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Thursday 4 June 2015 – 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
- Protractor
- Ruler (cm/mm)

Duration: 2 hours

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Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert (Advance Notice) 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. 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 **24** pages. Any blank pages are indicated.
- The questions in Section C are based on the material in the Insert.

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Answer **all** the questions.

SECTION A

1 Here is a list of physical quantities.

displacement **force** **mass** **potential energy** **power**

(a) Which one could have the units $kg\,m\,s^{-2}$?

.... **[1]**

(b) Which of the quantities are vectors?

.... **[2]**

2 The following five expressions represent familiar physical quantities in different situations. Each symbol has its usual meaning.

$$\frac{hc}{\lambda} \qquad d\sin\theta \qquad F\Delta s \qquad \frac{\Delta v}{\Delta t} \qquad \left(\frac{u+v}{2}\right)t$$

(a) Which **two** expressions represent energy?

.... **[2]**

(b) Which **two** expressions represent distance?

.... **[2]**

3 Light of wavelength 590 nm is incident on a diffraction grating. The grating spacing is 2.8 μm.

(a) Calculate the angle of diffraction θ for the first order of diffraction from this grating.

θ = ... ° **[2]**

(b) There is also a diffraction maximum at an angle of 57.4°. Calculate the order n of diffraction which occurs at this angle.

n = ... **[2]**

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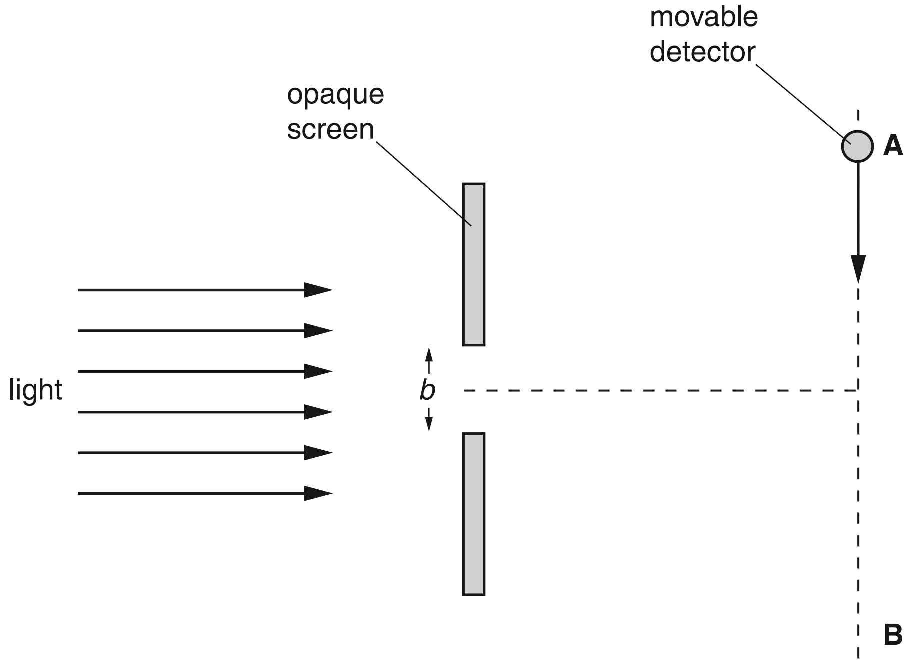
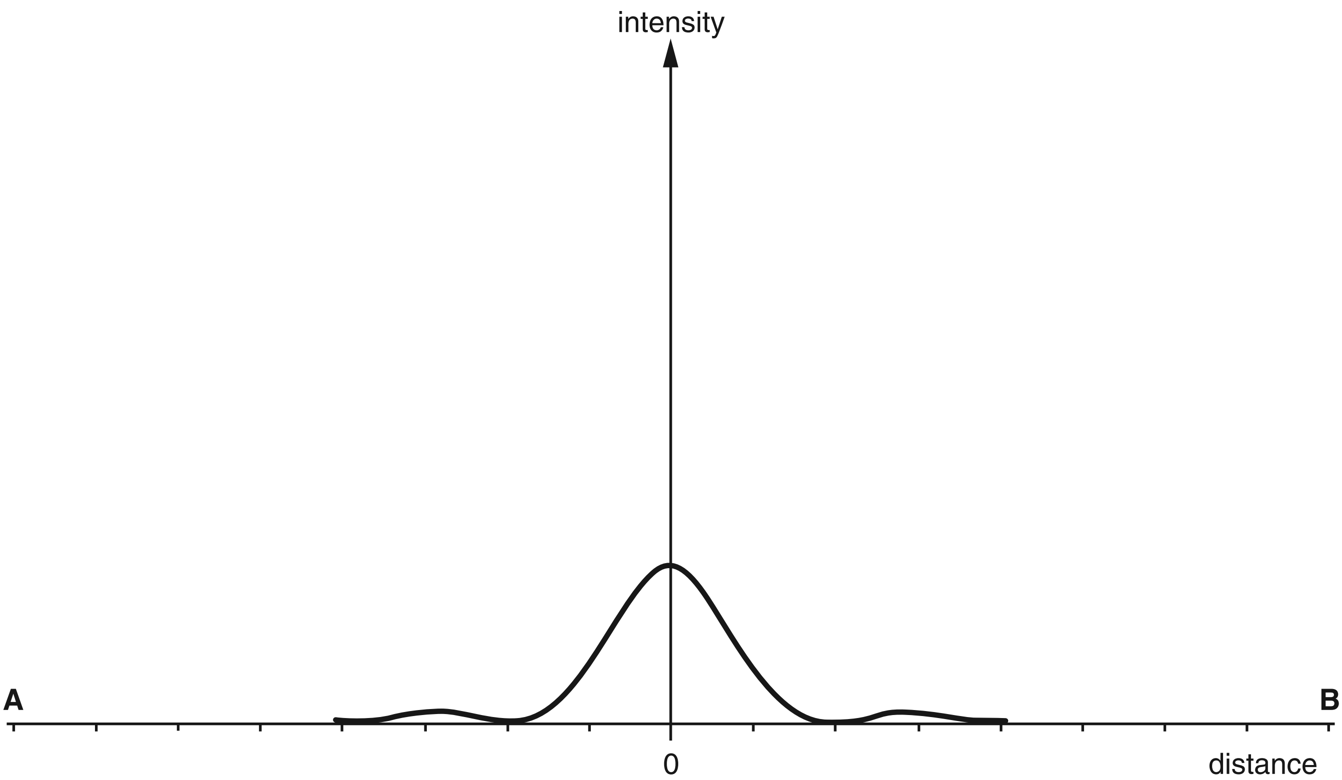
4 The diagram shows a parallel beam of light incident on an aperture of width b in an opaque screen. A detector on the other side of the aperture is moved from **A** to **B**.



