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Wednesday 5 June 2013 – Morning

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
- Protractor
- Ruler (cm/mm)

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found in the centre of 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. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- 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.
- The questions in Section C are based on the material in the Insert.

Answer **all** the questions.

SECTION A

1 Here is a list of units.

$m\,s^{-2}$ **$kg\,m\,s^{-2}$** **$N\,kg^{-1}$** **$N\,m$** **$J\,s^{-1}$**

Choose the correct units for

(a) energy

.... **[1]**

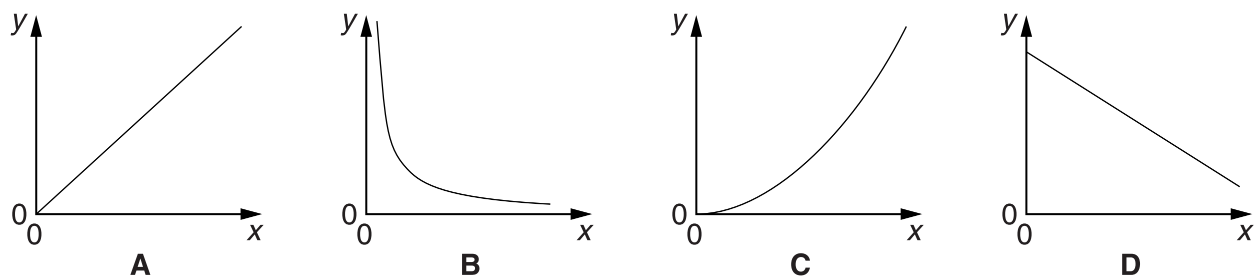
(b) power

.... **[1]**

(c) force

.... **[1]**

2



Which graph, **A**, **B**, **C** or **D**, is obtained when the *y*- and *x*- axes represent the two quantities given in each case below?

(a) y-axis: the potential energy gained when an object is lifted a given height
x-axis: the mass of the object

.... **[1]**

(b) y-axis: the distance moved by an object accelerating at a constant rate from rest
x-axis: the time for which the object has been accelerated

.... **[1]**

(c) y-axis: the energy of a photon of electromagnetic radiation
x-axis: the wavelength of the radiation

.... **[1]**

3 When monochromatic light from a distant source passes through two narrow slits separated by a small distance *d*, an interference pattern is seen on a screen a distance *L* away, (Fig. 3.1).

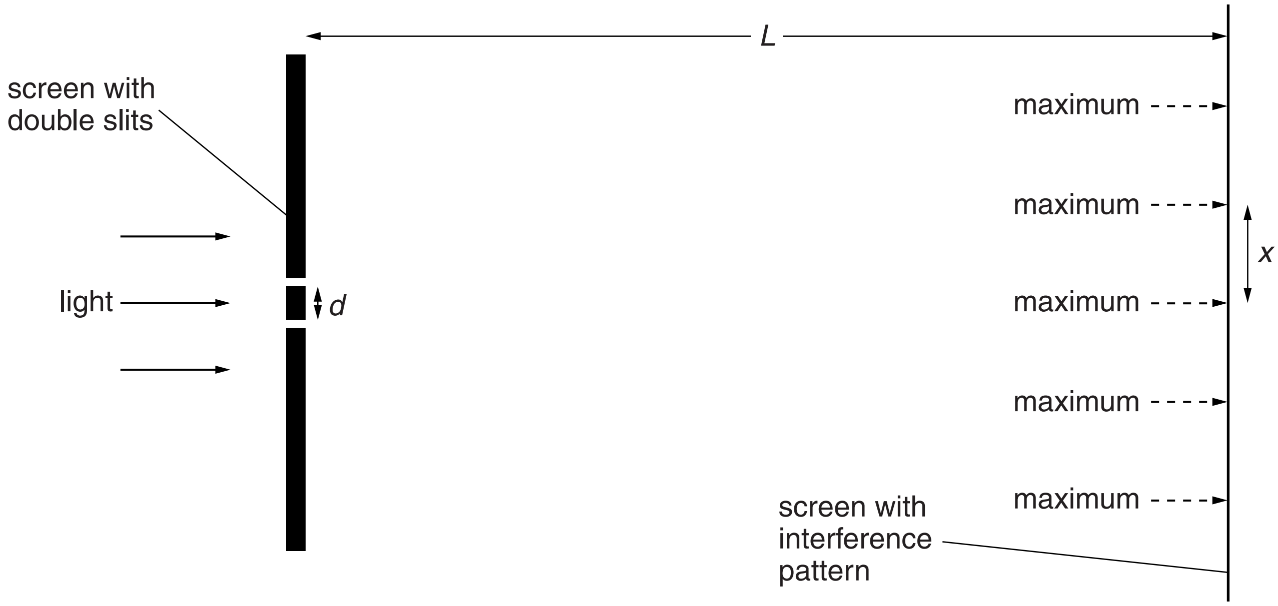


Fig. 3.1

Which two of the following changes would increase the spacing *x* of the maxima on the screen? Put ticks (✓) in the two correct boxes.

increasing the distance *L*	☐
increasing the intensity of the light	☐
increasing the frequency of the light *f*	☐
increasing the separation of the slits *d*	☐
increasing the wavelength of the light λ	☐

[2]

4 An 11 W compact fluorescent lamp emits 45% of the input power as visible light.

(a) Calculate the energy of the visible light emitted in 1 second.

energy = ... J **[2]**

(b) Assuming that all the light is emitted at a frequency of 6.0×10^{14} Hz, calculate the number of photons of visible light emitted in one second.

Planck constant, $h = 6.6 \times 10^{-34}$ J s

number of photons = ... **[3]**

5 When parallel waves of wavelength λ pass through a gap of width b as shown in Fig. 5.1, they spread out by diffraction. The intensity is a maximum in the forward direction, dropping away to zero intensity at an angle θ on each side.

