OCR
RECOGNISING ACHIEVEMENT

SPECIMEN

Advanced Subsidiary GCE

G492 QP

PHYSICS B (ADVANCING PHYSICS)

Unit G492: Understanding Processes, Experimentation and Data Handling

Specimen Paper

Candidates answer on the question paper.

Additional Materials:

Data, Formulae and Relationships Booklet
Electronic calculator

Time: 2 hours

Candidate Name	

Centre Number						Candidate Number					

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- ✎ Where you see this icon you will be awarded marks for the quality of written communication in your answer.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **100**.

FOR EXAMINER'S USE		
Section	**Max.**	**Mark**
A	**20**	
B	**40**	
C	**40**	
TOTAL	**100**	

This document consists of **25** printed pages; **3** blank pages and an Insert.

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[Turn Over

Answer **all** the questions.

Section A

1

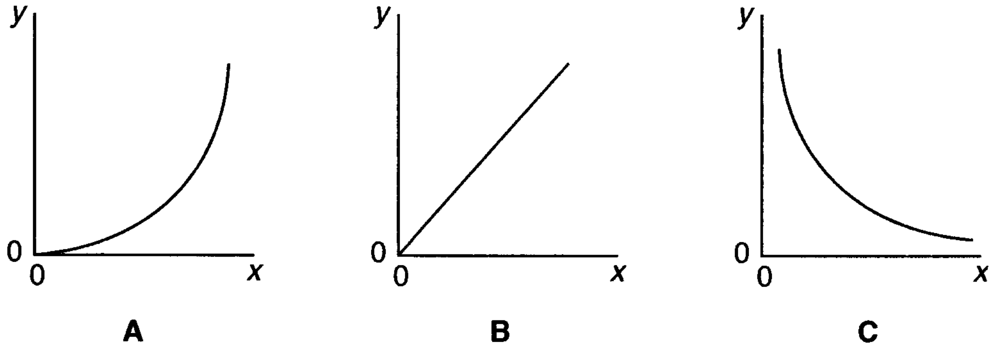


Fig. 1.1

Which graph, **A, B, or C,** in Fig. 1.1, is obtained when the y and x axes represent the two quantities given below?

(a) y-axis: the **acceleration** of objects of the same mass

x-axis: the **resultant force** acting on each object

answer .... **[1]**

(b) y-axis: the **kinetic energy** of a tennis ball

x-axis: the **velocity** of the tennis ball

answer .... **[1]**

2 A narrow beam of light is always reflected from a mirror at an angle *r* equal to the angle of incidence *i*, as shown in Fig. 2.1.

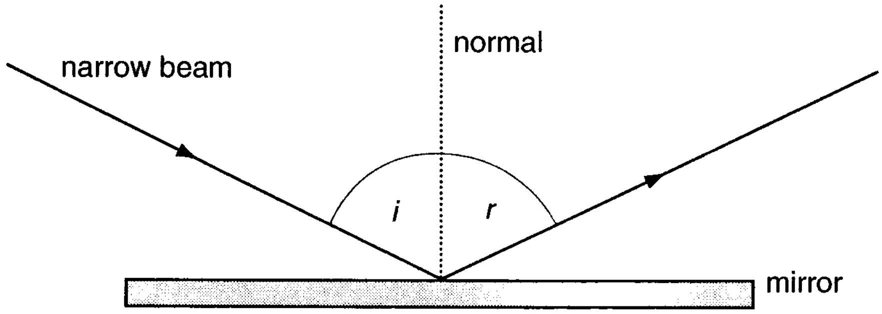


Fig. 2.1

Select from the statements (A, B and C) below the one that is the best explanation of this fact in terms of the quantum behaviour of photons.

A The angles are equal because the photons rebound elastically from the surface.

B Only for paths very close to the observed path do the phasor amplitudes all combine in phase.

C The observed path is the only one along which the momentum of the photon is unchanged. answer

answer.. **[1]**

3 Fig. 3.1 shows how the speed of a car changes with time during an emergency stop.

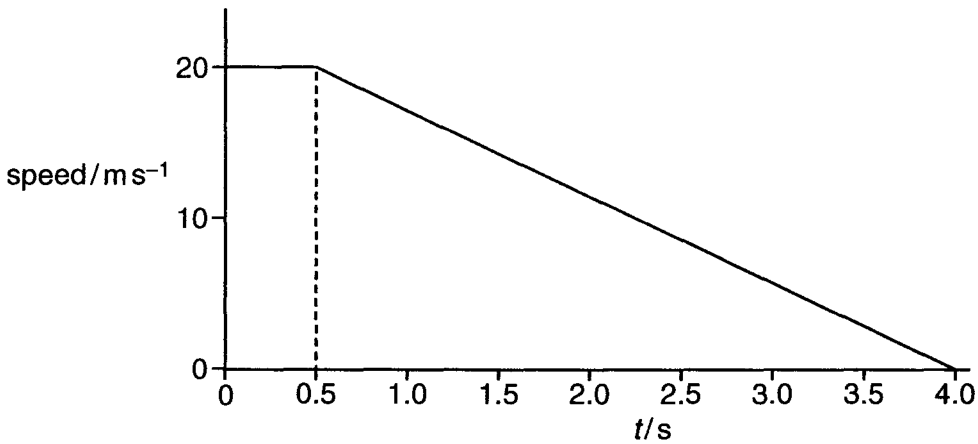


Fig. 3.1

The driver recognises there is a hazard at time $t = 0$, and the car comes to a halt 4.0 seconds later.

Use the graph to find

(a) the initial speed of the car

initial speed = ... m s^{-1} **[1]**

(b) the time taken for the driver to apply the brakes after seeing the hazard

time = ... s **[1]**

(c) the total stopping distance of the car.

total stopping distance = ... m **[2]**

[Turn Over

4 This question is about a TV remote control device.

(a) The light emitting diode (LED) of a remote control for a TV set emits pulses of radiation of frequency 3.2 x 1014 Hz.

Calculate the energy of each photon of this radiation.

the Planck constant $h = 6.6 \times 10^{-34}$ Js

photon energy = ...J **[1]**

(b) The sensor in the TV set will respond to a pulse of radiation from the remote control when the signal power received during the pulse is at least 1.0×10^{-7} W.