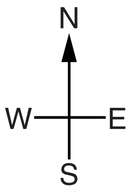
The detected intensity varies with distance as shown in the graph.

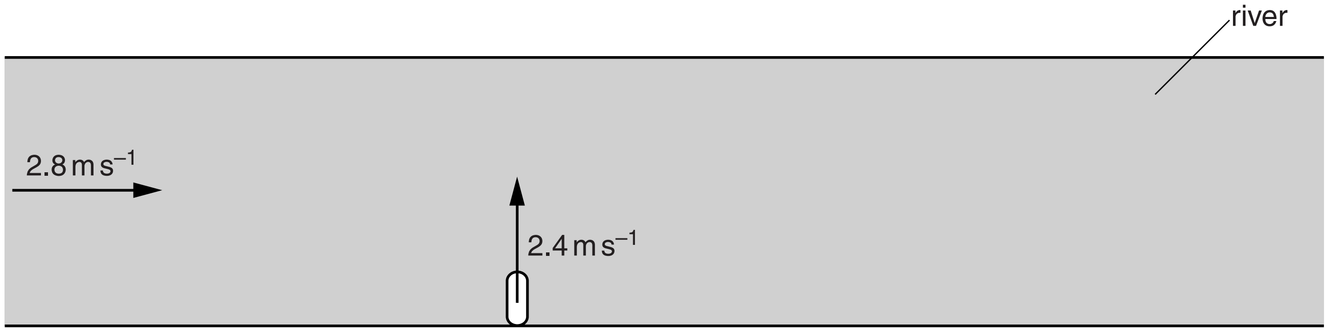


The width of the aperture is increased to $2b$. The source of light remains the same.

Sketch on the graph above the variation in intensity that would be expected. **[2]**

5 A boat heads out north to cross a river as shown in the diagram.





The boat moves at 2.4 m s^{-1} in still water. The river is flowing due east at 2.8 m s^{-1}.

By scale drawing or by calculation, find the resultant velocity of the boat.

magnitude = ... m s^{-1}

direction = ...

[3]

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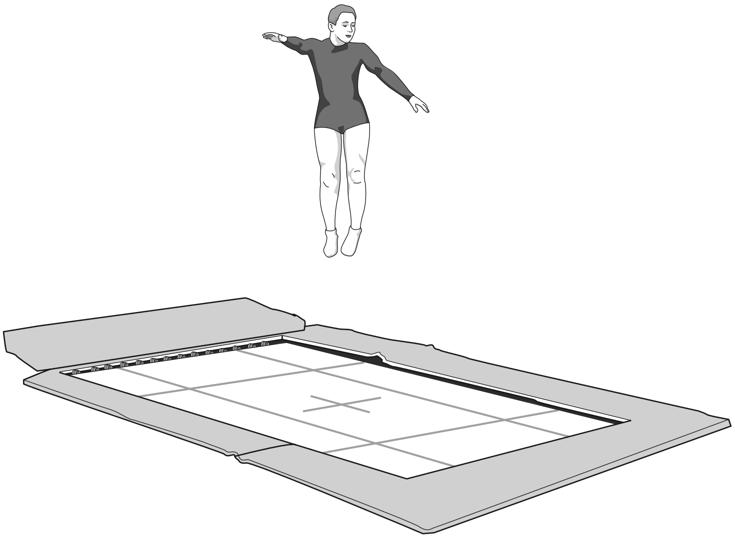
6 A gymnast leaves the surface of a trampoline with an initial vertical velocity of $12\,\mathrm{m\,s^{-1}}$.

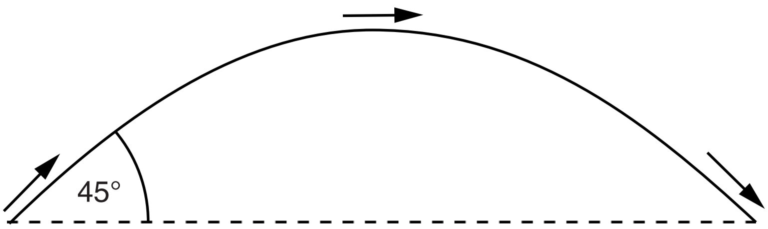


Calculate the height into the air that she rises. State any assumption that you make.

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

height = ... m **[3]**

7 A ball thrown at 45° to the horizontal follows the path shown in the diagram.



On the diagram, sketch the path the ball may take when it is thrown at the same speed but at an angle greater than 45° (and less than 90°) to the horizontal. **[2]**

SECTION B

8 Tom connects two loudspeakers to a signal generator of variable frequency and then mounts them on a bench facing each other as shown in Fig. 8.1. A microphone is moved along the line joining the two loudspeakers and its output is detected with an oscilloscope.

