OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE

PHYSICS B (ADVANCING PHYSICS) G492

Unit G492: Understanding Processes / Experimentation and Data Handling

Candidates answer on the Question Paper

OCR Supplied Materials:
- Insert (Advance Notice Article for this question paper) (inserted)
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator
- Ruler (cm / mm)

Monday 17 January 2011
Afternoon

Duration: 2 hours

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Use black ink. Pencil may be used for graphs and diagrams only.
- 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).
- Answer **all** the questions.
- 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.

Answer **all** the questions.

Section A

1 Here is a list of equations used to calculate the quantities F, W, P, v^2 and s in certain situations.

$$F = ma \qquad W = F\Delta s \qquad P = Fv \qquad v^2 = u^2 + 2as \qquad s = ut + \tfrac{1}{2}at^2$$

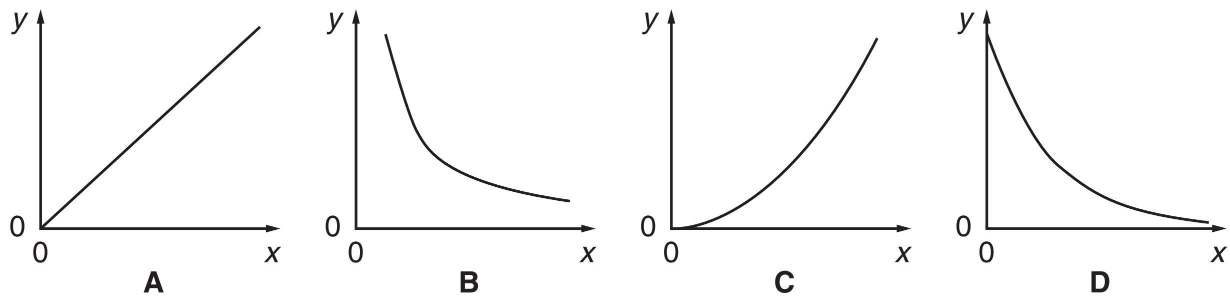
(a) Which of the quantities F, W, P, v^2 and s could be measured in J?

.... **[1]**

(b) Which of the quantities F, W, P, v^2 and s are vectors?

.... and .... **[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 energy of a photon of electromagnetic radiation
x-axis: the frequency of the radiation

.... **[1]**

(b) y-axis: the acceleration of an object subject to a constant resultant force
x-axis: the mass of that object

.... **[1]**

(c) y-axis: the wavelength of a wave
x-axis: the period of that wave

.... **[1]**

3 An electron is a quantum object.
An electron leaves a hot wire and arrives at a screen.
For all possible paths of this electron, the phasors are combined to give the total phasor amplitude *A* at any particular point on the screen.

Which of the following statements are correct for all points on the screen?
Put ticks (✓) in the **two** correct boxes.

The phasors will all cancel out.	
The phasors are all in phase.	
Phasors are added as vectors.	
The electron always takes the shortest path.	
The probability of the electron reaching any point is proportional to A.	
The probability of the electron reaching any point is proportional to A^2.	

[2]

4 The frequency of a photon emitted by a red LED is 4.8×10^{14} Hz.

(a) Show that the energy of a photon is about 3×10^{-19} J.

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

[1]

(b) The output power of the LED is 50 mW.

Calculate the number of photons emitted each second, assuming they all have a frequency of 4.8×10^{14} Hz.

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

5 The town of Lymington in southern England is midway between two Radio 5 Live medium wave transmitters (**X**), each broadcasting the same strength signal at 909 kHz.

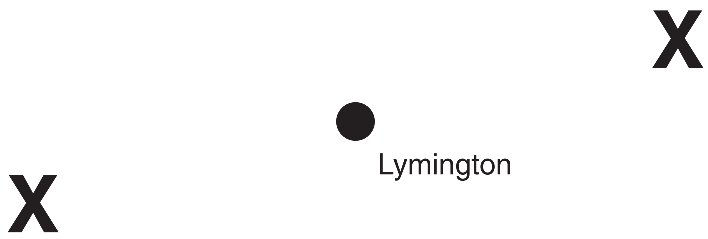


Fig. 5.1

(a) Show that the wavelength of 909 kHz radio waves is about 300 m.