Calculate the minimum rate at which photons arrive during the pulse.

rate = ... photons per second **[2]**

5 Fig. 5.1 shows a human reflex test.

The tester, **A**, holds the top of a £20 note, while the person being tested, **B**, holds his hand still, with thumb and forefinger apart and level with the bottom of the note.

Without warning, **A** releases the note.

B must grasp it before it has passed through his fingers.

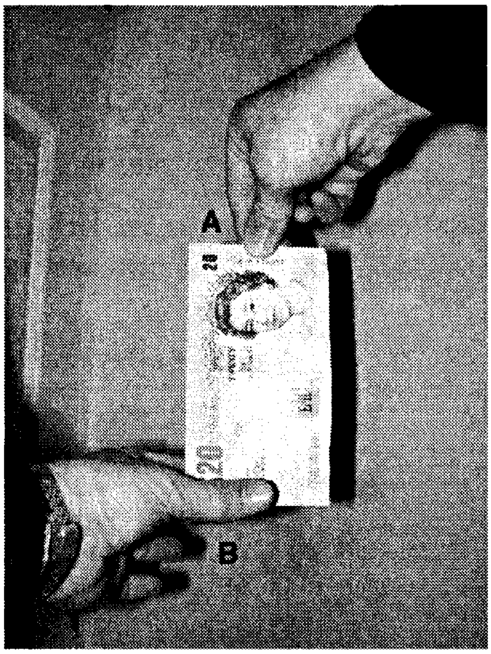


Fig. 5.1

The length of a £20 note is 150 mm.

B has a reaction time of 0.2 s. Can he catch the note?
Neglect any effects of air resistance, and show your working clearly.

$g = 9.8\ \text{ms}^{-2}$

[3]

6 This question is about a rocket leaving the surface of a distant planet.

(a) A rocket of mass 10 000 kg lifts off from the surface of the planet with an initial acceleration of 3.1 m s^{-2}.

Calculate the resultant force acting on the rocket.

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

(b) The initial thrust on the rocket is 7.5 x 10^4 N.

Fig. 6.1 shows the two forces acting on the rocket at the moment of lift-off.

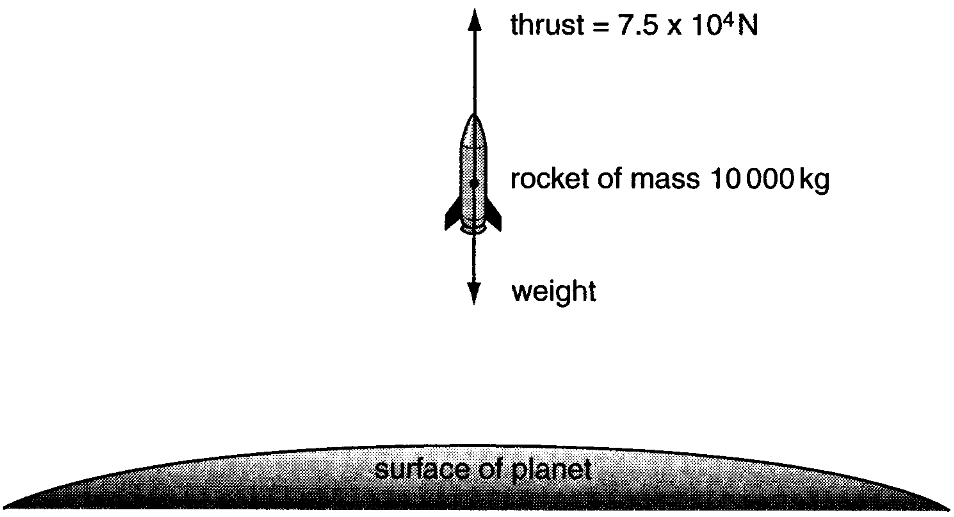


Fig. 6.1

Calculate the initial weight of the rocket.

weight = ...N **[1]**

(c) Calculate the gravitational field strength at the surface of the planet.

gravitational field strength = ... N kg^{-1} **[1]**

7 Fig. 7.1 shows a beam supported on two blocks a distance x apart.

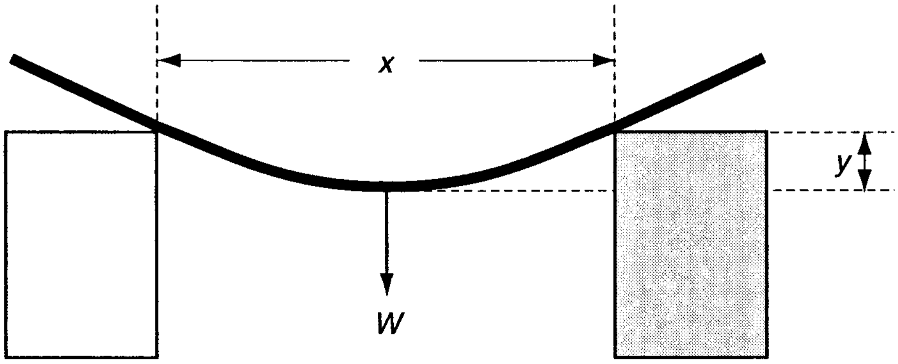


Fig. 7.1

In an experiment, the distance y that the beam sags when a fixed weight W is hung from its centre is measured for different values of the distance x between the blocks.

Here is a set of measurements.

x/ m	*y*/ m
0.90	0.080
0.70	0.037
0.50	0.014

A student wishes to check if the relationship between y and x in this experiment is of the form $y = kx^2$ where k is a constant.

Propose and carry out a test to check if the **data** support the relationship.

test proposed	***working***

State your conclusion.