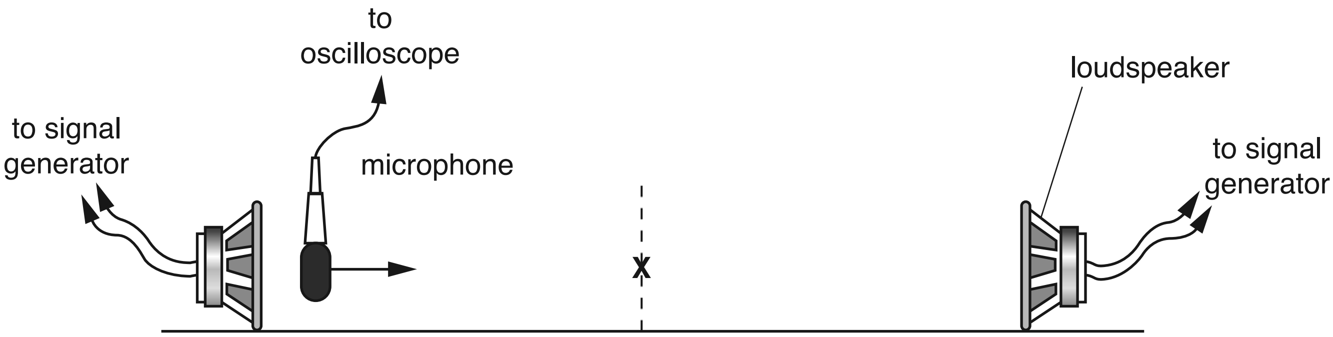


Fig. 8.1

(a) It is observed that the sound level detected by the microphone varies. The sound level is at a maximum at several places, including the position **X**, mid-way between the two loudspeakers. Explain why the sound level varies and why it is a maximum mid-way between the two loudspeakers.

[3]

(b) The frequency of the signal generator is set at 2000 Hz. Calculate the distance between **X** and the nearest adjacent maximum.

speed of sound in air = $340\,\mathrm{m\,s^{-1}}$

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

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(c) Sam uses the same signal generator and loudspeakers to set up this experiment, but her observations are different from Tom's.

(i) The distance between adjacent maxima in Sam's experiment is half the distance calculated in **(b)**.

Explain what she must have done differently from Tom in setting up the experiment to obtain this result.

[2]

(ii) Sam observes that the sound level is a minimum, not a maximum, at the central point **X**.

State what this observation tells you about the waves leaving the two loudspeakers.

[1]

(d) The experiment is repeated outdoors. It is found that the variation of the sound level is much easier to detect than in the laboratory.

Suggest, with an explanation, why this is so.

[2]

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9 Standard 50 W filament lamps are often replaced by LED lamps such as the one shown in Fig. 9.1.

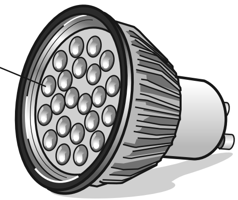

Fig. 9.1

(a) The power consumption of the set of 22 LEDs is 5 W.

(i) Calculate the number of photons emitted by **one** LED each second.
Assume that the mean photon frequency is 5.0×10^{14} Hz and that the energy efficiency is 100%.

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

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

(ii) The 5 W LED lamp has the same brightness as the 50 W filament lamp.
For both lamps, virtually all the power input is radiated as photons of electromagnetic radiation.

Explain what this implies about the nature of the photons emitted by the filament lamp.

[2]

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(b) The photons emitted by the LED lamp are not all of the same wavelength and frequency. The variation of power emitted with wavelength is given in Fig. 9.2.

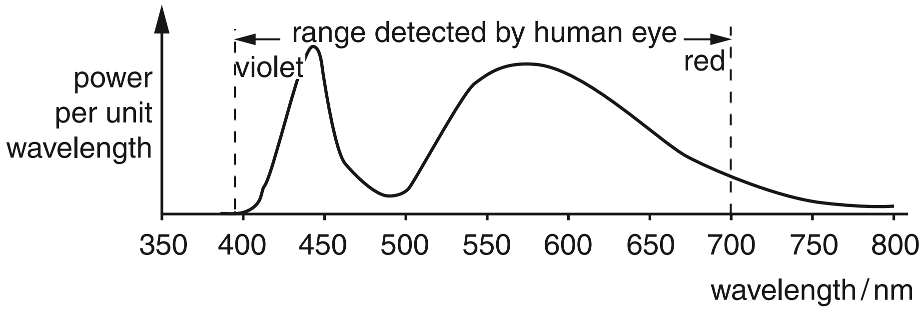

Fig. 9.2

In **(a)(i)** it was assumed that the mean photon frequency is 5.0×10^{14} Hz.

Explain how Fig. 9.2 shows that 5.0×10^{14} Hz is **not** a very accurate estimate of the mean frequency of photons emitted by the LED.

$c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$

[2]

(c) The manufacturers of the lamp giving the spectrum of Fig. 9.2 produce a similar lamp which emits light with the spectrum shown in Fig. 9.3.

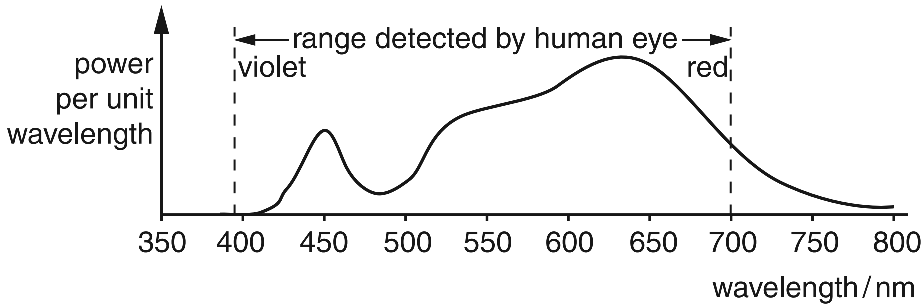

Fig. 9.3

Explain how, viewing the light emitted by both lamps, you are able to tell which lamp produced the spectrum shown in Fig. 9.3, and suggest an environment for which it would be more suitable than the other.

[2]

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10 In October 2012, the Austrian skydiver Felix Baumgartner jumped from a balloon more than 36 km above the Earth's surface. He fell freely for over four minutes before opening his parachute.

Fig. 10.1 shows how his velocity changed during that time.