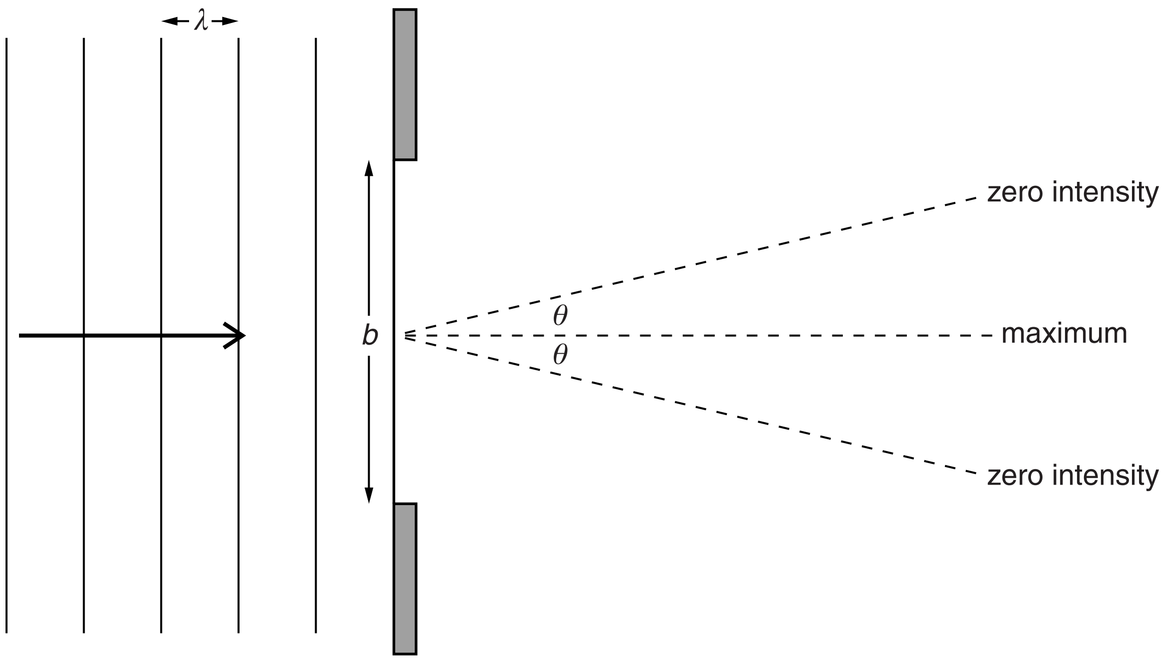


Fig. 5.1

(a) Which one of the following changes to the wavelength λ and the gap spacing *b* would result in an increase of the angle θ?

Put a tick (✓) in the correct box.

doubling λ and halving *b* ☐

halving λ and doubling *b* ☐

doubling λ and doubling *b* ☐

halving λ and halving *b* ☐

[1]

(b) The way in which the intensity varies can be explained in terms of phasors from each tiny part of the wavefront in the gap.

State how all these phasors together can produce zero intensity at the angle θ.
You may sketch phasor arrows in your answer if you wish.

[1]

6 Fig. 6.1 shows the forces acting on a car of mass 1940 kg travelling along a horizontal road.

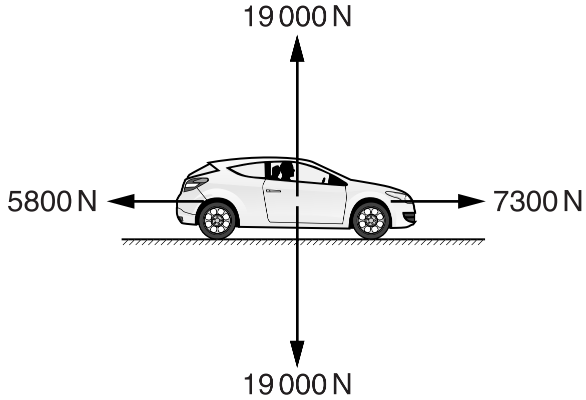


Fig. 6.1

(a) Find the resultant force acting on the car.

magnitude = ... N

direction ....

[2]

(b) Calculate the magnitude of the acceleration of the car.

acceleration = ... $m\,s^{-2}$ **[2]**

(c) At the instant shown in Fig. 6.1, the car has a speed of $22\,m\,s^{-1}$.
Calculate the power dissipated against resistive forces at this instant.

power = ... W **[2]**

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Question 7 begins on page 8

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SECTION B

7 Professional footballers can kick a football at speeds greater than $35\,m\,s^{-1}$.

Fig. 7.1

(a) A footballer kicks a stationary football. The foot and the ball are in contact for about 0.05 seconds. Immediately after contact, the ball is moving at $35\,m\,s^{-1}$.
Show that the mean force applied to the ball is about 300 N.
mass of football = 0.44 kg

[3]

(b) The force F on the ball is not constant, but varies with time t as shown in Fig. 7.2.