....**[3]**

Section A Total [20]

[Turn Over

Section B

8 Speed skiing is claimed to be `the fastest non-motorised sport on Earth'.

In this sport, competitors, starting from rest, accelerate under gravity down a very steep slope. They are then timed over the next 100 m length of slope. (Fig. 8.1)

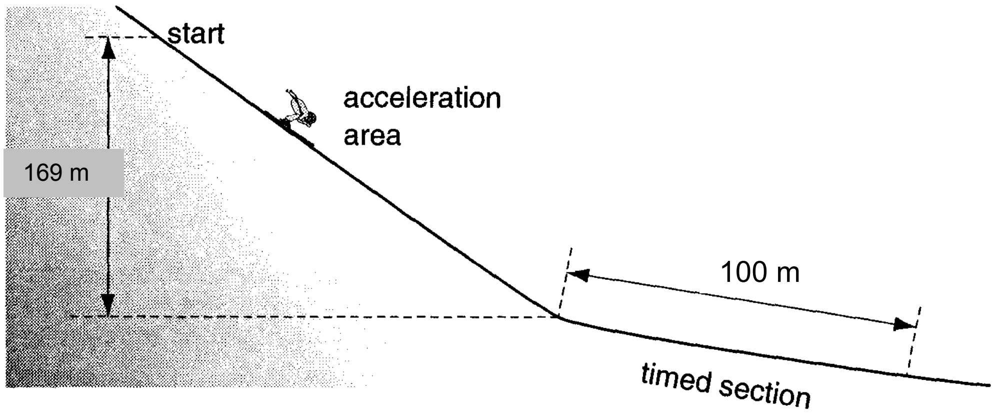


Fig. 8.1

(a) The **vertical** drop in the acceleration area is 169m.

Show that the **maximum** possible speed at which a competitor could enter the timed section is about 60 m s^{-1}.

g = 9.8 m s^{-2}

[2]

(b) In a recent competition, a skier completed the 100 m timed section of the course in 2.12 s. Show that his **average** speed through the timed section was in excess of 160 km $hour^{-1}$ (100 m.p.h.).

[2]

(c) The timed section of the course is 100 m long and drops a vertical distance of 26 m. The angle of the slope is 15 degrees to the horizontal.

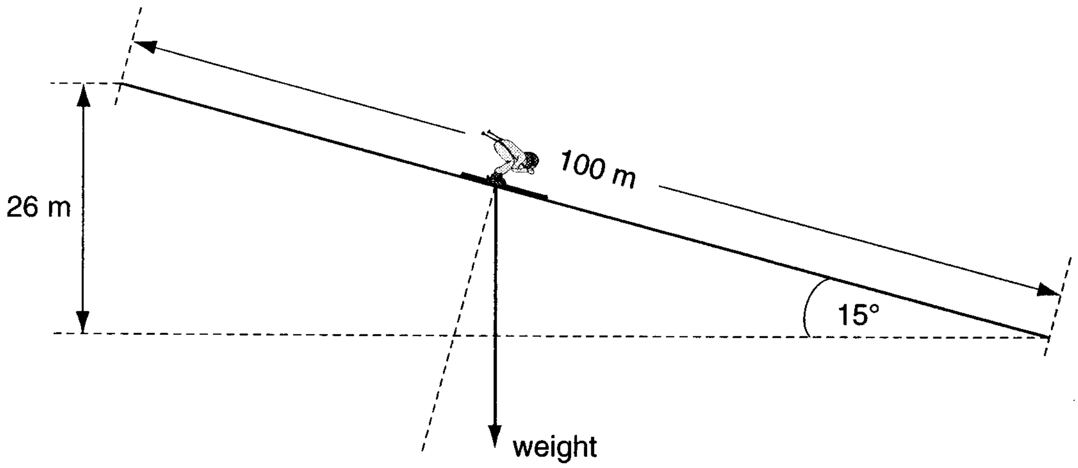


Fig. 8.2

Fig. 8.2 shows a skier of mass 72 kg travelling down the timed section of the course.

(i) Calculate the weight of the skier.

g = 9.8 N kg^{-1}

weight = ... N **[1]**

(ii) By scale drawing or some other method of your choosing, calculate the component of the weight in the direction parallel to the slope.

[2]

(iii) The speed of the skier through the timed section is constant. Explain how this can be so.

[1]

Total [8]

[Turn Over

9 This question is about a method of finding the wavelength of light from a laser.

A thin, parallel beam of light of a single wavelength falls on a diffraction grating, as shown in Fig. 9.1.

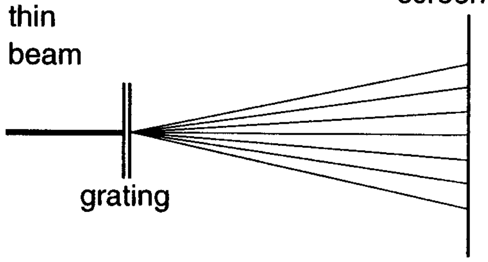


Fig. 9.1

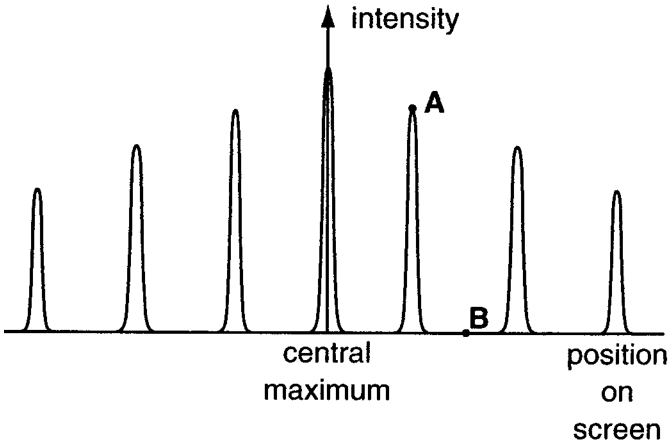


Fig. 9.2

Light passes through the grating and a regular pattern of light and dark regions is observed on the screen.

(a) Fig. 9.2 shows how the intensity pattern varies across the central region of the screen.

(i) Describe the main features of the intensity pattern shown in Fig. 9.2.

[3]

(ii) Explain the difference in intensity between points **A** and **B** in the pattern (Fig. 9.2), using the idea of **superposition** of waves.

[1]

(b) Fig. 9.3 shows the experimental arrangement in more detail.