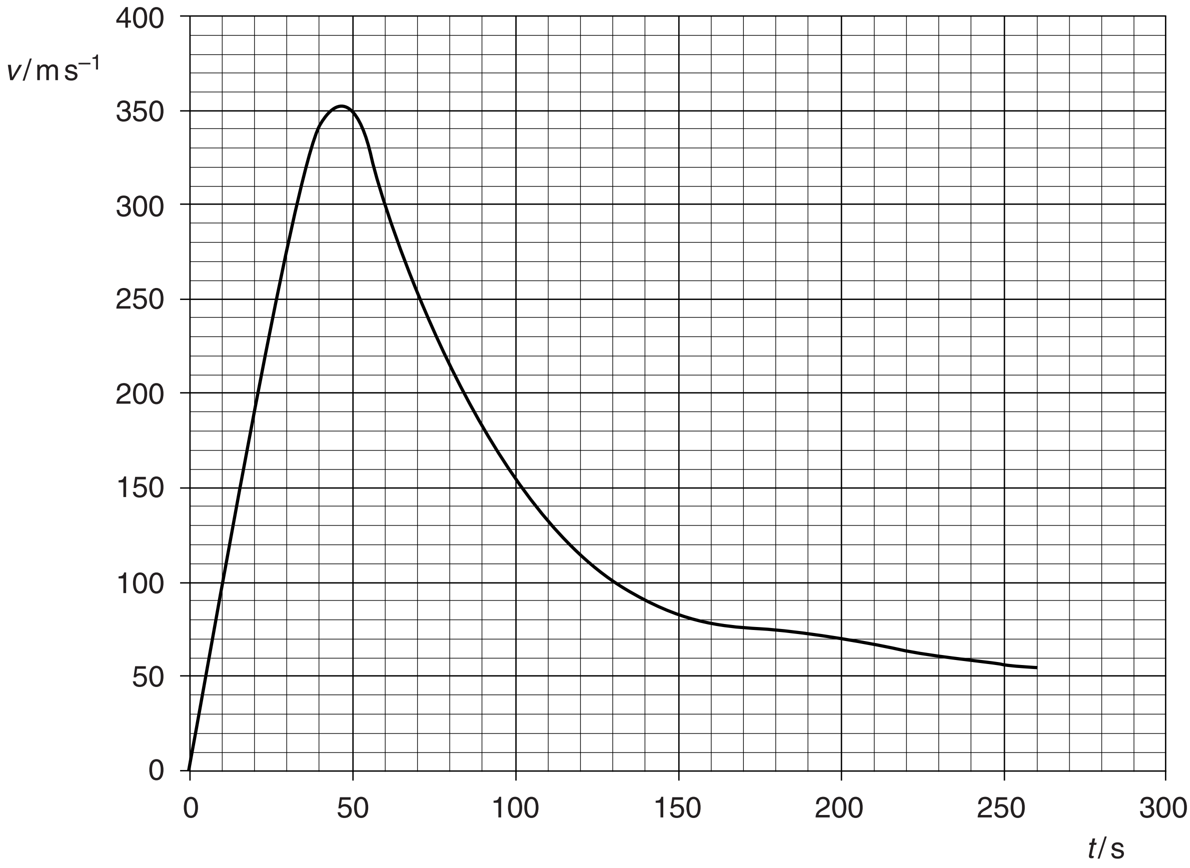

Fig. 10.1

(a) At the height from which Baumgartner jumped, the atmosphere is of very low density. As he fell, the air became denser.

(i) Using the graph of Fig. 10.1 show that, 30 s after he started to fall, his acceleration was about 7 m s^{-2}. Show your working clearly.

[2]

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(ii) Calculate the upward force F acting on Baumgartner at this point.

total mass of Baumgartner = 95 kg

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

force = ... N **[3]**

(b) Describe the shape of the graph between 30 s and 70 s. Explain the velocity changes in terms of changes in the air through which Baumgartner was falling. You may wish to label any point(s) of interest on Fig. 10.1.

[3]

(c) It has been claimed that Baumgartner fell more than 35 km in the 260 seconds before he opened the parachute.

Use the graph of Fig. 10.1 to check whether this claim is correct.

Show your method clearly.

[3]

11 This question is about the energy losses from a moving vehicle caused by forcing the air in front of it out of its way.
Fig. 11.1 shows a bus moving at a constant velocity v along a straight, level road through still air.
The bus is modelled as having a uniform cross-section.

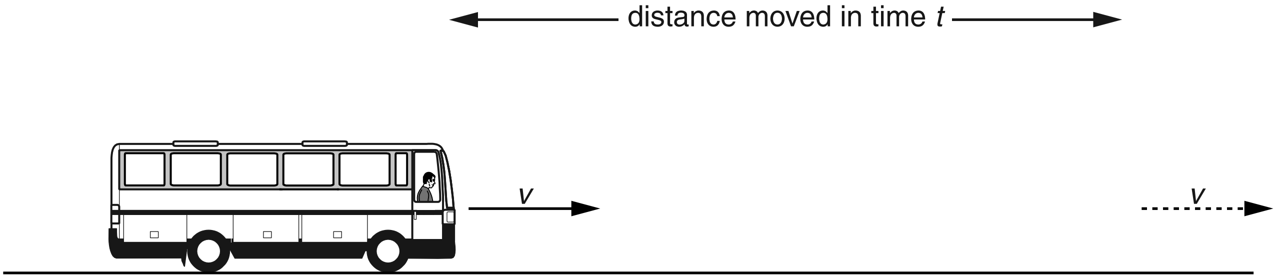

Fig. 11.1

The effects of a streamlined shape on the drag forces have been ignored in this model.

(a) The cross-sectional area of the bus is A.
Use appropriate algebraic equations to explain why the mass m of air displaced by the bus in a time t is given by

$$m = \rho A v t$$

where ρ is the density of the air.