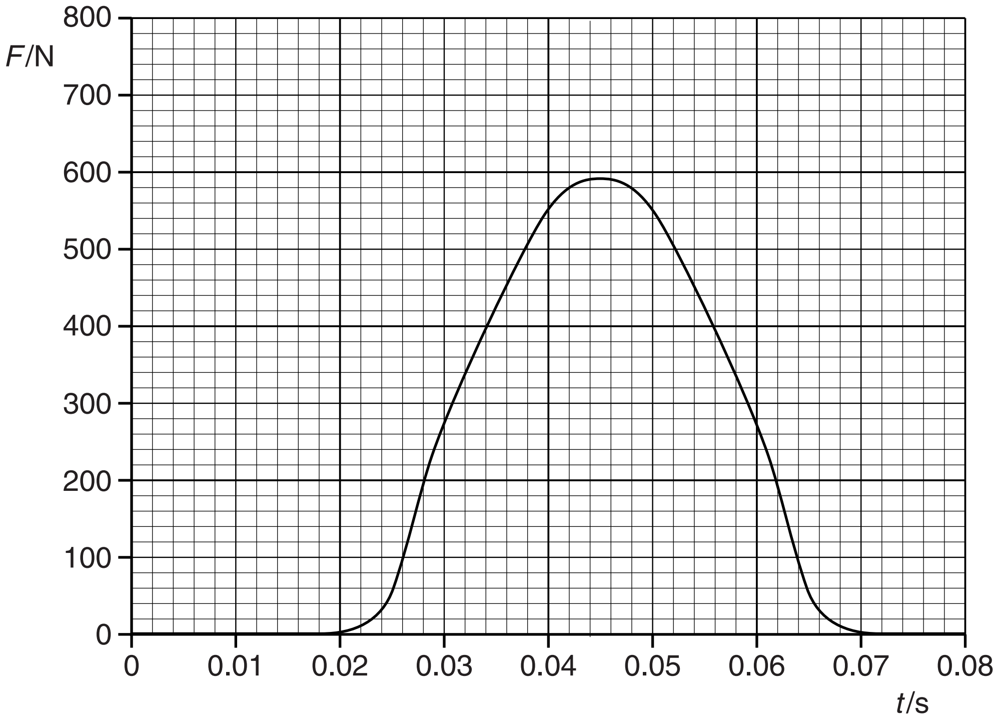

Fig. 7.2

Use data from the graph to show that the maximum acceleration of the ball is about 140 g.
$g = 9.8\,\mathrm{m\,s^{-2}}$

[3]

(c) On the axes of Fig. 7.3, sketch carefully the velocity-time graph for the football kicked at $35\,\mathrm{m\,s^{-1}}$. No calculations are needed.
The variation of force with time is indicated by the dashed line.

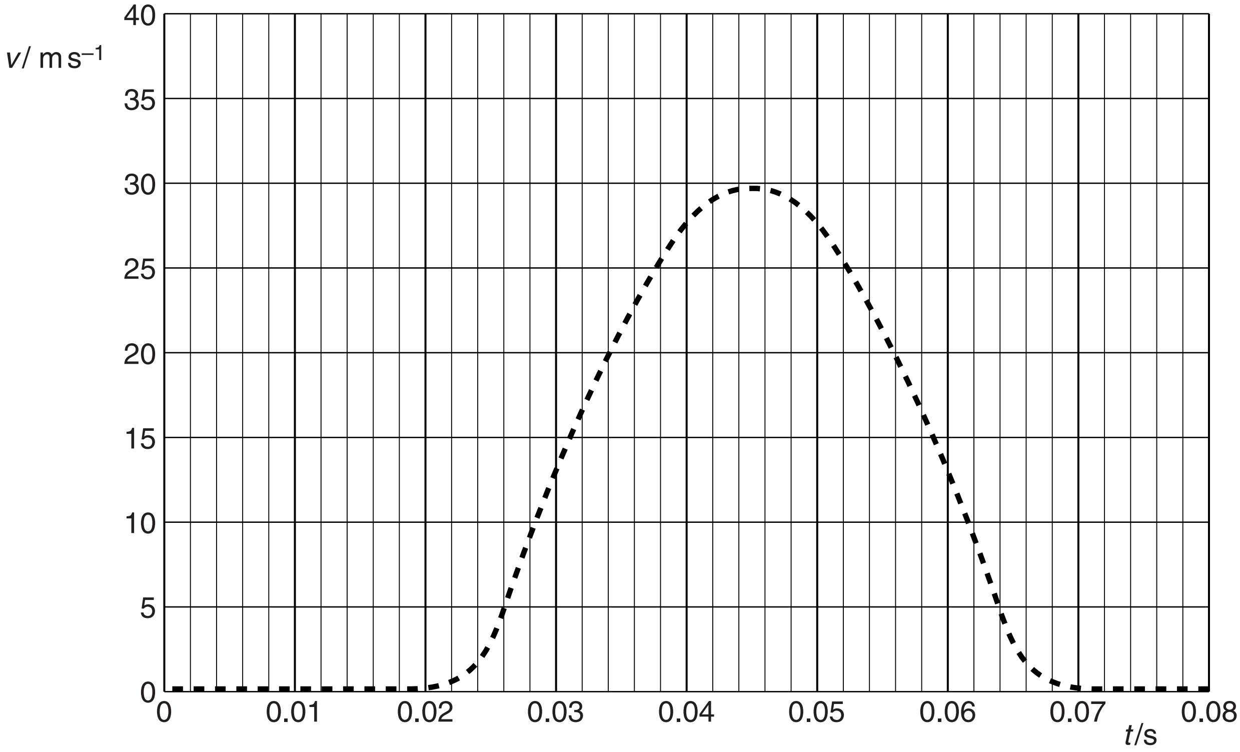

Fig. 7.3

[4]

[Total: 10]

8 This question is about wave superposition.

A vibration generator produces standing waves on a string as shown in Fig. 8.1.

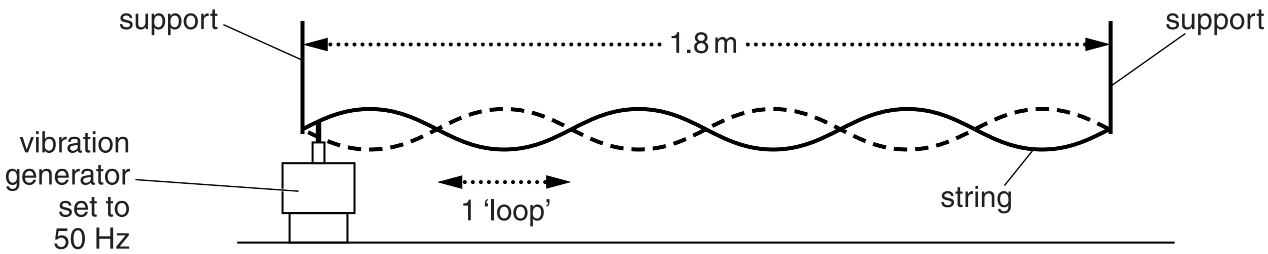

Fig. 8.1

(a) Explain how transverse waves passing along the string can produce a standing wave pattern.