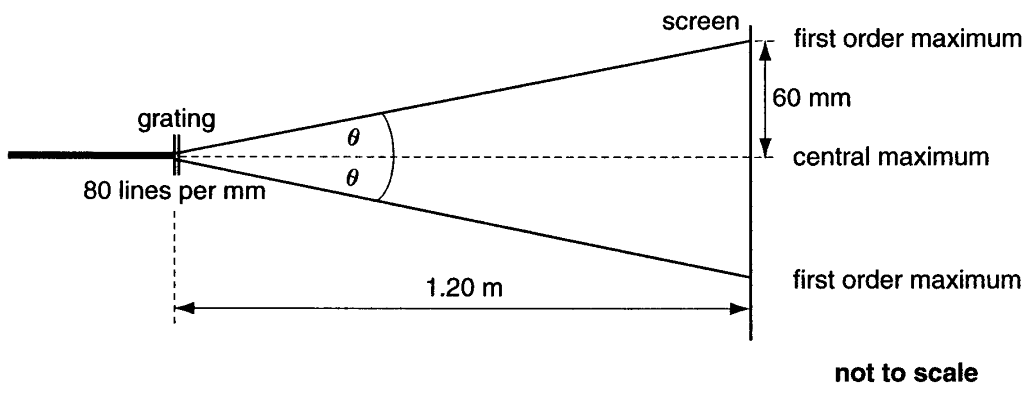


Fig. 9.3

(i) The grating has 80 lines per mm.

Show that the spacing d between the lines on the grating is 1.25×10^{-5} m.

[1]

(ii) The distance between the central maximum and first order maximum is measured on the screen and found to be 60 mm.

The screen is 1.20 m away from the grating.

Calculate the wavelength λ of the light, using the information above.

[4]

(c) Suggest **one** change that could be made to the experimental arrangement to improve the accuracy of the wavelength measurement. Explain your reasoning.

[2]

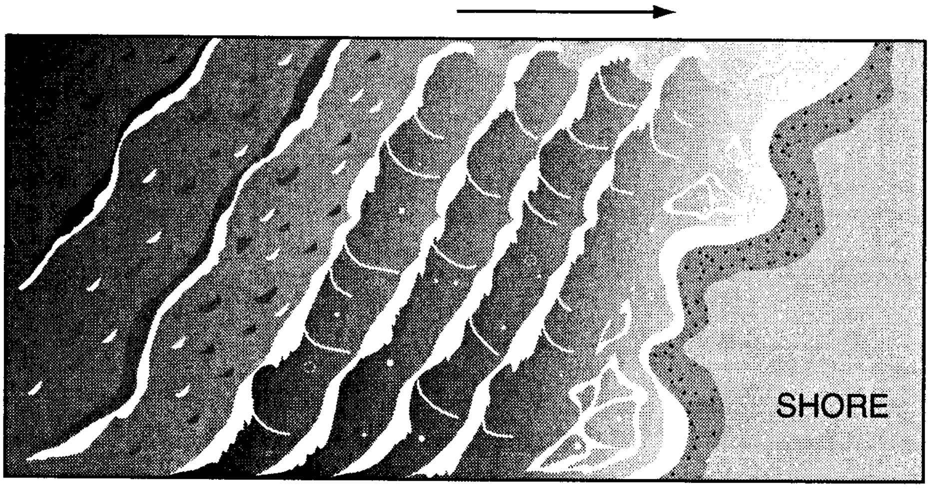
Total [11]

[Turn Over

10 This question is about wave energy.

Fig. 10.1 shows a group of waves travelling across the sea towards a beach.

velocity of group of waves = 12 m s^{-1}



each 1 m^2 of the sea
surface carries energy
towards the shore at 12 m s^{-1}

Fig. 10.1

(a) The energy ε carried by every 1 m^2 of surface of the sea is given by

$\varepsilon = \frac{1}{2} g\rho x^2$

where g is the gravitational field strength

ρ is the density of the sea water

and x is the amplitude of the waves in the group.

Show that $\frac{1}{2} g\rho x^2$ has the units J m^{-2}. Take the units of g as N kg^{-1}.

[2]

(b) Waves with a peak-to-trough height of 1.8 m approach a beach as shown in Fig. 10.2.

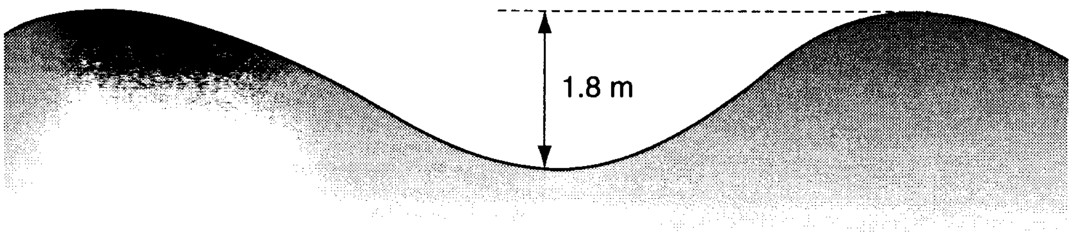


Fig. 10.2

(i) State the amplitude x of these waves.

x = ... m **[1]**

(ii) Calculate the energy ε carried by these waves per m^2 of sea surface, using the equation given in (a).

ρ = 1030 kg m^{-3}

g = 9.8 N kg^{-1}

ε = ... Jm^{-2} **[2]**

(iii) The wave energy is being carried onto the beach with the group of waves shown in Fig. 10.1 at a velocity of 12 m s^{-1}.

Calculate the energy arriving per second on a 0.5 km length of the beach.

Express your answer in megawatt.

energy per second = ... MW **[4]**

(iv) Suggest **one** possible consequence, or use, of this wave power being delivered to the shore.

[1]

Total [10]

[Turn Over

11 This question is about the quantum behaviour of photons.

Yellow light of a single wavelength falls on the vertical surface of a soap film.

Photons of the light reflect from the film and horizontal bands can be seen in the soap film, as shown in Fig. 11.1. The bands are alternately yellow and black.

