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Thursday 9 June 2016 – Afternoon

AS GCE PHYSICS B (ADVANCING PHYSICS)

G492/01 Understanding Processes / Experimentation and Data Handling

Candidates answer on the Question Paper.
OCR supplied materials:
- Insert (Advance Notice for this question paper) (inserted)
- Data, Formulae and Relationships Booklet (sent with general stationery)

Other materials required:
- Electronic calculator
- Ruler (cm / mm)
- Protractor

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found inside this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **100**.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The values of standard physical constants are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
  This means, for example, you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- This document consists of **28** pages. Any blank pages are indicated.

Answer **all** the questions.

SECTION A

1 Here is a list of physical quantities.

acceleration **force** **kinetic energy** **power** **work**

(a) Choose the correct two quantities to complete this equation.

.... = mass × .... **[1]**

(b) Which two quantities have the same unit?

.... and .... **[1]**

(c) Which two quantities are vectors?

.... and .... **[1]**

2 In each of the four equations below, k is a constant.

$y = kx$	$y = kx^2$	$y = k\sqrt{x}$	$y = \frac{k}{x}$
A	**B**	**C**	**D**

Which is the correct equation, **A**, **B**, **C** or **D**, to represent the relationship between y and x in each of the situations below?

(a) y: the probability of a photon arriving at a particular location
x: the amplitude of the vector sum for all possible phasor paths

.... **[1]**

(b) y: the energy of a photon of electromagnetic radiation
x: the wavelength of that radiation

.... **[1]**

(c) y: the velocity of an object accelerating from rest at a constant rate
x: the distance that the object has travelled

.... **[1]**

(d) y: the kinetic energy of a vehicle travelling at a constant speed
x: the mass of the vehicle

.... **[1]**

3 Here is a list of orders of magnitude.

10^{-6} 10^{-4} 10^{-2} 1 10^{2} 10^{4}

(a) Choose the value closest to the wavelength, in metres, of microwave radiation.

.... **[1]**

(b) Choose the value closest to the thickness, in metres, of one page of this examination paper.

.... **[1]**

4 When parallel waves of wavelength λ pass through a gap of width b as shown in Fig. 4.1, they spread out by diffraction. The intensity is a maximum in the forward direction, dropping away to zero intensity at an angle θ to the forward direction. Fig. 4.1 shows incident wavefronts on the left of the gap, and the directions of maximum and zero intensity on the right.

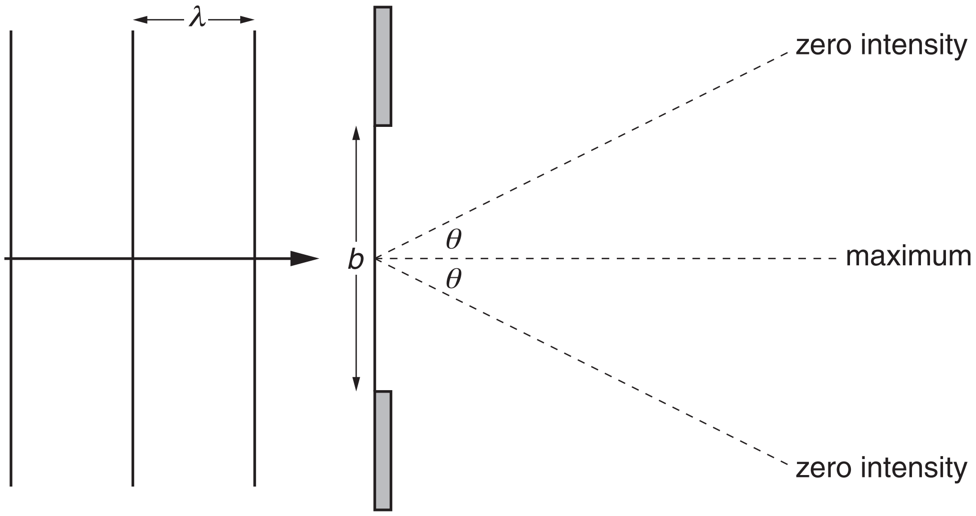
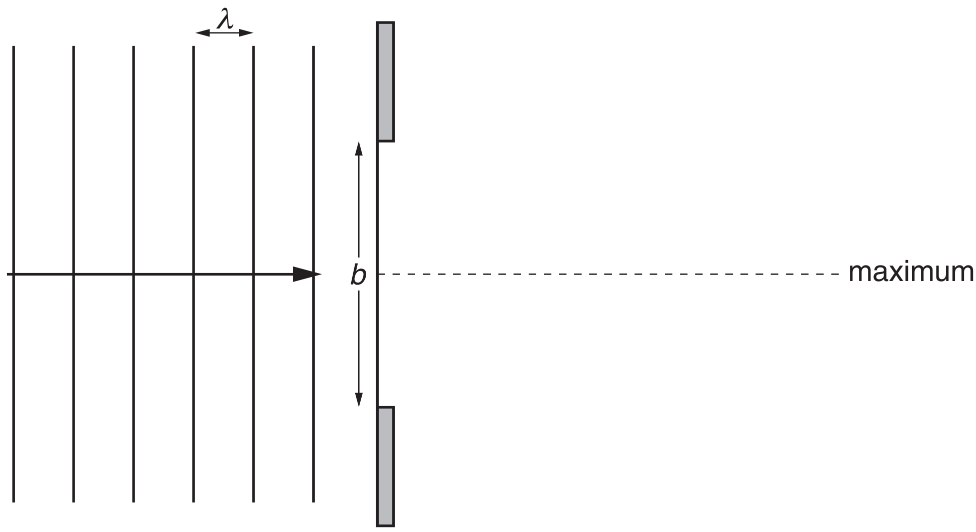