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

[2]

(b) Explain why there are places in Lymington where the Radio 5 signal at 909 kHz is very poor, and calculate the smallest separation between those places.

separation = ... m **[2]**

6 Measuring the speed of light in the laboratory is difficult.

Give a reason why the percentage uncertainty in the value of the speed of light measured in the laboratory is likely to be quite large.

[2]

7 A stone is thrown vertically upwards at $12\,\mathrm{m\,s^{-1}}$.

(a) Calculate the speed v of the stone when it is 3.0 m above the point of projection.

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

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

(b) When the equation $s = ut + \frac{1}{2}at^2$ is used to calculate the time taken to reach a point 3.0 m above the point of projection, two answers of 0.28 s and 2.2 s are obtained.
Explain, without calculation, how the displacement can be the same at two different times.

[1]

[Section A Total: 20]

Section B

8 Waves on water are usually produced by wind blowing across the surface.
Under certain conditions, standing waves called *seiches* can be produced on a shallow lake.
Antinodes occur at opposite ends of the lake.
Fig. 8.1 shows the cross-section of a lake where a seiche is occurring, at equal intervals of time.

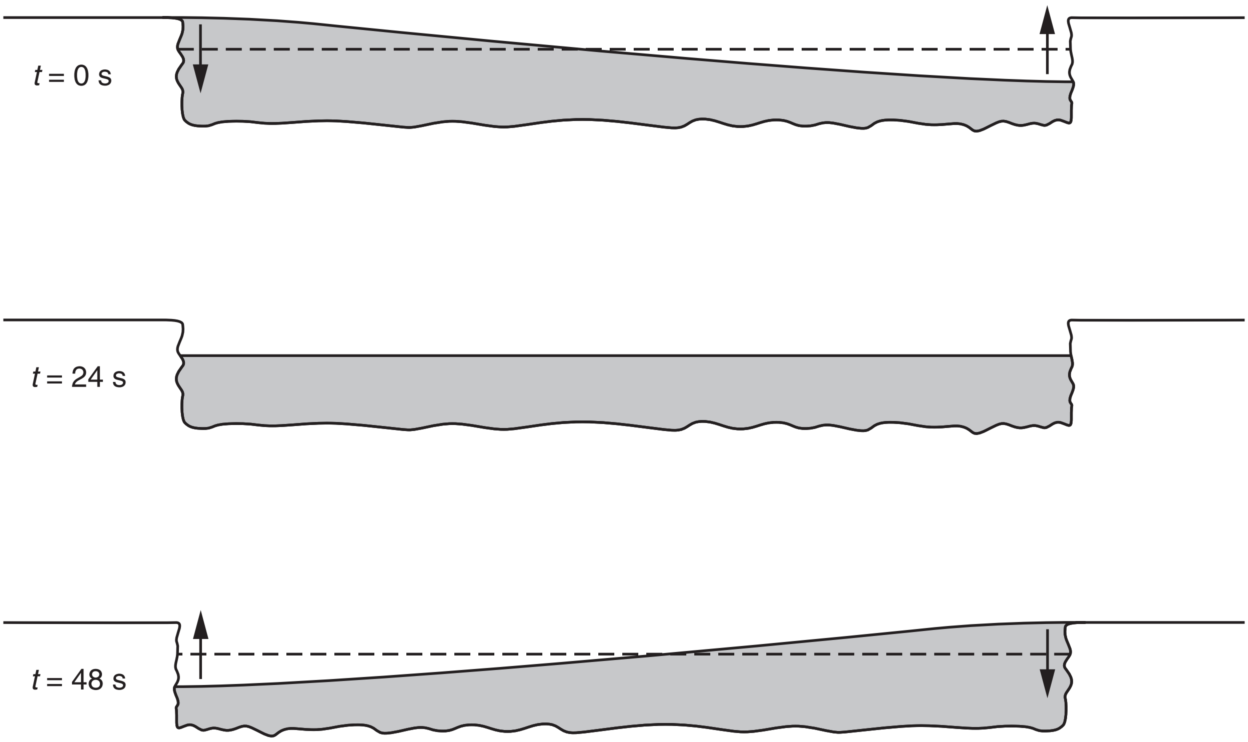


Fig. 8.1

(a) The standing waves shown in Fig. 8.1 occur in a small lake, 800 m long. They have a period of 96 s and amplitude of 1 m.

(i) Describe how someone viewing the lake might be aware that there were **standing waves** on the lake.

[2]