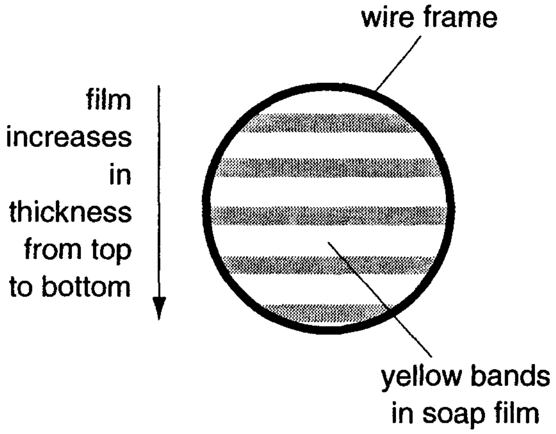


Fig. 11.1

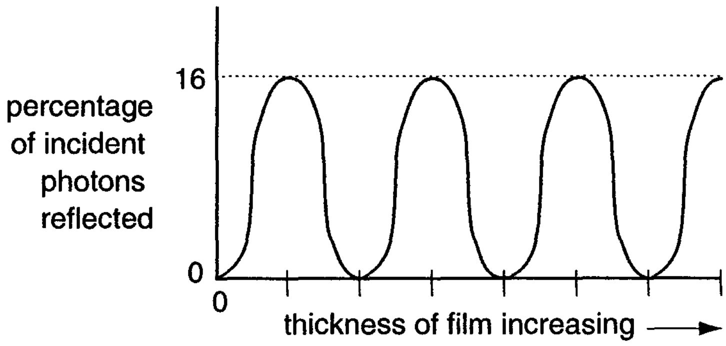


Fig. 11.2

(a) Fig. 11.2 shows how the **percentage** of incident photons **reflected** by the film varies as its thickness changes.

Use the information in Fig. 11.2 to describe in words how the percentage of photons reflected varies with the thickness of the soap film.

✎ *You will be awarded marks for the quality of your written communication.*

[4]

(b) An incident photon can reflect off either the **front** or **back** surface of the soap film to reach the detector. If it does not reflect, it will pass through the film (Fig. 11.3).

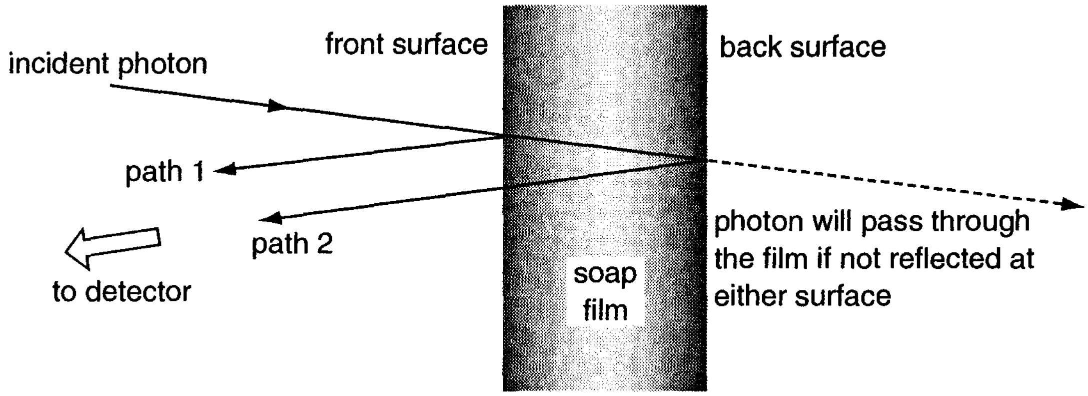
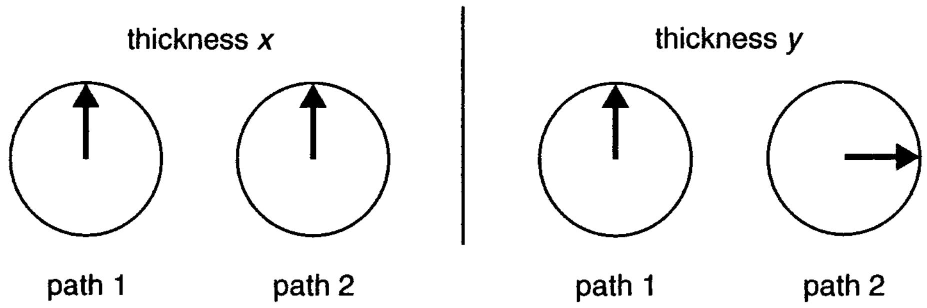


Fig. 11.3

Some photons reach the detector after reflecting from two different places on the film where the film thickness is x and y.

Rotating phasors for the two paths of a photon reaching the detector are shown below, for the two thicknesses of film. (scale: 1 cm represents amplitude 2.0)



(i) By scale drawing or some other method of your choosing, calculate the magnitude of the **resultant** phasor amplitude in each case.

Each phasor has an amplitude of 2.0.

thickness *x*	thickness *y*
resultant phasor amplitude =.................	resultant phasor amplitude = ...

[3]

(ii) Show that the **probability** of photons being reflected from film of thickness x is **twice** that from film of thickness y.

[2]

(iii) At certain thicknesses of film, dark bands are produced indicating that few, if any, photons are reflected there.

How do you account for this?

[2]

Total [11]

Section B Total [40]

[Turn Over

Section C

The questions in this section are based on the Advance Notice material.

12 This question is about uncertainties and errors in measurements in science.

(a) The situations below involve random uncertainty, systematic error or both. In each case, discuss which are present and explain their effect on the measurements made.

(i) Timing an eclipse of the Moon, which lasts about two hours, using a clock which runs slightly 'fast', recording a day as slightly more than 24 hours.

[2]

(ii) Measuring the length of a room with an accurate steel measuring tape.

[2]

(b) For **one** of the two measurements **(i)** and **(ii)** above, suggest how a better measurement could be made.

[2]

Total [6]

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13 The table below gives some measurements of the velocity of light, *c*.

year	**experimenter**	**observed velocity/ km s^{-1}**
1875	Cornu	299 990 ± 200
1880	Michelson	299 910 ± 150
1883	Michelson	299 850 ± 60
1906	Rosa-Dorsey	299 784 ± 10
1928	Middelstaedt	299 778 ± 10
1932	Michelson with others	299 774 ± 4
1941	Anderson	299 776 ± 6
1951	Bergstrand	299 793.1 ± 0.3

The graph opposite shows these measurements.