Fig. 4.1

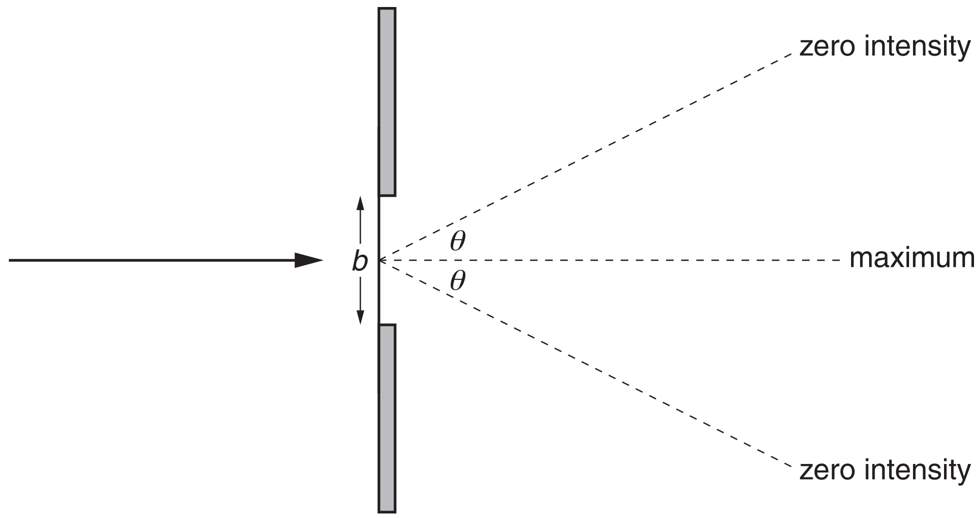
Complete the following two diagrams. No calculations are necessary.

(a) Complete the **right-hand side** of this diagram in a similar way to Fig. 4.1.



[1]

(b) The width b is reduced.
Complete the **left-hand side** of this diagram in a similar way to Fig. 4.1.



[1]

5 An arrow of mass 0.025 kg leaves a bow at a speed of 60 m s^{-1}.

(a) Show that its kinetic energy is about 50 J.

[2]

(b) The arrow is in contact with the bow-string over a distance of 0.60 m as it is fired.
Calculate the average force exerted on the arrow.

average force = ... N **[2]**

6 When white light passes through two narrow parallel slits marked on a blackened slide, an interference pattern of fringes is produced on a distant screen. Measurements of the fringe separation can be difficult because the fringes are dim and fuzzy and closely spaced.

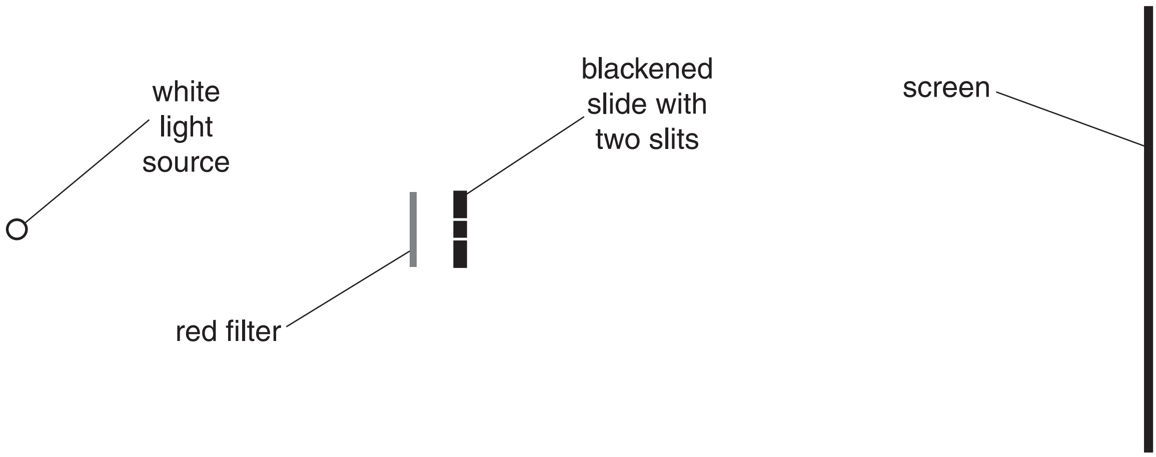


Fig. 6.1

In an attempt to produce clearer fringes, a student puts a red filter between the white light source and the slits as shown in Fig. 6.1.
Describe and explain **one** change in the clarity of the fringes when the red filter is in place.