[2]

(b) In this model, the air displaced by the bus is forced to move at the same speed v as the bus.
Show that the kinetic energy E_K gained by the air displaced in a time t is given by

$$E_K = ½\ \rho A v^3 t.$$

[1]

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(c) Use the equation given in **(b)** to calculate the power dissipated into the air when a bus of cross-sectional area 9.0 m^2 travels at a constant speed of 20 $m\,s^{-1}$.

$\rho = 1.2\,kg\,m^{-3}$

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

(d) A typical car carries two or three people while a typical coach carries 45 people (Fig. 11.2).

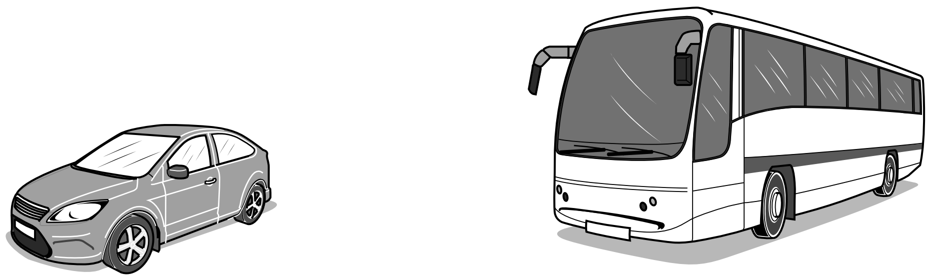

Fig. 11.2

Discuss the advantages and disadvantages of travelling between towns by these different methods.

In your answer, you should include comparisons of energy losses and other factors of importance for travellers.

[4]

SECTION C

The questions in this section are based on the material in the insert.

12 This question is about the article *The response time of thermistors*.

When the sensors were all plunged into the hot water at time $t = 0$ as described in the article the results were as follows.

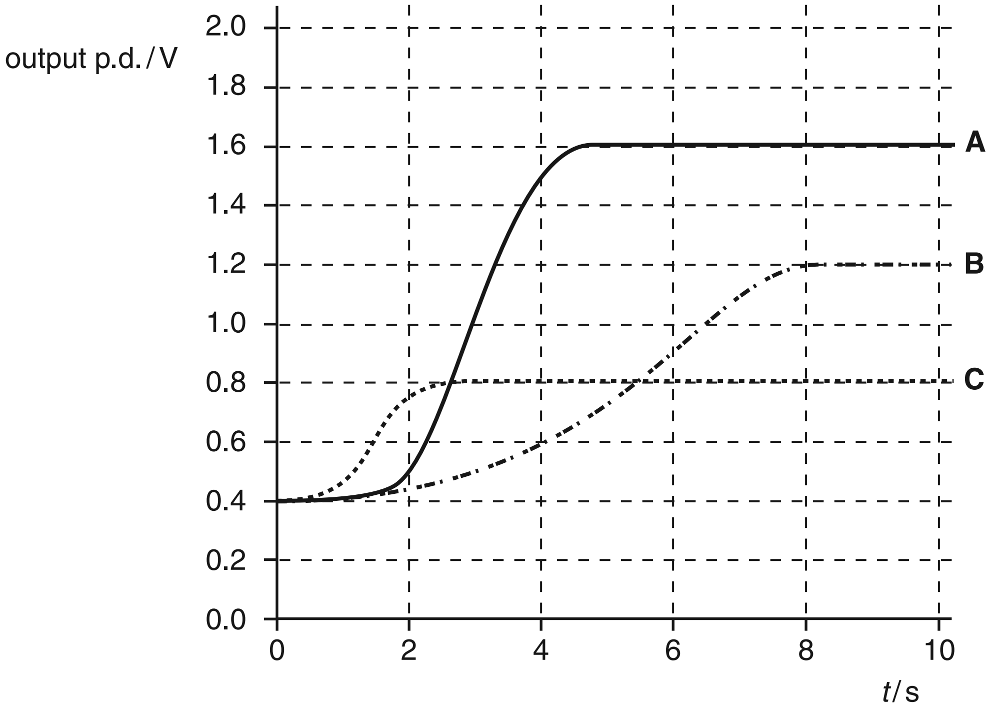

Fig. 12.1

(a) (i) State the sensor with the shortest response time.

....

State the sensor with the longest response time.

....
[1]

(ii) State the sensor with the greatest sensitivity.

....

State the sensor with the least sensitivity.

....
[1]

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(b) The temperature rise was 50 °C for all sensors.

Calculate the sensitivity of sensor **A**.

sensitivity of sensor **A** = ... unit .... **[3]**

(c) A sensor is needed to provide an early warning system in a baby incubator to prevent overheating.

(i) State, giving reasons related to sensitivity and response time, which of **A**, **B** or **C** is the best choice of sensor for this purpose.

[2]

(ii) Draw one additional line on Fig. 12.1 to represent a sensor which, when exposed to a 50 °C temperature rise, has a response time between that of sensors **A** and **B** and greater sensitivity than all of the other three sensors. You can assume that the output p.d. of the new sensor is 0.4 V at room temperature. **[3]**

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13 This question is about the article *Electricity consumption in an American home*.