(a) Explain why the speed of light is difficult to measure.

[2]

(b) The American physicist Albert Michelson was famous for his skills in measurement.

Explain how the table and the Advance Notice article show this.

✐ *You will be awarded marks for the quality of your written communication.*

[4]

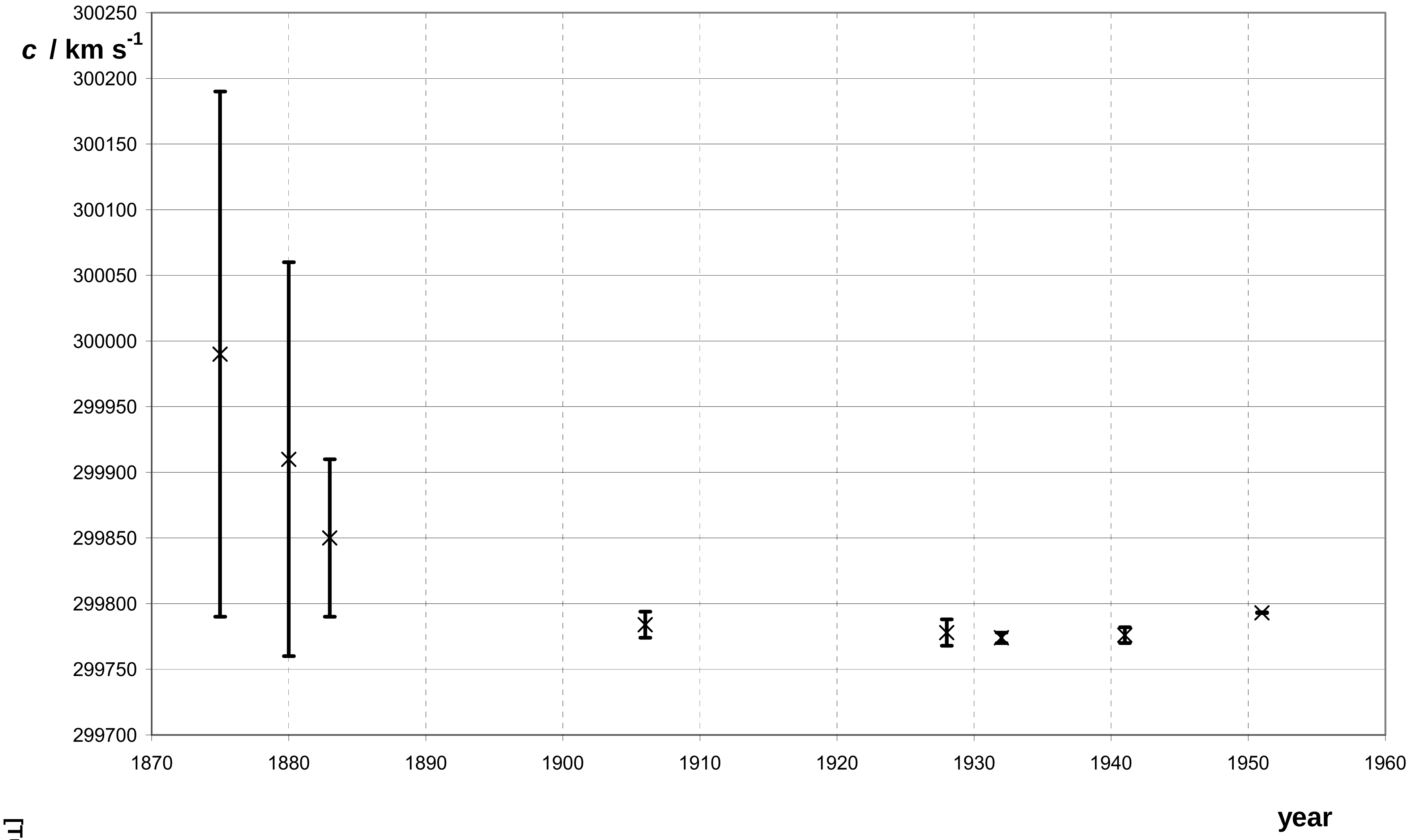
(c) In 1973, the recommended value of the velocity of light was 299 792 458 ± 1 m s^{-1}. explain why it is now defined to be exactly 299 792 458 m s^{-1}.

[1]

(d) The velocity of light is now defined as 299 792.458 km s^{-1}. Draw a horizontal line on your graph to indicate this defined value. Which experimenters appear to have underestimated the uncertainties in their experiments?

[2]

Total [9]


c / km s-1
300250
300200
300150
300100
300050
300000
299950
299900
299850
299800
299750
299700
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
year

[Turn Over

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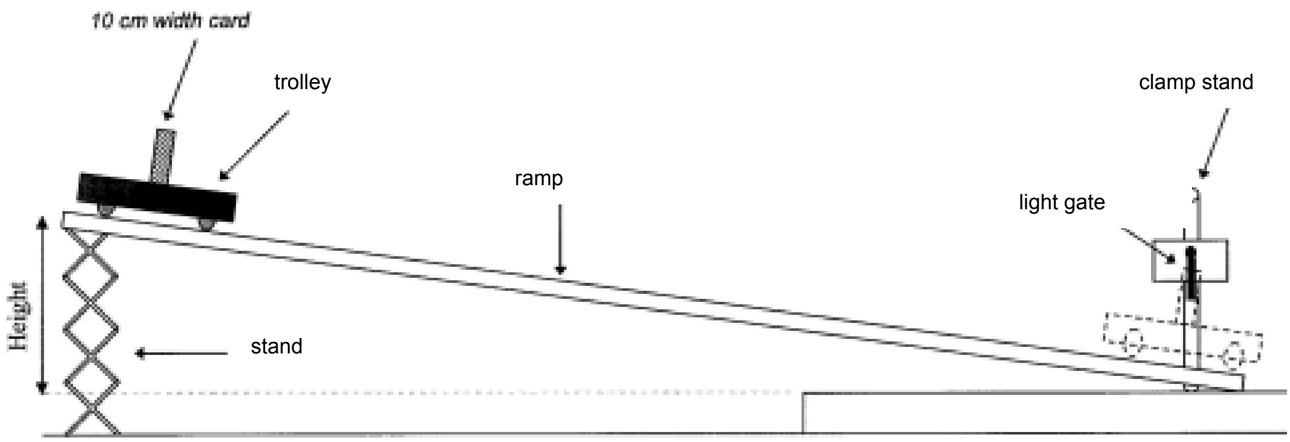
14 This set of data is about the motion of a trolley down a ramp as shown in the diagram below. The experiment was carried out by two AS students, Fiona and Tom.