[2]

7 In deep water, the waves on the surface of the sea do not all travel at the same speed.

Their speed varies with wavelength λ and is given by

$$v = \sqrt{\frac{g\lambda}{2\pi} + \frac{k}{\lambda}}$$

where g is the acceleration due to gravity, and k is a constant of value $0.005\,\text{m}^3\,\text{s}^{-2}$.

(a) Explain why this equation approximates to

$$v = \sqrt{\frac{g\lambda}{2\pi}}$$

for waves of wavelength longer than about a metre.

[2]

(b) A storm at sea creates waves of different wavelengths that travel away from it and can be detected a long way from the storm. Use the approximate equation in **(a)** to describe and explain differences in the time of arrival of these waves coming from the distant storm.

[2]

SECTION B

8 This question is about the use of diffraction gratings to investigate infrared spectra.
Fig. 8.1 shows part of an infrared (IR) spectrometer.

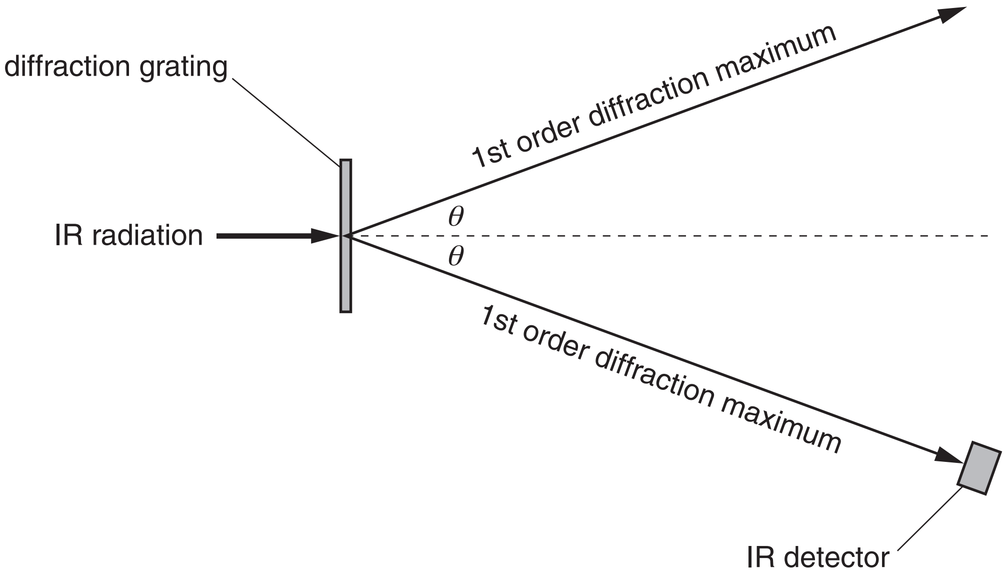


Fig. 8.1

(a) The diffraction grating in Fig. 8.1 has a grating spacing d of 8.0 μm.

(i) Diffraction gratings are labelled with the number of lines per mm rather than the grating spacing.
Calculate the number of lines per mm for this diffraction grating.

number = ... mm^{-1} **[2]**

(ii) Explain why infrared of wavelength longer than 8.0×10^{-6} m could not be detected with this diffraction grating.

[2]

(b) In most practical spectrometers, the detector shown in Fig. 8.1 does not move. The diffraction grating is rotated. This effectively reduces the grating spacing, as shown in Fig. 8.2.