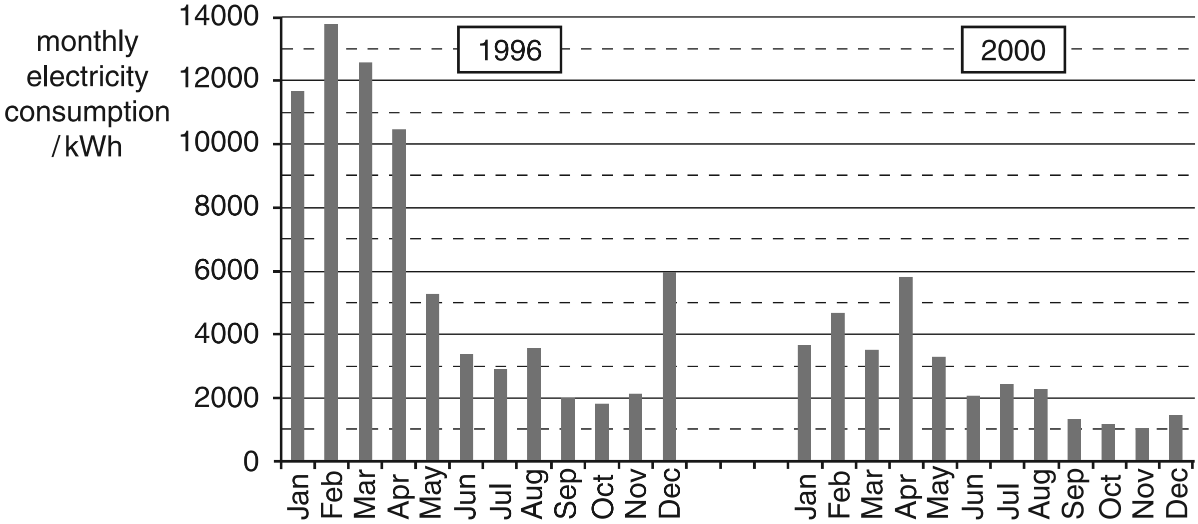

Fig. 13.1

(a) Discuss the effect on the monthly electricity consumption of the changes made in 1998.

In your answer, use data from Fig. 13.1 and Tables 1 and 2 in the article.
In this part, you should ignore any changes in the number of people living in the house.

[3]

(b) Use data from Tables 1 and 2 in the article to calculate the energy reduction in joules between 1996 and 2000 for the month of May.

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

(c) Fig. 13.2 uses data that take into account the number of people in the house.

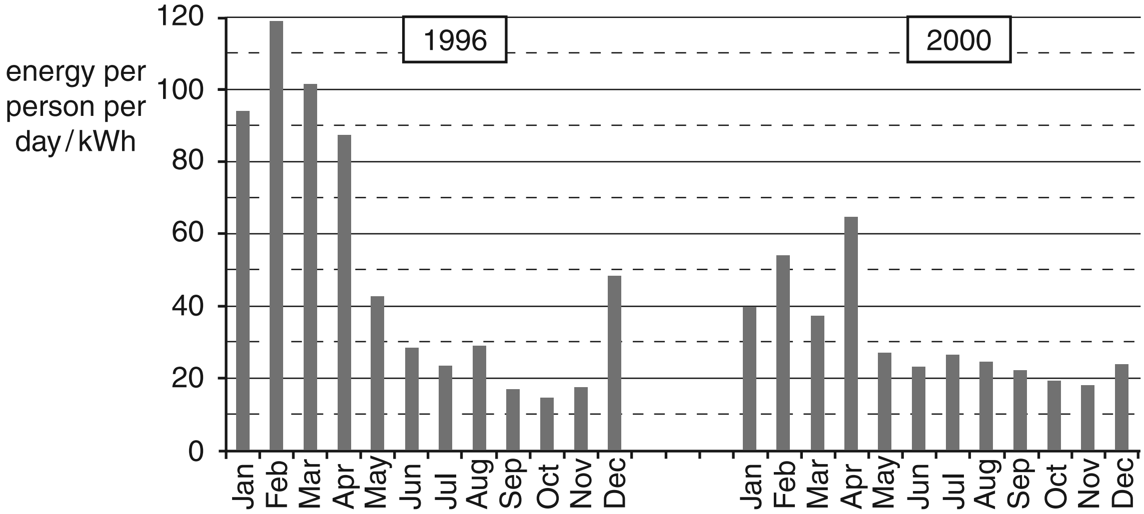

Fig. 13.2

(i) Give one reason for, and one reason against, taking the number of people into account.

[2]

(ii) State **two** separate features of Fig. 13.2 that provide evidence that there were differences in average monthly **temperatures** between the two years.

[2]

(iii) The average monthly temperatures have not been recorded, only the long-term average over many years.

Explain why this makes the comparisons of the two data sets less straightforward.

[2]

(d) Fig. 13.3 shows the relationship between temperature and daily energy use per person **in 1996** based on the thirty-year average monthly temperature data.

A best-fit line has been added to the data.

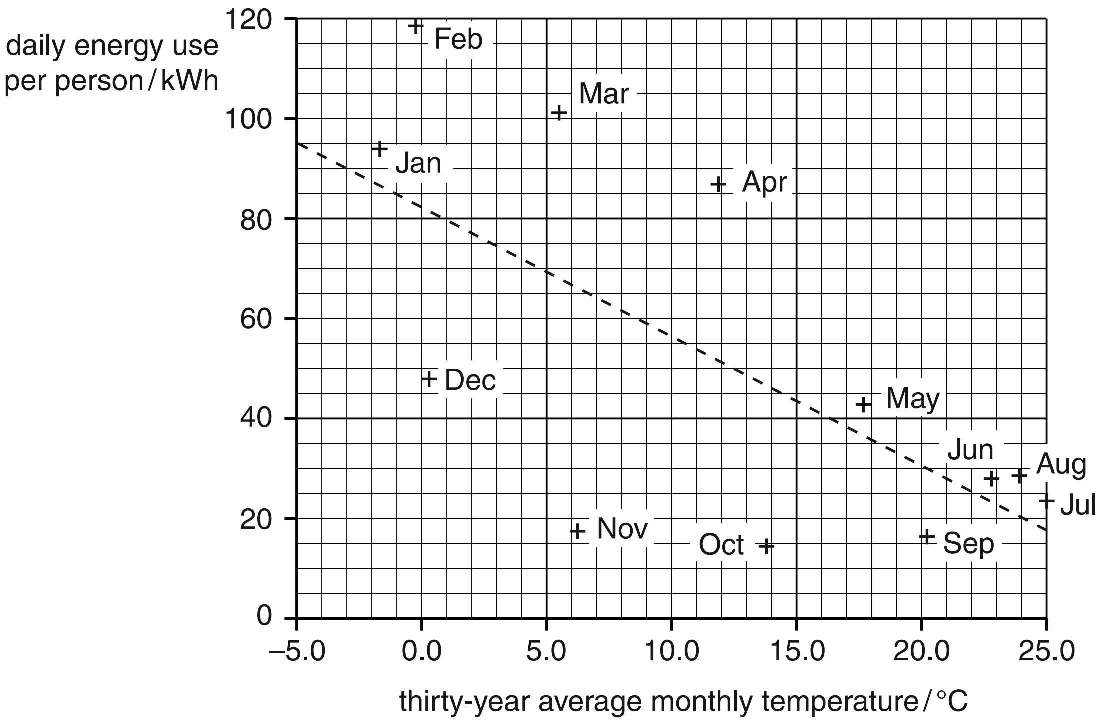

Fig. 13.3

Comment on the relationship between temperature and energy use shown by this graph.