[3]

(b) Use information from Fig. 8.1 to calculate the speed of transverse waves along the string.

speed = ... $m\,s^{-1}$ **[2]**

(c) Fig. 8.1 shows a standing wave made up of 6 'loops'.
By varying the frequency f, standing waves may be obtained with different numbers n of loops.
Each value of n corresponds to a frequency f_n and a wavelength λ_n.

Show that the wavelength λ_n, in metres, of a standing wave with n loops is given by

$$\lambda_n = \frac{2 \times 1.8}{n}.$$

[2]

(d) Give **one** other example of a standing wave.
Identify the type of wave involved, and explain how the standing wave is formed in this case.

[2]

[Total: 9]

9 This question is about the modelling of an object falling freely under gravity without air resistance. Use $g = 9.8\,\text{m}\,\text{s}^{-2}$ wherever it is needed.

(a) (i) Calculate the speed of the object, falling from rest, after 0.3 s.

Show your working.

speed = ... $\text{m}\,\text{s}^{-1}$ **[1]**

(ii) Show that the distance fallen in 0.3 s is more than 0.4 m.

[2]

(b) A computer program is used to model this fall.

The computer produces the following data.

Time *t* / s	**Velocity *v* / $\text{m}\,\text{s}^{-1}$**	**Displacement *s* / m**
0.0	0.00	0.000
0.1	0.98	0.000
0.2	1.96	0.098
0.3	2.94	0.294

(i) How do the **velocity** data in the table show that the acceleration is **uniform**?

[1]

(ii) How do the **displacement** data in the table show that the object is accelerating between 0.1 s and 0.3 s?

[1]

(c) Each set of data is calculated by the computer model using the following steps.

- The object starts at time $t = 0$ with $s = 0$ and $v = 0$.
- Calculations are made at equal time intervals of $\Delta t = 0.1$ s.
- During each time interval, the velocity is assumed to be constant at the value it had at the beginning of that time interval.
- At the end of each time interval, the velocity is increased by an amount $g\Delta t$.
- At the end of each time interval, the displacement is increased by an amount calculated from the value of velocity at the beginning of that time interval.

(i) Use this information to explain why the displacement at $t = 0.1$ s is still zero according to the model.

[1]

(ii) Explain why the distance fallen in 0.3 s given by the model is less than the correct value calculated in **(a)(ii)**.

[2]

(iii) Explain how a change to the value of Δt used could improve the accuracy of the model.

[2]

[Total: 10]

10 An LED (light-emitting diode) produces yellow light by mixing two colours, red and green. The red and green colours are monochromatic, each consisting of a single wavelength. When the light is passed through a diffraction grating, the spectrum shown in Fig. 10.1 is seen.

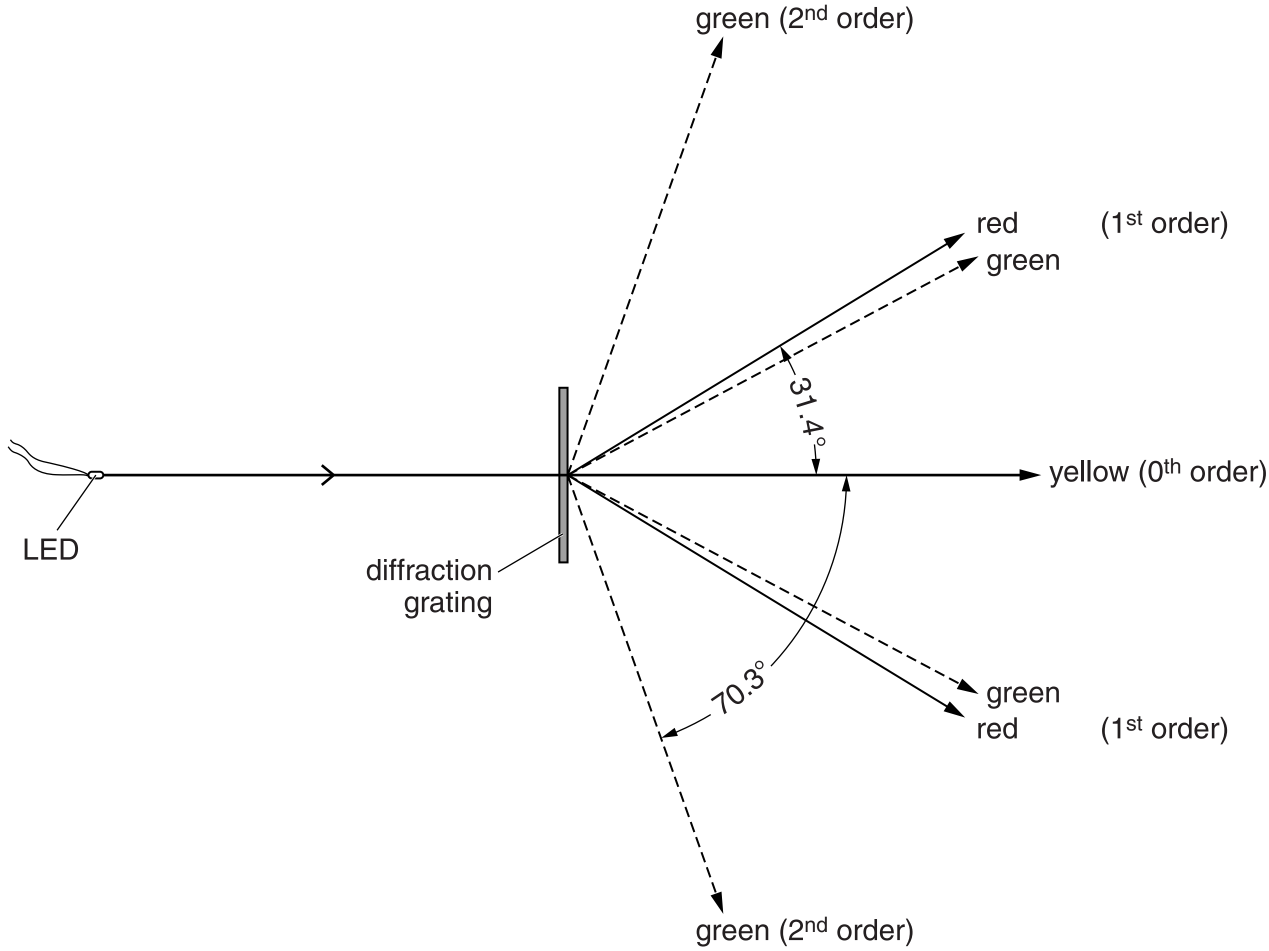

Fig. 10.1

(a) State why the 'straight through' 0^{th} order maximum appears yellow.