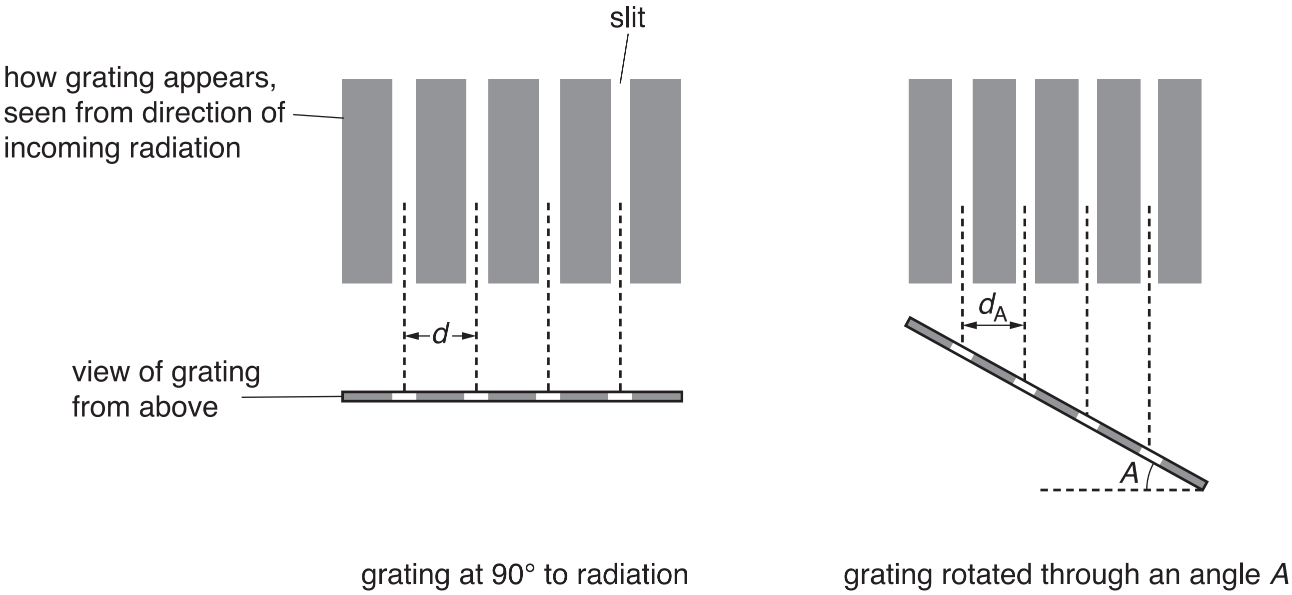


Fig. 8.2

When the grating is rotated through an angle A, it produces the same diffraction pattern as a grating of spacing d_A.
Explain why $d_A = d \cos A$.

[2]

(c) Infrared spectrometers are used to detect a wide range of wavelengths as shown below.

	Wavelength range / μm
near infrared	0.74 to 2.5
mid infrared	2.5 to 25
far infrared	25 to 300

Explain why different diffraction gratings are needed for the different wavelength ranges.

[2]

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Question 9 begins on page 12

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9 This question is about infrared radiation with a wavelength of 1064 nm.

(a) Calculate the energy of an infrared photon of wavelength 1064 nm.
Give your answer to an appropriate number of significant figures.
$c = 2.998 \times 10^{8}\,\mathrm{m\,s^{-1}}$, $h = 6.626 \times 10^{-34}\,\mathrm{J\,s}$.

energy = ... J **[3]**

(b) This infrared radiation is emitted in short pulses of energy from a laser.
Each pulse has energy 100 μJ and duration 10 ns.
The energy of each photon is 2×10^{-19} J.

(i) Show that the power during a pulse is several kilowatts.

[1]

(ii) Calculate the number of photons in a single pulse.

number = ... **[2]**

(c) Pulses of light from this laser can be passed through a crystal of lithium triborate which absorbs the infrared radiation and emits monochromatic green light of wavelength 532 nm.

(i) The lithium triborate crystal is often called a 'frequency doubler'.
Explain why this description is appropriate.

[2]

(ii) The number of infrared photons absorbed by the frequency doubler crystal is more than the number of green light photons emitted.
Explain why this must be so.

[2]

(iii) This process converts an infrared laser into a green light laser.
Suggest **one** application where a green light laser would be more appropriate than an infrared laser.

[1]

10 This question is about a light hollow ball falling from rest through air.
The graphs in Fig. 10.1 show the displacement *s* and velocity *v* against time *t* from release.

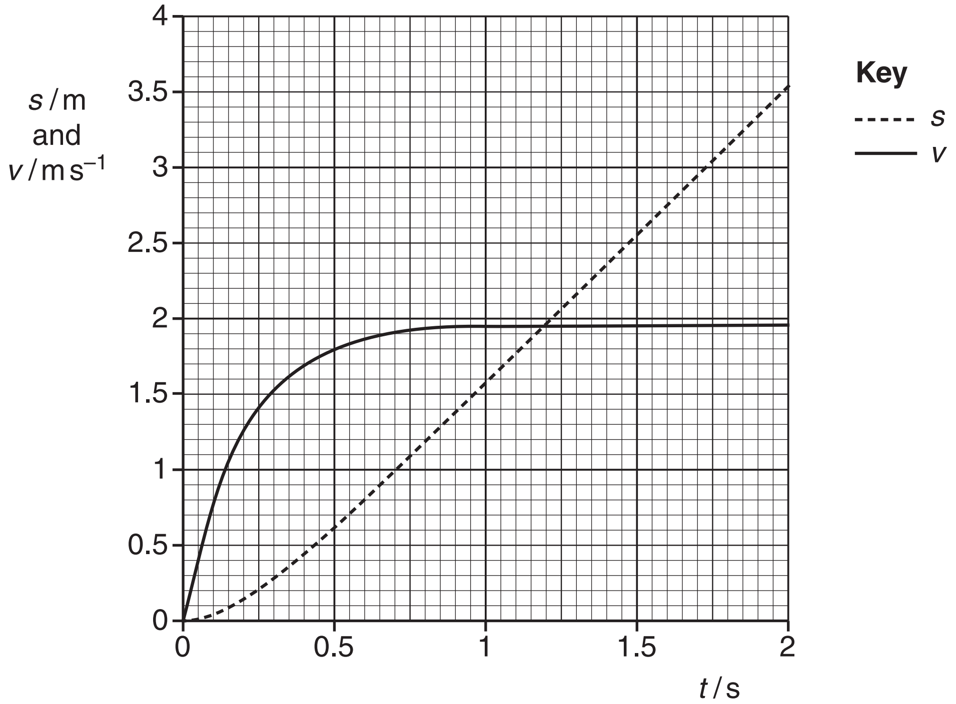


Fig. 10.1

(a) Explain in terms of the forces acting why the *s*-*t* graph is curved at the start, but straight after about 1 second of fall.