(ii) For the standing wave, label each antinode **A** and each node **N** on the bottom diagram of Fig. 8.1.
Use the labels to explain why the wavelength of the water waves is 1600 m.

[2]

(iii) Explain why Fig. 8.1 shows that the period of the waves is 96 s.
Use this to calculate the speed of water waves in the lake.

speed = ... m s^{-1} **[4]**

(b) Explain why standing waves of period 48 s might also be observed on this lake.

In your answer, you should make clear the logical steps.

[3]

(c) In another lake, the longest period of seiche standing waves observed is about 14 hours, not 96 s. Suggest and explain **one** way in which this other lake may differ from the one in Fig. 8.1.

[1]

[Total: 12]

9 In one extreme sport, BASE jumping, people jump off structures such as buildings or bridges. They open a parachute as late as they dare (Fig. 9.1).

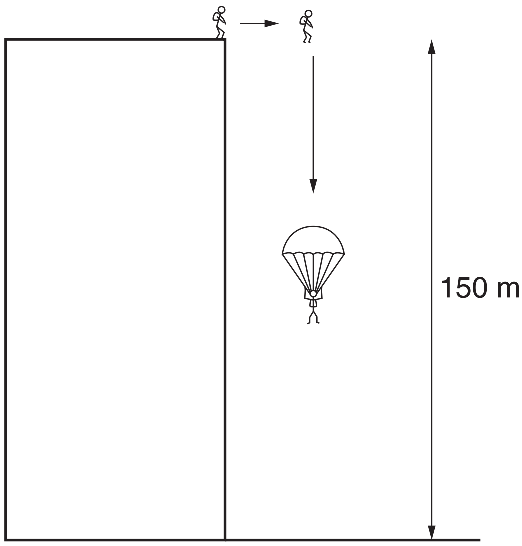


Fig. 9.1

(a) In one BASE jump, the building used is 150 m high.
In a simple model of the jump, a jumper accelerates uniformly with $a = g$ before she opens her parachute.

(i) Show that it takes a little over 1 s for the free-falling BASE jumper to reach a speed of $12\,\mathrm{m\,s^{-1}}$.

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

[1]

(ii) Show that the distance fallen by the BASE jumper before she reaches a speed of $12\,\mathrm{m\,s^{-1}}$ is about 7 m.

[2]

(iii) Assume that her parachute opens instantly after the first 7 m of free-fall, and that she then falls at a steady speed of 6.0 m s^{-1} for the rest of the fall.
Calculate the **total** time she takes to reach the ground.

total time = ... s **[2]**

(b) The graph for the jump described by the model in **(a)** is shown in Fig. 9.2.