[1]

(b) (i) The diffraction grating is marked '820 lines per mm'. Show that this corresponds to a grating spacing of about 1 μm.

[1]

(ii) The red light emitted by the LED has wavelength 635 nm.
Use data from Fig. 10.1 to confirm that the grating spacing is about 1 μm.

[2]

(c) Explain why there are no 2^{nd} order red maxima.

[2]

(d) The LED is connected to a power supply set at 2.4 V. When the voltage is reduced to 2.1 V, it is observed that the four green maxima disappear, and that the 0^{th} order maximum becomes red. The two red maxima remain at 31.4°.
Use ideas about photons and energy to explain these observations.
Each volt across the LED corresponds to an electron transferring 1.6×10^{-19} J of energy as it passes through.

You should support your answer with appropriate calculations.

Planck constant, $h = 6.6 \times 10^{-34}$ J s
frequency of green light = 5.3×10^{14} Hz
frequency of red light = 4.7×10^{14} Hz

[4]

[Total: 10]

SECTION C

11 This question is about the article *Simple measurements using a temperature sensor*.

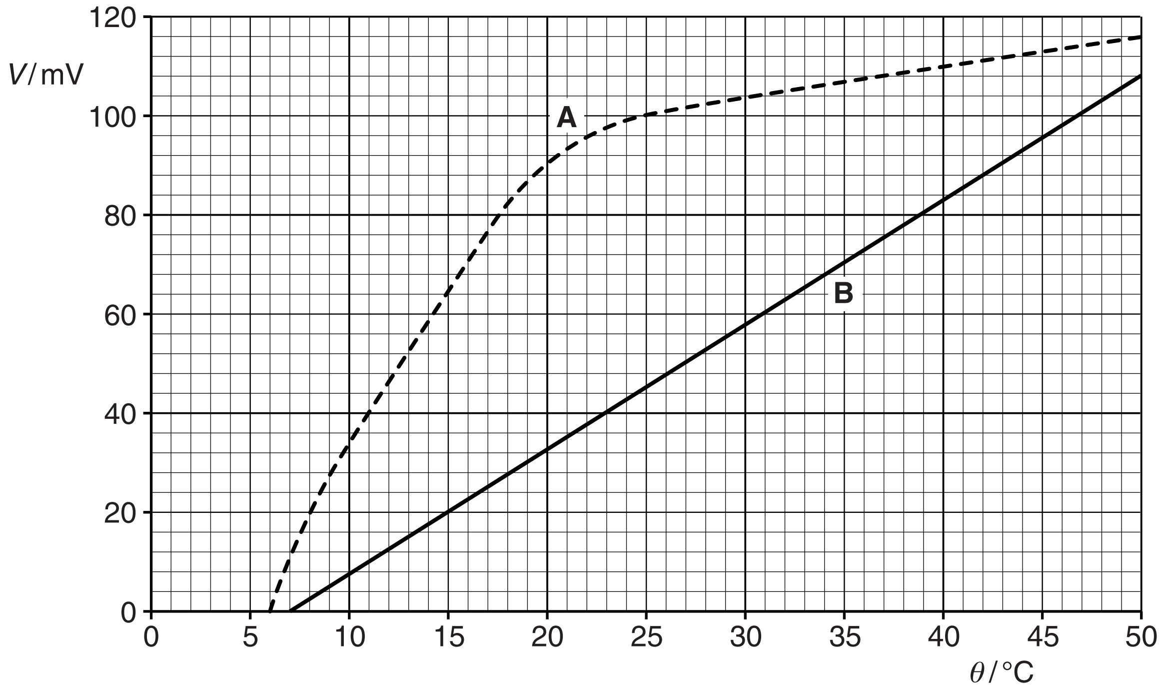

Fig. 11.1

(a) Calculate the average sensitivity of each sensor shown in Fig. 11.1 over the range 10° to 20°C.

sensitivity of sensor **A** = ... unit ....

sensitivity of sensor **B** = ... unit ....

[3]

(b) (i) Suggest a reason why sensor **A** might be a better choice for measuring small changes in temperature over the range 10° to 20°C.

[1]

(ii) Suggest a reason why sensor **B** might be a better choice for measuring changes of temperature over the range 10° to 50°C.

[1]

(c) (i) The voltmeter used to record the p.d. across sensor **B** reads to the nearest 0.1 mV. Show that the resolution of the sensor is about 0.04°C.

[2]

(ii) In an experiment to measure the change of water temperature in a bath, sensor **B** records a change of output of 100 mV.
Calculate the overall temperature change. Give your answer to an appropriate number of significant figures.

temperature change = ... °C **[2]**

[Total: 9]

12 This question is about the article *Trolley down a ramp*.

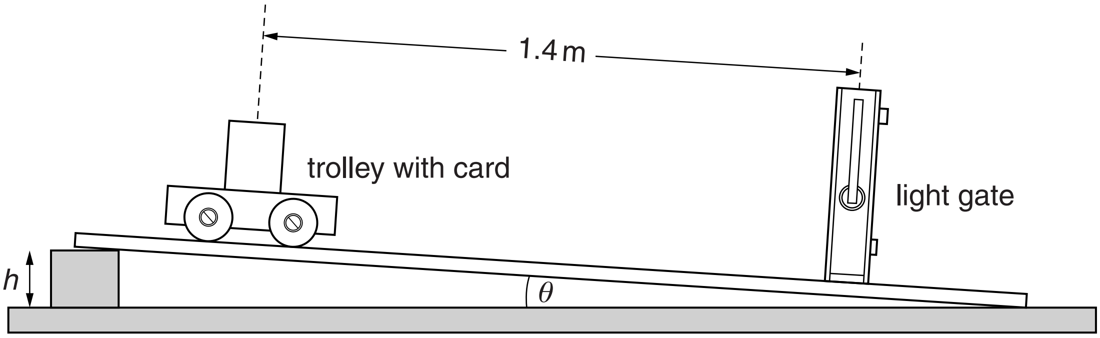

Fig. 12.1

(a) (i) In a particular experiment the angle θ of the ramp is increased in 5° steps from 10° to 40°. The trolley released from rest accelerates down the ramp, travelling a distance of 1.4 m. The final velocity v is measured at the light gate. Values for the final velocity are recorded in the table below. Values for v^2 and sin θ have been tabulated.