[2]

(b) Use the *v*-*t* graph to confirm the plotted value of displacement *s* at 0.50 seconds. Show your working.

[3]

(c) Find the acceleration at time $t = 0.5\,\text{s}$ by drawing a suitable tangent to one of the curves in Fig. 10.1.

[2]

(d) The light hollow ball is now crushed into a pellet and dropped from rest as before.
Compare the *v*-*t* graph for this fall with the *v*-*t* graph in Fig. 10.1.

In your answer, you should link the forces acting on the falling objects with the shape of the graphs.

[3]

11 This question is about the high jump in athletics.

The most successful modern technique involves twisting the body so that the centre of mass of the athlete is as low as possible (Fig. 11.2).

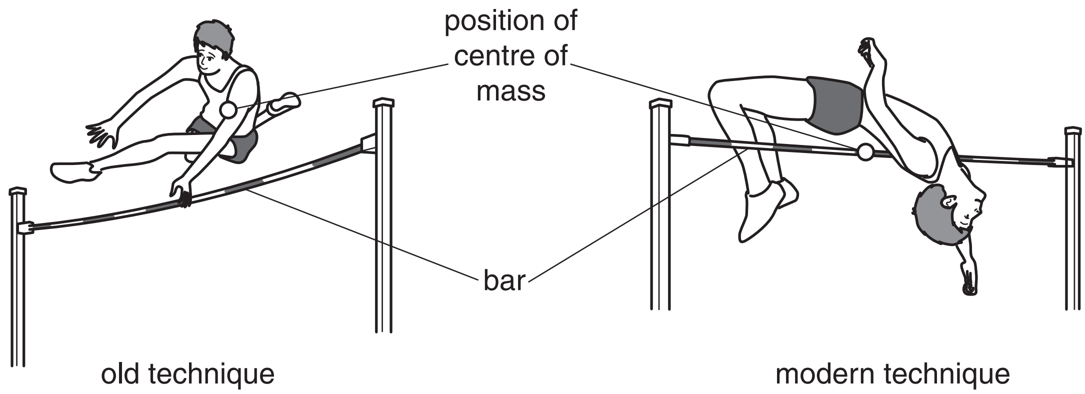


Fig. 11.1 **Fig. 11.2**

(a) The modern technique requires less gravitational potential energy than the old technique with the bar set at the same height.
Calculate the **extra** gravitational potential energy required to jump over a bar 1.5 m above the ground using the old technique.
Make appropriate estimates for quantities that you need.

estimates

calculation

[3]

(b) A recent world record holder for the men's high jump is nearly 2 m tall. Suggest why it is an advantage for a high jumper to be tall.

[1]

(c) In one particular high jump, the centre of mass of the athlete rises a height of 1.1 m.

(i) Show that the athlete must leave the ground with a vertical component of velocity of more than $4\,\text{m}\,\text{s}^{-1}$.

[2]

(ii) The athlete runs up to the bar with a horizontal velocity of $8.0\,\text{m}\,\text{s}^{-1}$. When the athlete leaves the ground, his velocity is $6.0\,\text{m}\,\text{s}^{-1}$ at an angle of 53° to the horizontal, as shown in Fig. 11.3.

Fig. 11.3

Draw a vector diagram to show that the magnitude of the velocity change during the jump is more than $6\,\text{m}\,\text{s}^{-1}$.

[2]

(iii) The athlete's jumping foot is in contact with the ground for 180 ms before take-off. Calculate the mean accelerating force exerted by his foot while the velocity is changing.

mass of athlete = 82 kg

force = ... N
[2]

SECTION C

12 This question is about the article *Dot plots*.
The data in Fig. 12.1 show values of extension obtained when a spring is stretched by a standard laboratory mass of 1 kg.

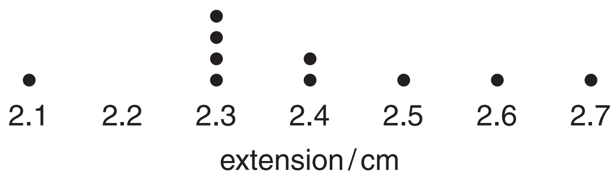


Fig. 12.1

(a) Find the mean and the spread of the data in Fig. 12.1.
Give both your numerical answers to an appropriate number of significant figures.

extension = ... ± ....cm **[2]**

(b) The spring constant k for the spring can be found using the equation $F = kx$.

(i) Explain why the uncertainty in the mass can be ignored in this calculation.

[1]

(ii) Use the data to calculate the spring constant k in $N\,cm^{-1}$.

$g = 9.8\,N\,kg^{-1}$

k = ... ± ....$N\,cm^{-1}$ **[3]**

(c) A different spring has a spring constant of $k = 3.2 \pm 0.6\,N\,cm^{-1}$.
This spring becomes over-stretched when the extension exceeds 9.0 cm.
Taking into account the uncertainty in k, explain whether or not a force of 24 N will damage this second spring.

[2]

13 This question is about the article *Systematic errors*.

(a) (i) State and explain the difference between systematic errors and random uncertainties.