mass of trolley *m*	0.992 kg
"mask" width *w*	10.0 cm
runway length *s*	1.20 m

One end of the runway was raised to a height *h*. The trolley had a mass of 0.992 kg and had a card 'mask' of width 10.0 cm mounted on it. The time *t* taken for the card mask to pass through a light gate at the bottom of the 1.20 m long ramp was measured.

height *h* / cm	Time *t* / s
4.0	0.164
6.0	0.113
8.0	0.091
10.0	0.078
12.0	0.071
16.0	0.061
20.0	0.053

(a) The trolley was initially released from a height of 4 cm.

(i) Show that angle that the ramp makes with the horizontal when *h* = 4.0 cm is about 2°.

[2]

(ii) In the first measurement, when *h* = 4.0 cm and *t* = 0.164 s, show that the velocity of the trolley as it passed through the light gate was 0.610 m s^{-1}.

[2]

[Turn Over

(iii) Explain clearly why the velocity in **(a)(ii)** can be quoted to **three** significant figures, but not four.

[2]

(b) (i) The height was measured to the nearest 0.1 cm.

Calculate the percentage uncertainty in measuring the height for h = 4.0 cm.

[2]

(ii) Explain why the percentage uncertainty in measuring the height will be reduced as the ramp is raised.

[2]

(iii) Describe how the uncertainty in measuring the time for the trolley with the 10.0 cm card to pass through the light gate could be reduced.

✎ *You will be awarded marks for the quality of your written communication.*

[3]

Total [13]

15 Fiona suggests that the data in their experiment obeys the mathematical model

$$v^2 = kh$$

where k is a constant.

height h/cm	time t/s	velocity v/m s^{-1}	(velocity)^2 v^2/m^2 s^{-2}
4.0	0.164	0.61	0.37
6.0	0.113	0.88	0.78
8.0	0.091	1.1	1.2
10.0	0.078	1.3	
12.0	0.071	1.4	
16.0	0.061	1.6	
20.0	0.053	1.9	

(a) (i) Calculate values of v^2 and add them to the table above. The first three have been done for you. **[1]**

(ii) Plot a graph of v^2 (vertically) against h (horizontally) on the axes below.

Ensure that the axes are correctly labelled.

[4]

[Turn Over

(iii) Does the data support the relationship $v^2 = kh$? Justify your answer.

[2]

(b) Tom expects the kinetic energy gained by the trolley to be equal to the loss of gravitational potential energy.

By considering the loss of gravitational potential energy and gain of kinetic energy when the trolley drops through a height of 4.0 cm, check Tom's theory and account for the results.

$g = 9.8\ \text{m s}^{-2}$

[5]

Total [12]

Section C Total [40]

Paper Total [100]

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RECOGNISING ACHIEVEMENT

SPECIMEN

Advanced Subsidiary GCE

PHYSICS B (ADVANCING PHYSICS)

G492

Unit G492: Understanding Processes
Advance Notice

Specimen

May be opened and given to candidates upon receipt.

INSTRUCTIONS TO CANDIDATES

- Take this information away and read it carefully. Spend some time looking up any technical terms or phrases you do not understand. You are not required to research further the topic described.
- For the examination on ………. you will be given a fresh copy of this Advance Notice, together with a question paper. You will not be able to take your original copy into the examination with you.
- The value of standard physical constants will be given in the Advancing Physics Data, Formulae and Relationships booklet. Any additional data required are given in the appropriate question.

INFORMATION FOR CANDIDATES

- Questions in Section C of Paper G492, Understanding Processes, will refer to material in this Advance Notice.
- Section C will be worth about 40 marks.
- Sections A and B will not be based on the material in the Advance Notice.

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1. Uncertainties and errors in measurements in science

Random uncertainties are not mistakes, but are present in any measurement. They result in a scatter of readings about a mean value. They can be positive or negative. They result from the inability of the experimenter to repeat actions precisely.

Systematic errors may also be present in measurements. These result in all the readings taken being faulty in one direction. They can be caused by the apparatus or poor experimental technique.

2. The speed of light: from measurement to definition

Measurement of the velocity of light *c* was important in determining the nature of light.

Rømer and Huygens: observations of moons of Jupiter
The speed of light was first estimated from astronomical observations, when Rømer noticed up to 11 minute delays and advances in the times of eclipse of planets of Jupiter. At the time, it was no mean feat to have clocks that could measure differences in time of a few minutes over a six-month period. Using the best guess available for the diameter of the Earth's orbit, in 1690 Huygens arrived at a figure of about 200 000 km s^{-1} for the speed of light.

Fizeau, Foucault and Michelson: making measurements on Earth
It was not until 1849 that ways were found to make terrestrial measurements. First was Fizeau, who chopped a beam of light into pulses by sending it through the teeth of a rotating 720 tooth wheel. The pulses were sent to a mirror some kilometres away, and returned to the spinning toothed wheel, travelling a total of 17.2 km. Fizeau found that when the wheel rotated at 12.6 revolutions s^{-1}, each returning pulse of light was just blocked by the next tooth having moved into its path. This gave him a value of 313 300 km s^{-1} for the speed of light.

A year later, in 1850, Foucault found a way to do the experiment using a much shorter light path of 40 m. His idea was to reflect light from a rapidly spinning mirror, send it out to a fixed mirror and back to the rotating mirror. In the time taken for the light to go out and back, the spinning mirror turned through a small angle, so that the returning light was deflected through twice that angle. Because of the short light path, Foucault was able to send the light through water as well as air, and to show that light definitely travelled slower in water. This was what the wave theory of light had predicted, as opposed to the particle theory, which suggested the opposite.