Add the three missing values to the table.

v / m s^{-1}	v^2 / m^2 s^{-2}	θ / degree	sin θ
2.13		10	0.17
2.72	7.40	15	0.26
3.06	9.36	20	0.34
3.38	11.42	25	0.42
3.69	13.62	30	0.50
3.92	15.37	35	
4.16		40	0.64

[2]

(ii) Plot these new values on the graph of Fig. 12.2 and draw a line of best fit.

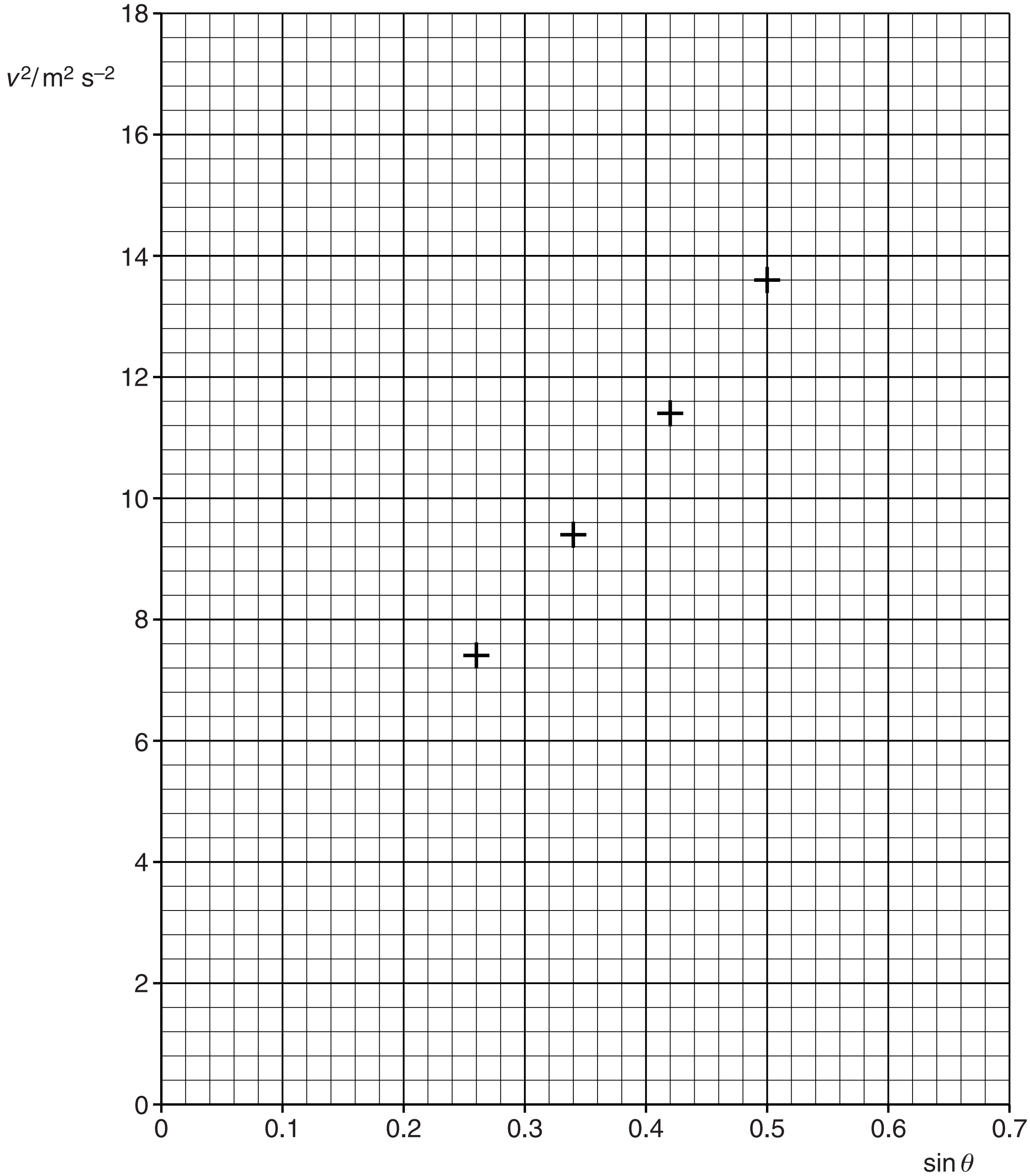

Fig. 12.2

[3]

(b) (i) Use data from the graph to calculate a value of the gradient of the graph.

gradient = ... unit .... **[3]**

(ii) Assuming no friction, Fig. 12.1 can be simplified to Fig. 12.3.

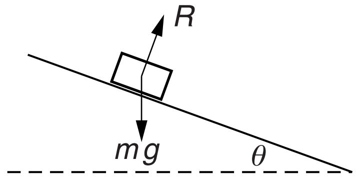

Fig. 12.3

Explain why the acceleration a down the ramp is given by $a = g \sin \theta$.

[2]

(iii) By using the relationships $v^2 = u^2 + 2as$ and $a = g \sin \theta$, show that the gradient of the graph of Fig. 12.2 is equal to $2.8\,g$.