[2]

(ii) Explain why systematic errors cannot be reduced by increasing the number of repeat readings taken.

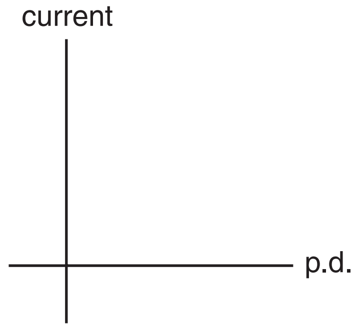
[1]

(b) The stretched measuring tape described in the article is used to measure the distance in an experiment to determine the speed of someone running.
State and explain the effect this would have on the final value of the speed.

[2]

(c) The results from a simple experiment to show that p.d. is directly proportional to current in a resistor are recorded and a straight line graph drawn. The ammeter used is the one described in the article.

Sketch the graph you would expect to see and explain what feature would indicate the systematic error.



[2]

14 This question is about the article *Measuring the speed of sound*.

(a) The experiment as described in the article is dependent on the use of the wave equation $v = f\lambda$.

(i) Show that the units of $f\lambda$ can be written as $\mathrm{m\,s^{-1}}$.

[1]

(ii) Sound waves from the loudspeaker set up standing waves in the tube.
Draw the standing waves in the tubes shown in Fig. 14.1 which correspond to the equations

$$L_1 + c = \tfrac{1}{4}\lambda \quad \text{and} \quad L_2 + c = \tfrac{3}{4}\lambda.$$

Label **all** displacement nodes (**N**) and antinodes (**A**) on both diagrams.

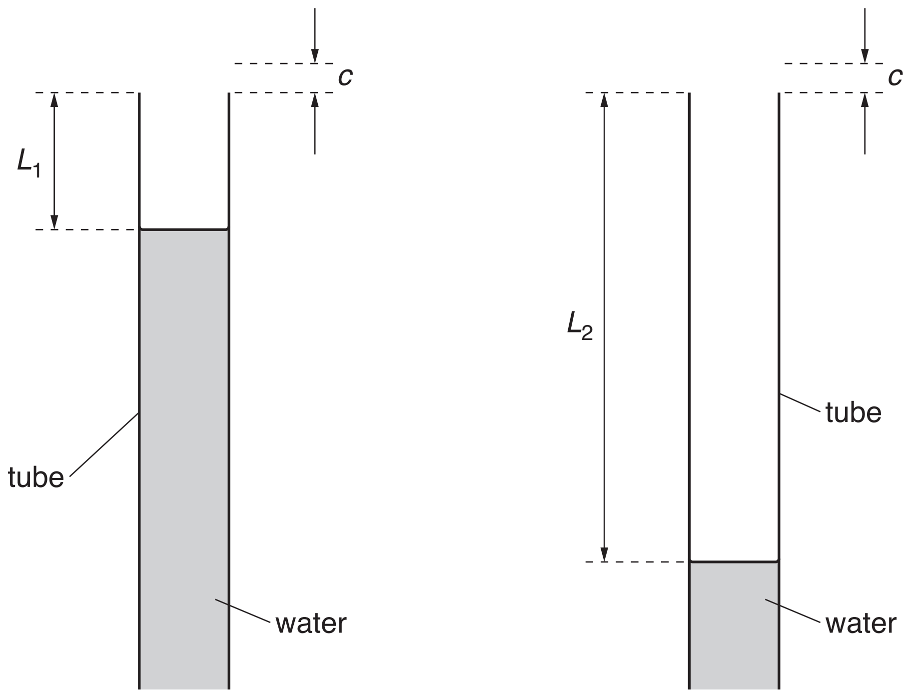


Fig. 14.1

[3]

(iii) Explain how standing waves are formed in the tube.

In your answer, you should use appropriate technical terms, spelled correctly.

[3]

(b) (i) Show how the two equations $L_2 + c = \frac{3}{4}\lambda$ and $L_1 + c = \frac{1}{4}\lambda$ can be combined to give $L_2 - L_1 = \frac{1}{2}\lambda$.

[1]

(ii) Combining the two equations eliminates the systematic error of the end correction. State the assumption that must be made for this to be valid.

[1]

(c) A student does a preliminary experiment to measure the two resonant lengths L_1 and L_2 for two different frequencies.

The data are shown in Tables 1 and 2 below.

first resonant length		
frequency / Hz	L_1 / cm	ΔL_1 / cm
200	38	±1.5
600	12	±0.5

Table 1

second resonant length		
frequency / Hz	L_2 / cm	ΔL_2 / cm
200	124	±2
600	41	±1

Table 2

The uncertainties ΔL_1 and ΔL_2 are estimated from the ranges of lengths over which the note emitted by the tube is much louder than the note from the loudspeaker alone.

(i) Suggest and explain **one** reason why $\Delta L_2 > \Delta L_1$ for each frequency.

[2]

(ii) The uncertainties ΔL_1 and ΔL_2 for f = 600 Hz are both less than for f = 200 Hz. However, calculation of the speed of sound using

$$L_2 - L_1 = \tfrac{1}{2}\lambda \text{ and } v = f\lambda$$

gives greater uncertainty in the final value of v when the values for L_1 and L_2 for 600 Hz are used rather than those for 200 Hz.
Explain why.

