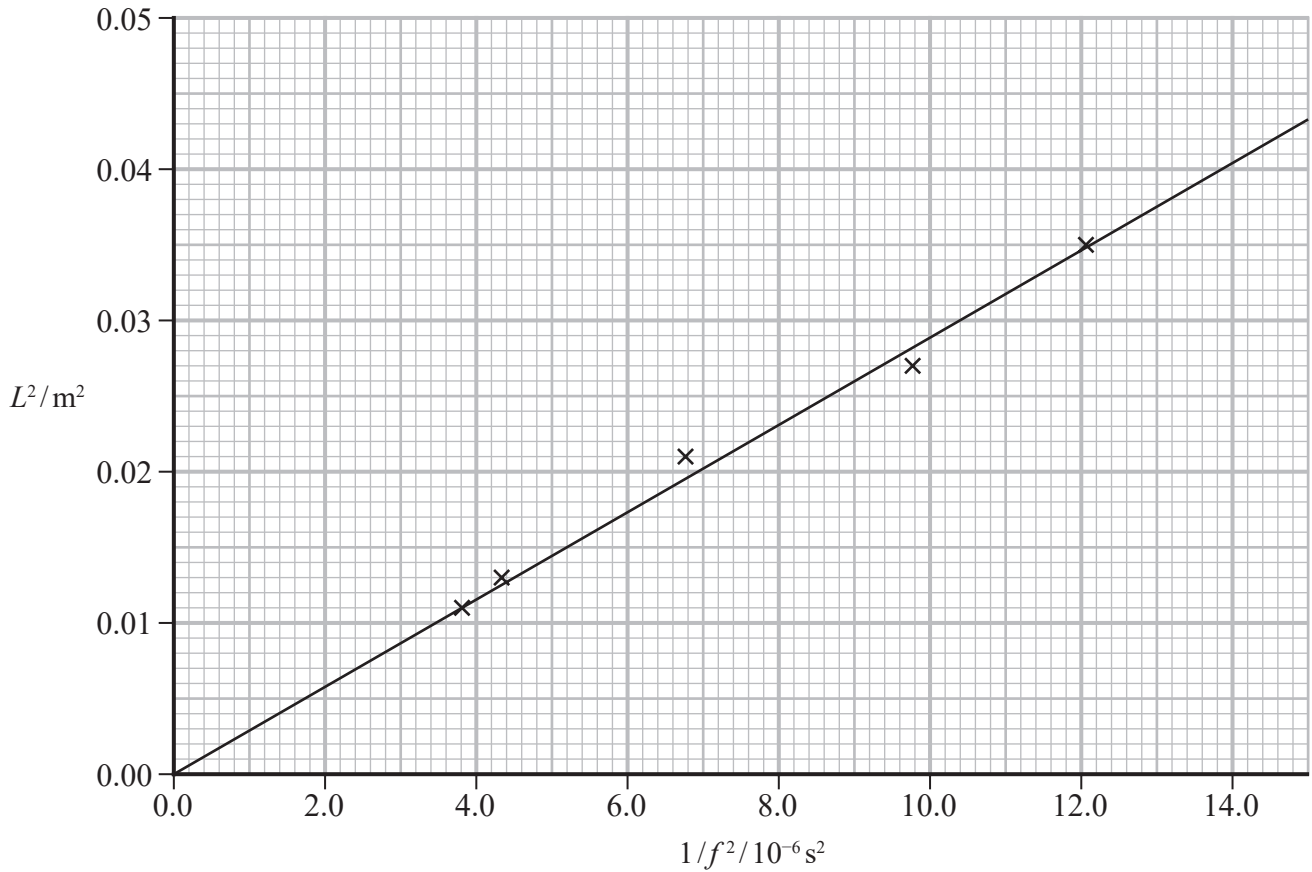
- (ii) The student plotted a graph of L^2 against $1/f^2$.

Show that the gradient of this graph is equal to $\frac{T}{4\mu}$

(3)



(iii) The student's graph is shown below.



The value of μ for different standard wire gauge (SWG) steel wire is shown in the table.

SWG	$\mu/\text{g m}^{-1}$
22	3.15
24	1.95
26	1.31

Deduce which wire the student used in the investigation.