[2]

(iv) Calculate a value for g.

g = ... $\mathrm{m\,s^{-2}}$ **[1]**

(c) Suggest and explain **two** experimental factors that may affect the value of *g* obtained by this method.

You should make clear the effect of each on the calculated value of g.

[4]

[Total: 17]

13 This question is about the article *Measuring the speed of light*.

(a) (i) Galileo's proposed measurement requires the second observer to uncover his lantern when he sees light from the first lantern.
Write down an estimate for the smallest time this would take, which is the human reaction time.

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

(ii) Light going from the first observer to the second observer and back has to travel 3.2 km.
Show that this takes a time of approximately 10^{-5} s.
speed of light, $c = 300\,000\,\text{km}\,\text{s}^{-1}$

[1]

(iii) Comparing the answers to **(a)(i)** and **(a)(ii)**, explain why Galileo's proposed method cannot detect any effect of the finite speed of light, and could at best show that the speed is greater than a few km per second.

[2]

(b) **(i)** Michelson's published value for the uncertainty in the speed of light was ± 50 km s^{-1}. A speed of 50 km s^{-1} is large enough to travel around the world in 15 minutes.

Explain whether an uncertainty of ± 50 km s^{-1} in a speed of 299 910 km s^{-1} is best thought of as large or small.

[2]

(ii) Explain why the improvements in the uncertainty of the measurement meant that Michelson had to include the correction of about 60 km s^{-1} for the difference between the speed of light in a vacuum and his measured speed in air.

[2]

(iii) The defined modern value of the speed of light, to six significant figures, is 299 792 km s^{-1}. What does this suggest about Michelson's claimed uncertainty of ± 50 km s^{-1}?

[2]

(c) The chocolate method of estimating the speed of light involves measurement of the separation of hotspots on a chocolate bar that has been kept stationary in a microwave oven for a few seconds.
An example is illustrated in Fig. 13.1, with a 1 cm grid behind it.
The microwaves in the oven used have a frequency of 2.45 GHz.

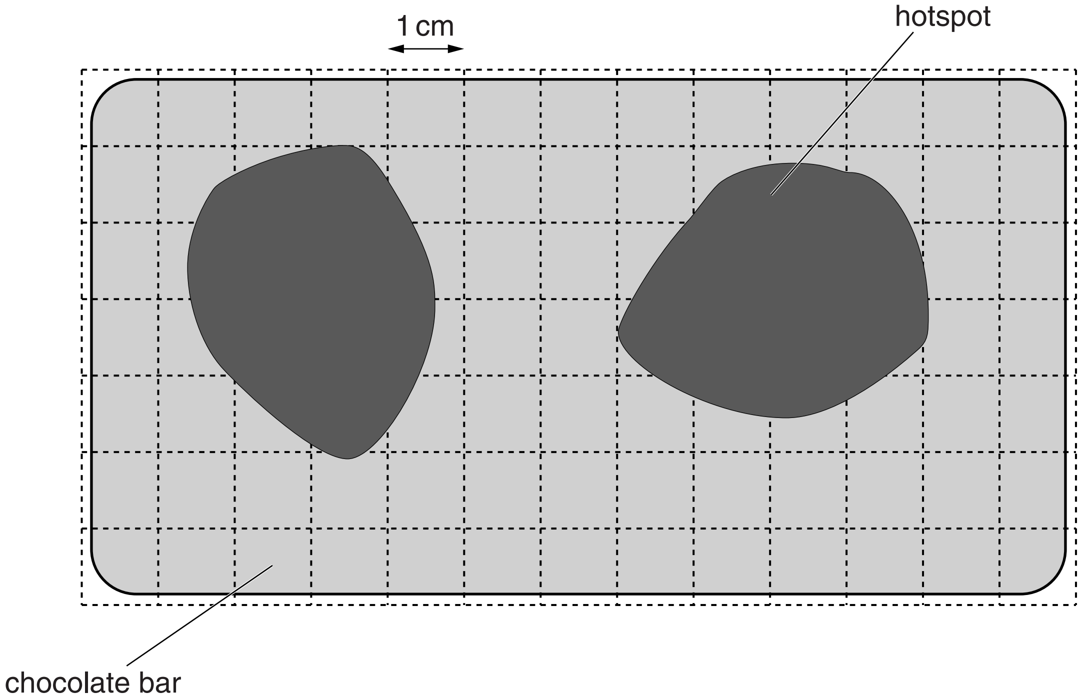

Fig. 13.1

(i) The article states that the uncertainty of measuring the distance between hotspots is approximately 1 cm.
Explain how this is illustrated in Fig. 13.1.

[1]

(ii) Use data from Fig. 13.1 to estimate a value for the speed of light and its uncertainty.

speed of light = ... ± .... $m\,s^{-1}$ **[3]**

[Total: 14]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined pages. The question number(s) must be clearly shown in the margins.

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Wednesday 5 June 2013 – Morning

AS GCE PHYSICS B (ADVANCING PHYSICS)

G492/01 Understanding Processes/Experimentation and Data Handling

INSERT

Duration: 2 hours

G412060613

INSTRUCTIONS TO CANDIDATES

- This Insert contains the article 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 Simple measurements using a temperature sensor

The data displayed in Fig. 1 shows the variation of p.d. V with celsius temperature θ obtained using two different temperature sensors **A** and **B**.