[2]

(iii) The student obtains data for a range of frequencies and plots an appropriate graph instead of calculating the speed of sound directly from the values in Tables 1 and 2. Suggest and explain reasons why the graphical method is better.

[2]

Turn over for part (d)

(d) Fig. 14.2 shows a graph that has been plotted with data from one such experiment using a range of frequencies from 200 Hz to 550 Hz.

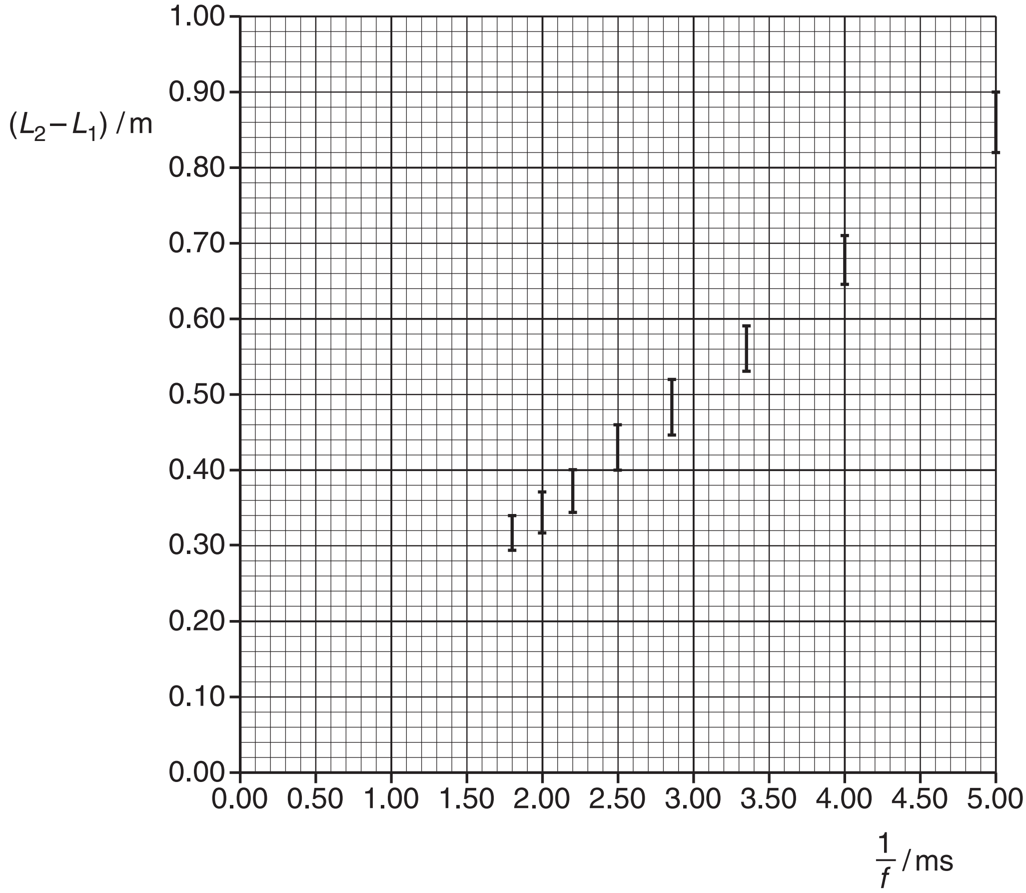


Fig. 14.2

(i) Explain why a graph of $(L_2 - L_1)$ plotted against $\frac{1}{f}$ should give a straight line of gradient $\frac{v}{2}$ which passes through the origin.

[2]

(ii) Draw a best-fit line and calculate a value for v, the speed of sound.

v = ... m s^{-1} **[3]**

(iii) Use data from Fig. 14.2 to estimate the uncertainty Δv in the value of the speed of sound calculated in **(d)(ii)**. Assume that the uncertainty in frequency measurement is negligible.

$\Delta v = \pm$ .... m s^{-1} **[3]**

(e) When the same experiment is repeated on the following day the measured lengths are found to be slightly longer. During this experiment the room temperature is higher than on the previous day.
Explain whether the changes found in the measurements are consistent with the fact that the speed of sound increases with increased air temperature.

[2]

END OF QUESTION PAPER

Oxford Cambridge and RSA

Thursday 9 June 2016 – Afternoon

AS GCE PHYSICS B (ADVANCING PHYSICS)

G492/01 Understanding Processes / Experimentation and Data Handling

Duration: 2 hours

INSERT

INSTRUCTIONS TO CANDIDATES

- This Insert contains the material required to answer the questions in Section C.

INFORMATION FOR CANDIDATES

- This document consists of **4** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

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1 Dot plots

When a force F is applied to a spring, the extension x is related to the force F acting on the spring according to the relationship

$$F = kx$$

where k is the spring constant.

In a simple experiment the extension of a spring is measured with a ruler when a standard laboratory mass of 1 kg is attached. The experiment is repeated ten more times. The results, presented as a simple dot plot, are shown in Fig. 1.