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(c) The student then found a value of μ for a brass wire, using a different method.

(i) He measured the diameter d of the wire using a micrometer.

Explain one technique the student should use when measuring d .

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(ii) The student obtained the following data.

d/mm			
0.55	0.59	0.57	0.58

The stated value of μ for the brass wire used by the student was $2.14 \times 10^{-3} \text{ kg m}^{-1}$.

Deduce whether the student's data supports this value for μ .

density of brass = $8700 \text{ kg m}^{-3} \pm 200 \text{ kg m}^{-3}$

(6)

(Total for Question 13 = 19 marks)

TOTAL FOR PAPER = 120 MARKS

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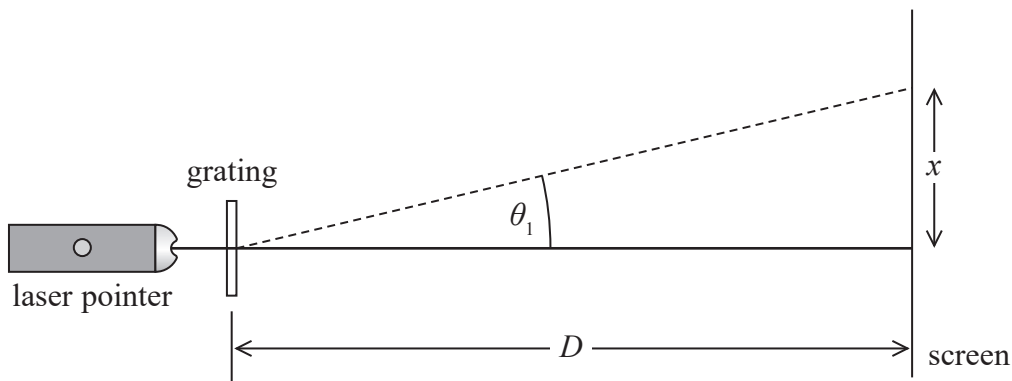
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P 6 9 4 4 4 A 0 3 1 3 6

Answer ALL questions in the spaces provided.

- 1 A student used a laser pointer to direct monochromatic light normal to the plane of a diffraction grating as shown.



A diffraction pattern was produced on the 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 .

- (a) The diffraction grating had 300 lines per mm.
The laser pen was marked with $\lambda = 520 \text{ nm}$.

Determine whether the spacing of the diffraction pattern was consistent with these values.

$$x = 43.5 \text{ cm}$$

$$D = 2.75 \text{ m}$$

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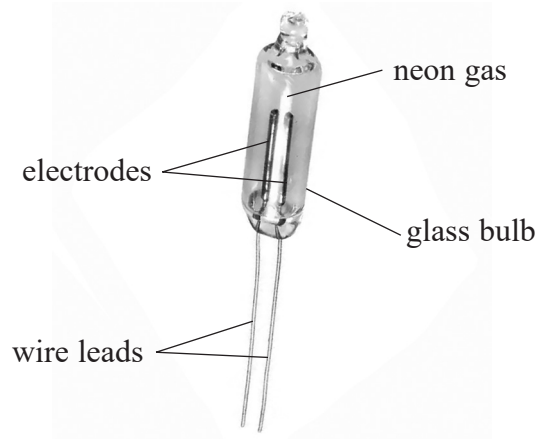
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7 The neon lamp shown is a glass bulb filled with neon gas at low pressure.



(Source: <https://media.digikey.com/Photos/Visual%20Communications%20Company%20VCC/A1A.JPG>)

*(a) When in use, the neon gas between the electrodes emits electromagnetic radiation.

Explain why this happens when there is an electric current between the electrodes.

(6)

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- (b) When light from the neon lamp is incident upon a metal surface, electrons with a maximum speed of $2.68 \times 10^5 \text{ ms}^{-1}$ are emitted from the surface.

The table shows the work functions of some metals.

Metal	Caesium	Potassium	Sodium
Work function / 10^{-19} J	3.36	3.68	3.84

Deduce which metal the light is incident upon.

frequency of light from the neon lamp = $5.56 \times 10^{14} \text{ Hz}$

(4)

(Total for Question 7 = 10 marks)

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