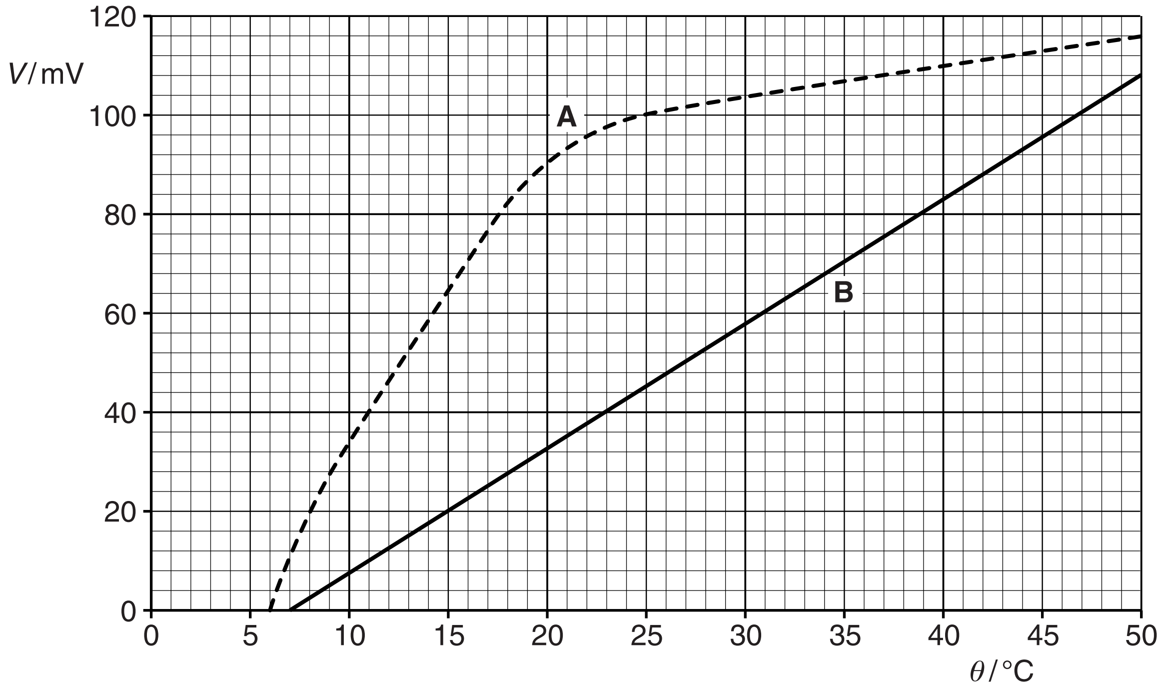


Fig. 1

The choice of a sensor for a given application depends on the following factors: range, resolution and sensitivity.

2 Trolley down a ramp

You may wish to try out these ideas in the laboratory so that you know in advance what the difficulties might be, how the experiment works and how the data can be used.

A trolley released from rest accelerates down a ramp. Its final velocity v is measured at a light gate. The simple arrangement of Fig. 2 can be used to carry out the practical task.

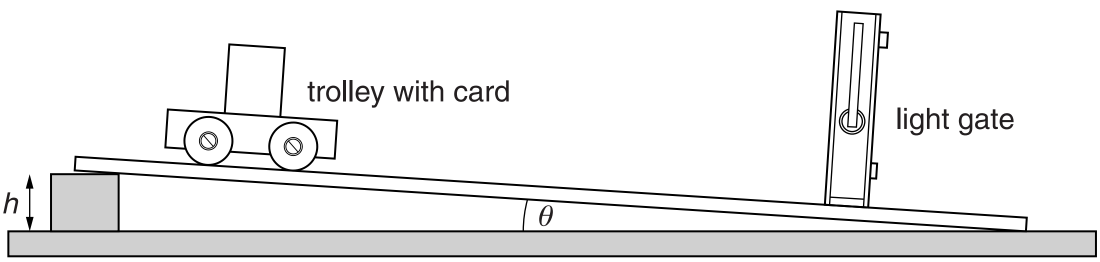


Fig. 2

The height h of the ramp can be raised to alter the angle θ of the ramp with respect to the horizontal.

The equation $v^2 = u^2 + 2as$ can be applied to the situation and used to determine a value for g, the acceleration due to gravity.

Factors that impact on the experiment and the consequent calculation of a value for g should all be considered. These could include friction on the trolley, energy loss, precision of the velocity measurement and measurement of the angle θ.

3 Measuring the speed of light

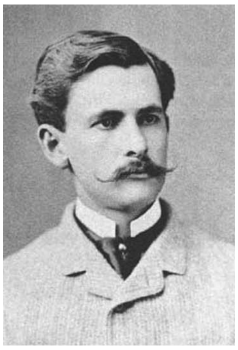
(Additional research is not required to answer the questions. **Do not try the 21st Century method described below except under supervision.**)

The modern value of the speed of light is, by definition, $299\,792\,458\,\mathrm{m\,s^{-1}}$.

16th Century

Galileo attempted to measure the speed of light. He proposed to have two men with lanterns stationed about a mile apart. One man was to uncover his lantern, and the second was to uncover the other lantern as soon as he saw the light from the first one. The first man would then attempt to detect any delay in the light returning to him. Of course, there was a delay due simply to the human reaction times involved, and no increase due to the travel time of the light could be detected, so the conclusion could only be that light travels at a speed larger than a certain minimum.

19th Century



In the late 1870s the young US Naval Officer Albert Michelson realised that he could use modern Naval equipment to redesign and greatly improve the measurement of the speed of light, using light reflected out from and back to a rapidly rotating mirror, as previously done in 1850 by Foucault.

His published result of $299\,910 \pm 50\,\mathrm{km\,s^{-1}}$, being many times more precise than the previous measurements, was featured in the New York Times in 1879 and made Michelson famous while still in his twenties. For the first time it became necessary to include a correction (adding about $60\,\mathrm{km\,s^{-1}}$) to the measured speed of light in air to find the larger speed of light in a vacuum.

21st Century

Later measurements of the speed of light have used interference of microwaves. It is possible to make an estimate of the speed of light using a bar of chocolate and a microwave oven. A chocolate bar placed in a microwave for a few seconds, with the turntable removed, will develop 'hotspots'. A hotspot is where the chocolate starts to melt, or is more melted than the rest of the chocolate. Making the assumption that a standing wave is established in the microwave oven, and that this is responsible for the hotspots, then the distance between adjacent hotspots is a half-wavelength of the waves being emitted in the microwave oven. Knowing the frequency of the microwaves, typically 2.45 GHz, and using $v = f\lambda$ it is possible to estimate the speed of light to a reasonable accuracy, taking into consideration the uncertainty of approximately 1 cm in measuring the distance between hotspots.

END OF ARTICLE