The rotating mirror method was much improved and developed over the next half century, culminating in two sets of measurements by Michelson and colleagues. These used rotating mirrors, but the mirrors were made 8-sided so that Michelson could look for the speed of rotation at which the light reflected out by one face of the mirror was reflected by the next face when it came back. Thus he had only to detect zero deflection of the image, which can be done with less uncertainty than measuring a small deflection, as Foucault had to do.

The first set of measurements were made over an 18 km light path, between Mount Wilson and Mount San Antonio in California, determined to within a claimed uncertainty of $\pm$3 mm, giving a value of 299 796 $\pm$ 4 km s^{-1}

Speed in air – speed in a vacuum
The uncertainty in the measurement of only a few km s^{-1} was now small enough that the refractive index of the air had to be taken into account. In the mountain-top conditions used by Michelson, the light travelled 67 km s^{-1} slower in air than it would have in a vacuum. Atmospheric conditions affect the speed of light in air and vary from day to day and along the light path, so Michelson could not be very sure of the correction to make to allow for the speed in air. Together with Pease and Pearson, he set about removing this source of uncertainty. The idea was simply to do the same experiment in a vacuum, so that no correction was needed.

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In 1932, a year after Michelson's death, results were published of the average of 3000 measurements made in a mile-long evacuated tube buried underground near the Californian sea-shore. Using multiple reflections up and down the pipe the total light path was about 16 km.

The result was 299 774 km s^{-1}, which is 22 km s^{-1} slower than Michelson's mountain-top measurement. The claimed uncertainty, because of the large number of measurements, was better than before. The new low value was internationally adopted, but with an increased uncertainty estimate. Thus for the 1930s and 1940s the speed of light was officially decided to be c = 299 774 ± 11 km s^{-1}.

War-time radar and microwave standing waves

In World War 2, radar was developed to detect enemy aircraft. Measuring the range of an aircraft involves measuring the time delay of a reflected radar pulse, and using the agreed value of the speed of light. It slowly became clear that there was a discrepancy. Objects at a known distance were regularly measured by radar to be a bit closer than they were known to be. The discrepancy was not large enough to spoil radar ranging of aircraft – about 7 m in 100 km. However, after the war, this led physicists to look again at measuring the speed of light, using the advances in microwave generation and frequency measurement made partly as a result of the war effort. A series of measurements, using interference in microwaves, converged on a value higher than the official 299 774 ± 11 km s^{-1}. One of the best, made by Froome in 1958, gave c = 299 792.5 ± 0.1 km s^{-1}.

Adopting a new value, then choosing the speed of light by definition

As lasers became available, and became more and more stable, it became possible to measure both their frequency and wavelength with high precision. By 1973 the uncertainty in the speed of light had been reduced by a factor of 100, to only ± 1 m s^{-1}. In 1973 the International Committee of Weights and Measures recommended the value

$$c = 299\,792\,458 \pm 1 \text{ m s}^{-1}.$$

It soon became clear that the limit to uncertainty was the measurement of distance. The old definition of the metre as the distance between two marks on a metal bar was subject to greater uncertainty than the wavelength measurements. As a result, in 1984, by international agreement, the physics community took the radical step of abandoning the historic definition of the metre. Instead, the speed of light was chosen to be

$$c = 299\,792\,458 \text{ m s}^{-1} \textit{ exactly.}$$

Since the, distances have been measured in terms of the time taken for light to travel them.

The following table shows the results obtained by some experimenters between 1875 and 1951.

year	experimenter	observed velocity/ km s^{-1}
1875	Cornu	299 990 ± 200
1880	Michelson	299 910 ± 150
1883	Michelson	299 850 ± 60
1906	Rosa-Dorsey	299 784 ± 10
1928	Middelstaedt	299 778 ± 10
1932	Michelson with others	299 774 ± 4
1941	Anderson	299 776 ± 6
1951	Bergstrand	299 793.1 ± 0.3

[Turn Over

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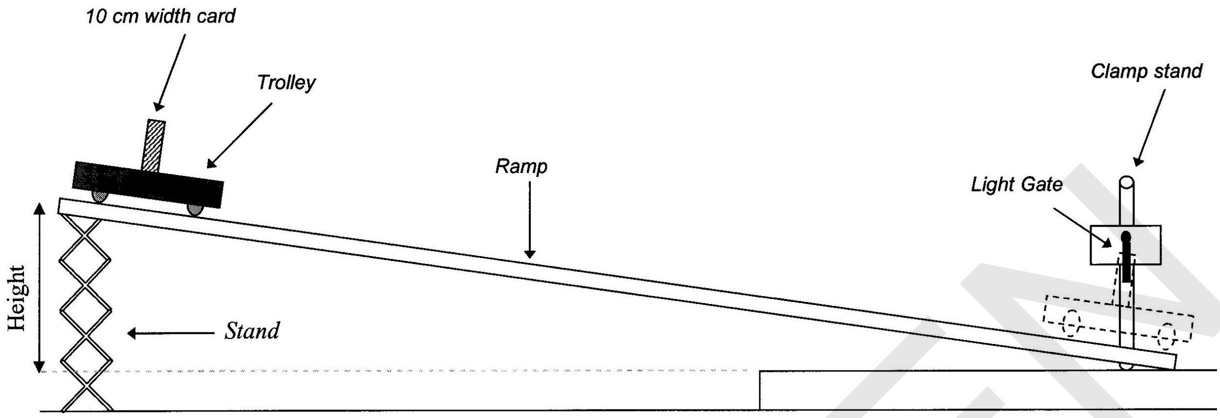
3. Fiona and Tom's trolley experiment

This set of data is about the motion of a trolley down a ramp as shown in the diagram below. The experiment was carried out by two AS students, Fiona and Tom.



mass of trolley *m*	0.992 kg
"mask" width *w*	10.0 cm
runway length *s*	1.20 m

One end of the runway was raised to a height *h*. The trolley had a mass of 0.992 kg and had a card 'mask' of width 10.0 cm mounted on it. The time *t* taken for the card mask to pass through a light gate at the bottom of the 1.20 m long ramp was measured.

height *h* / cm	time *t* / s
4.0	0.164
6.0	0.113
8.0	0.091
10.0	0.078
12.0	0.071
16.0	0.061
20.0	0.053

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