[3]

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14 This question is about the article *Thomas Young's double slit experiment*.

(a) **(i)** Suggest, with reasons, why the wave theory of light was not widely accepted in Britain before Young's experiment.

[2]

(ii) State and explain why in Young's original experiment the sunlight was passed through a tiny hole.

[1]

(iii) Suggest and explain **one** advantage of using a laser in a modern version of the experiment.

[1]

(b) A student sets out Thomas Young's experiment but uses a laser instead of sunlight. The experiment is set up to calculate a value for the wavelength of the laser light.

The thickness of the stiff paper used to split the laser beam is calculated from the measurement of a stack of 40 identical pieces of stiff paper.

Explain how this method reduces the uncertainty compared with making a measurement of the thickness of a single piece of paper.

[2]

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(c) The following values are measured in the student's experiment:

thickness of paper, $d = 0.11 \pm 0.01$ mm

distance from paper to the screen, $L = 6.40 \pm 0.05$ m

separation of fringes on the screen, $x = 2.4 \pm 0.1$ cm.

(i) The student wrongly states that the percentage uncertainty in the wavelength is roughly equal to the percentage uncertainty in x, the separation of the fringes, because the other two percentage uncertainties are much smaller.

Comment on the student's statement.

Use calculations to support your answer.

[3]

(ii) Use the equation $\lambda = \frac{xd}{L}$ and the student's measurements, to calculate a mean value for the wavelength.

λ = ... m **[2]**

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(iii) Calculate the maximum value for the wavelength λ using the uncertainties quoted in the student's measurements.

$\lambda_{maximum}$ = ... m **[2]**

(iv) The value of $\lambda_{maximum}$ from the student's data is significantly lower than the manufacturer's value for the wavelength of the laser used in the experiment, which is 635 nm.

Explain how this value supports the statement in the article:
The systematic error introduced by placing the card at an angle to the beam could considerably exceed the uncertainties in measurements of the fringe separation and the thickness of the card.

[3]

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

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

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Thursday 4 June 2015 – Afternoon

AS GCE PHYSICS B (ADVANCING PHYSICS)

G492/01 Understanding Processes, Experimentation and Data Handling

INSERT

Duration: 2 hours

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INSTRUCTIONS TO CANDIDATES

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

INFORMATION FOR CANDIDATES

- This document consists of **8** pages. Any blank pages are indicated.

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1 The response time of thermistors

The following graph shows the results of an experiment set up to investigate the response time of three thermistors when they were exposed to the same sudden change in temperature. A potential divider circuit is set up so that a rise in temperature gives an increase in output p.d. across the thermistor. The thermistors at room temperature were all plunged into hot water at time $t = 0$ and the output p.d. (across the thermistor) and time were measured. A graph of the results for the first 10 seconds is shown in Fig. 1.

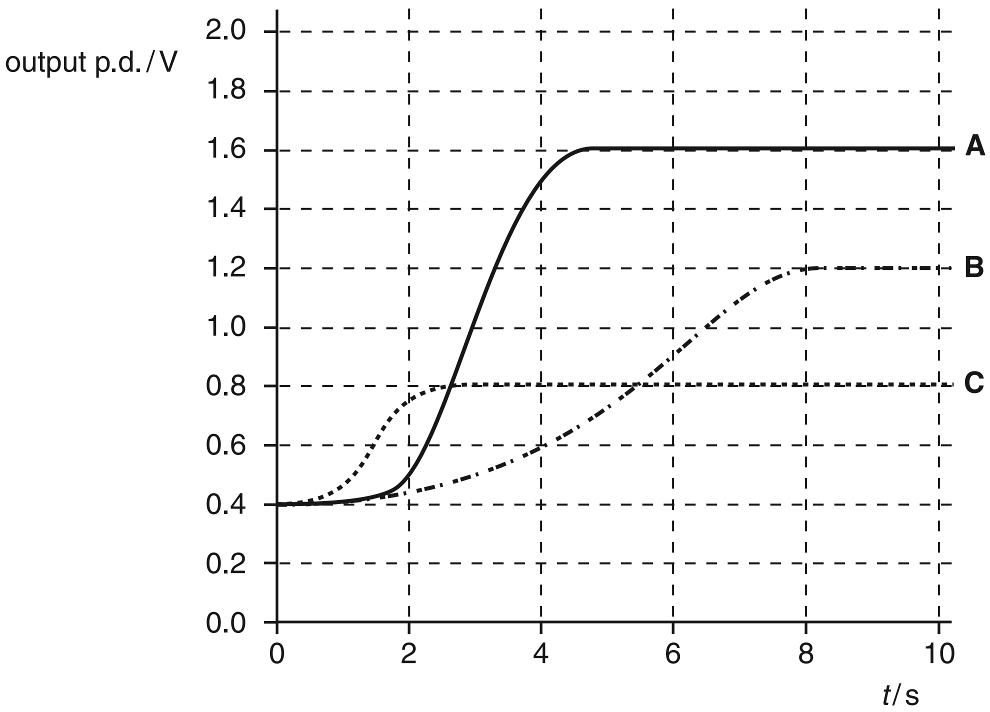

Fig. 1

These data allow both the response time and sensitivity of the thermistors to be compared.