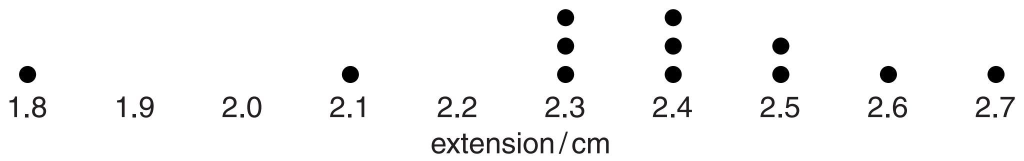

Fig. 1

With a dot plot you can look at the distribution and range of values in a set of data to find the mean and its uncertainty. The spread of the data, which is half the range, gives a useful estimate of the uncertainty.

It is useful to have a rough rule of thumb to identify whether a particular value is so far from the mean that it might be suspected to be an outlier, and so should be investigated further. One such rule is to identify as a possible outlier any value that lies more than twice the spread above or below the mean, temporarily excluding the suspected value from the calculation of mean and spread.

The uncertainty in the extension x can be used to determine an uncertainty in the final calculated value of the spring constant k.

2 Systematic errors

Systematic errors can arise from experimental procedures or from the measuring instruments themselves. They are reproducible inaccuracies that are consistently in the same direction. Unlike random uncertainties, systematic errors cannot be detected or reduced by increasing the number of observations. Two examples are a measuring tape becoming stretched over years of use giving false readings, and a **zero error** on an instrument making all readings too large or small by a set amount, such as an ammeter that reads –0.01 A when there is no current.

Understanding the impact of the systematic error in terms of the direction of the error is also important. If a systematic error is suspected in one variable, it is important to think about whether this error would make the final result too large or too small.

3 Measuring the speed of sound

You may wish to try this at school with the appropriate health and safety procedures.

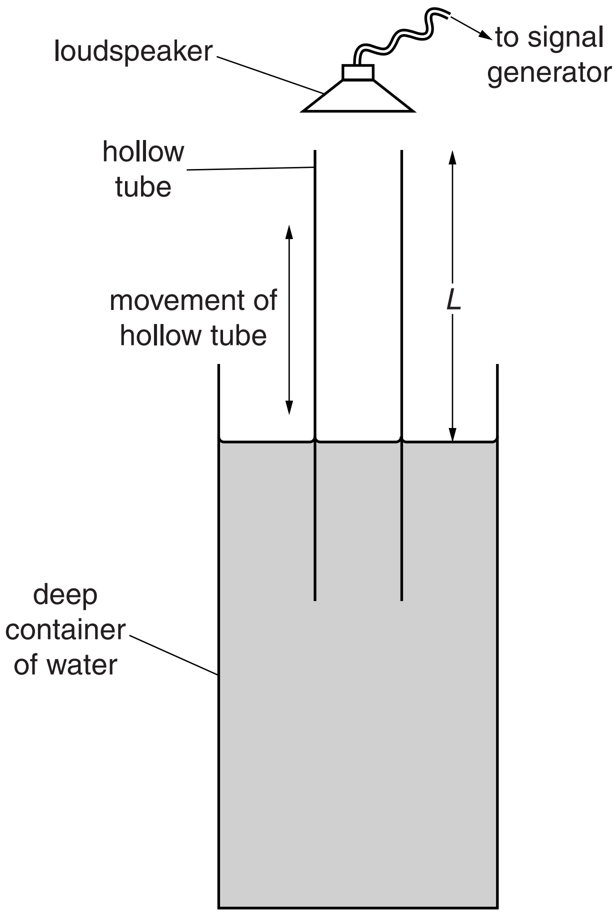

Fig. 2

A loudspeaker connected to a signal generator is mounted above the top of the hollow tube as shown in Fig. 2 and sound waves travel down the tube. The tube is slowly moved up in the water, altering its length, until a resonance is heard. At this point there is a standing wave in the tube with a displacement node at the bottom and a displacement antinode at the top.

A systematic error exists in the experiment because the antinode is not at the open end of the tube, but a small distance beyond it. This is known as the end correction *c* and it depends on the diameter of the tube.

The shortest value of L at which the resonance is heard, L_1, is given by

$$L_1 + c = \tfrac{1}{4}\lambda. \qquad (1)$$

Raising the tube further, another standing wave is formed when the length of the tube above the water level is L_2, where

$$L_2 + c = \tfrac{3}{4}\lambda. \qquad (2)$$

The L_2 resonance is quieter than the L_1 resonance so making the measurement of L_2 more difficult.

The two equations can be combined to give

$$L_2 - L_1 = \tfrac{1}{2}\lambda$$

which removes the need to measure or know the value for the end correction *c*.

The frequencies used in the experiment need to be carefully matched to the length of the hollow tube and the depth of the container of water. A graph of $(L_2 - L_1)$ against $\frac{1}{f}$ is the most reliable way of calculating the speed of sound from these results. Signal generators now produce very stable and accurately determined frequencies. Therefore the largest uncertainty in the value obtained for the speed of sound comes from the uncertainty in determining the resonant lengths L_1 and L_2.

END OF ARTICLE