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2 Electricity consumption in an American home

Table 1 shows the electricity consumed, for each month of the year, by an American home in the year 1996. Table 2 shows the same data four years later, for the year 2000, after changes were made to the heating system.

The house was all-electric, using only electricity as the source of power for heating in winter, cooling in summer, cooking, lighting, etc.

Month in 1996	Number of people living in house	Electricity used /kWh	Electricity used per day /kWh	Energy per person per day /kWh
Jan	4	11644	376	94
Feb	4	13784	475	119
Mar	4	12544	405	101
Apr	4	10463	349	87
May	4	5280	170	43
Jun	4	3371	112	28
Jul	4	2898	94	23
Aug	4	3567	115	29
Sep	4	1992	66	17
Oct	4	1784	57	14
Nov	4	2105	70	18
Dec	4	5975	192	48

Table 1 Electricity consumption in an American home in 1996

Month in 2000	Number of people living in house	Electricity used /kWh	Electricity used per day /kWh	Energy per person per day /kWh
Jan	3	3658	118	39
Feb	3	4681	161	54
Mar	3	3455	112	37
Apr	3	5805	194	65
May	4	3311	107	27
Jun	3	2062	69	23
Jul	3	2434	79	26
Aug	3	2253	73	24
Sep	2	1320	44	22
Oct	2	1182	38	19
Nov	2	1055	35	18
Dec	2	1462	47	24

Table 2 Electricity consumption in the same home in 2000

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In 1998, the occupiers, worried that their electricity bills were too large, replaced their existing electrical heating and air conditioning system with heat pumps. A heat pump heats a house (rather like a refrigerator in reverse) by cooling the ground outside the house a little and pumping the energy extracted from the ground into the house, at a higher temperature. The reverse process operates during hot summer weather. Heat pumps can be very efficient and the occupiers hoped in this way to reduce their electricity consumption.

Tables 1 and 2 show that there were fewer people living in this house after the changeover, so perhaps some reduction should be expected anyway, for this reason. Tables 1 and 2 therefore show, as well as the total energy consumed each month, the energy consumed per person per day.

Unfortunately the monthly average temperatures for these two years were not available. Table 3 shows the average monthly temperature data over a thirty-year period, including the years in question.

Month	**Thirty-year average monthly temperature /°C**
Jan	–1.6
Feb	–0.3
Mar	5.5
Apr	11.9
May	17.6
Jun	22.7
Jul	24.9
Aug	23.9
Sep	20.2
Oct	13.8
Nov	6.3
Dec	0.3

Table 3 Monthly average temperatures for the environment of the home studied

The data in Tables 1 to 3 can be expressed graphically and used to explore whether the heat pumps did indeed reliably reduce energy consumption. The data are limited and could be improved.

3 Thomas Young's double slit experiment

"The experiments I am about to relate ... may be repeated with great ease, whenever the Sun shines, and without any other apparatus than is at hand to everyone."

This is how Thomas Young, speaking in 1803 to the Royal Society, began his description of his historic experiment. His audience, an august gathering of notables in science, was steeped in Isaac Newton's idea that light is made of tiny bullet-like particles, because it is always observed (or so Newton thought) to travel in straight beams, in contrast to the ripple-spreading behaviour which Christiaan Huygens had linked with wave motion. Young's talk was published in 'Philosophical Transactions'. The journal became a classic, still reprinted and read today; it gave for the first time the decisive evidence which clearly demonstrated that light has the properties of waves. This conflicted with Newton's view and gave rise to the issue of whether light behaves as a wave or a particle.

Fig. 2

"...It will not be denied by the most prejudiced," Young chided his sceptical listeners, *"that the fringes are produced by the interference of two portions of light."*

It is a little-known fact that the original, historic "double slit" experiment, demonstrating that light can be diffracted, was not done with a double slit at all. This first light interference experiment used a different method which Young claimed was so simple that it could be easily reproduced in the classroom. The double slit experiment historically came later.

A narrow beam of sunlight was split with what Young described as *"a slip of card, about one thirtieth of an inch in breadth (thickness)"* (1 inch = 2.54 cm). The slip of card was held edgewise into the sunbeam, which was made to enter the room horizontally and through a tiny hole in a "window shutter". The sunbeam had a diameter slightly greater than the thickness of the card. The card was then placed to split the beam into two slivers, one passing on each side of the slip of card.

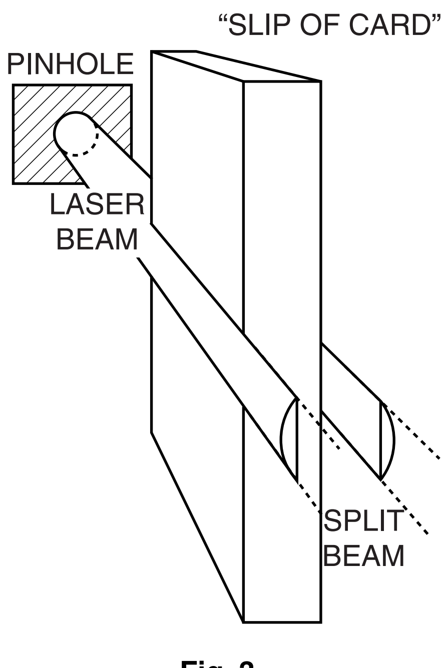

Fig. 3

You can try this experiment in the laboratory using a room-length projection distance. The card should not be reflective, or extra paths of light may be introduced confusing the interference pattern. It is also important to use a card or slip of stiff paper as thin as possible or the interference maxima will be too close together. It is possible to produce a pattern of interference fringes, with measurable separation using a laser. There are several advantages of using a laser but health and safety requirements must be followed.

Demonstration of the wave nature of light – Thomas Young's original purpose – can be achieved with this experiment, although errors in aligning the card parallel to the laser beam make accurate measurement of the wavelength difficult. The systematic error introduced by placing the card at an angle to the beam could considerably exceed the uncertainties in measurements of the fringe separation and the thickness of the card.

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