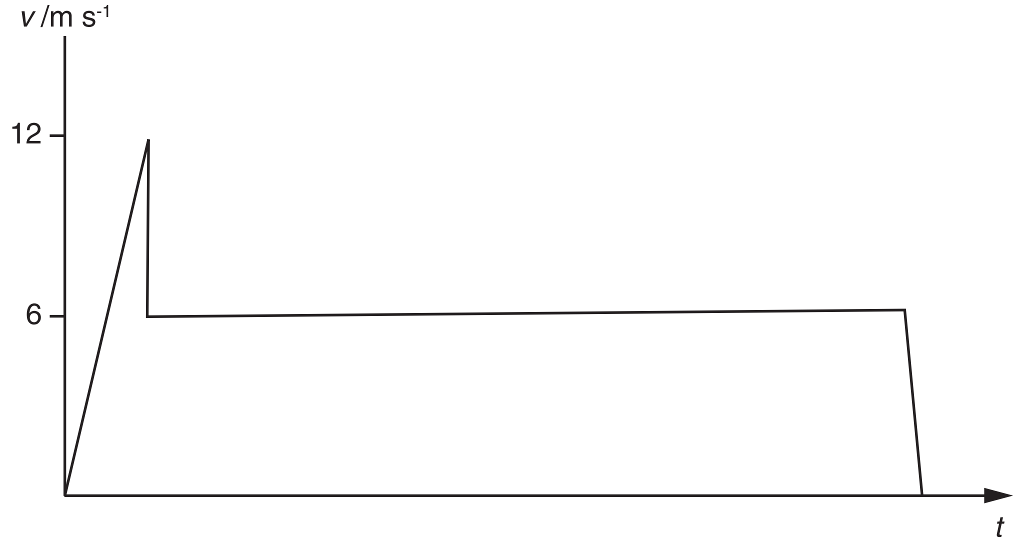


Fig. 9.2

Sketch on Fig. 9.2 the actual curve you would expect for the BASE jumper. When the parachute is opened, her terminal velocity is 6.0 m s^{-1}.

[2]

(c) The BASE jumper hits the ground at a speed of $6.0\,\mathrm{m\,s^{-1}}$. On landing, she folds her legs and rolls over onto the ground.

(i) Explain why these actions make the landing safer.

[1]

(ii) Calculate the average resultant force on the BASE jumper during landing if the time taken from first touching the ground to being completely stopped is 0.25 s.

mass of BASE jumper = 53 kg

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

[Total: 10]

10 In a simple wave model to explain the diffraction of waves at a gap, the gap of width *b* is divided into three equal parts as shown in Fig. 10.1.
The centre of each part is treated as a source of waves.

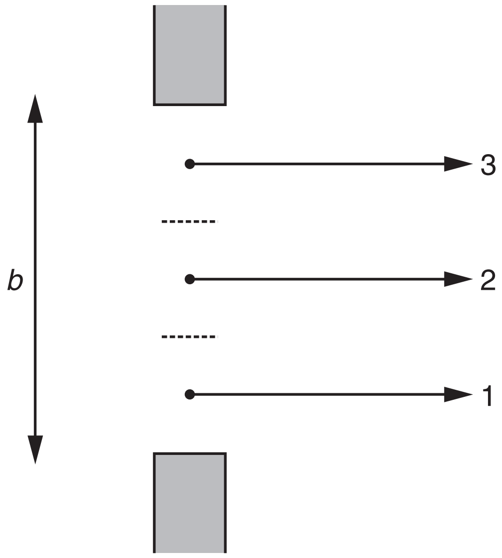


Fig. 10.1

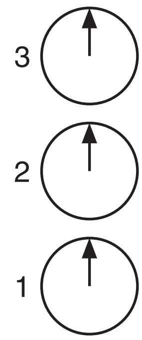


Fig. 10.2

(a) The phasors for the waves from each of the three parts of the gap reaching a distant screen in the straight-on direction are shown in Fig. 10.2.

(i) The paths taken by the waves in Fig. 10.1 are all equal in length. Explain how the phasors in Fig. 10.2 confirm this.

[1]

(ii) Each phasor has an amplitude *A*. Write down the amplitude of the resultant phasor at the distant screen.

amplitude = ... **[1]**

(b) At an angle θ to the straight-on direction, the path difference between neighbouring paths is Δx, as shown in Fig. 10.3. For one particular value of θ, the resultant intensity is **zero**.

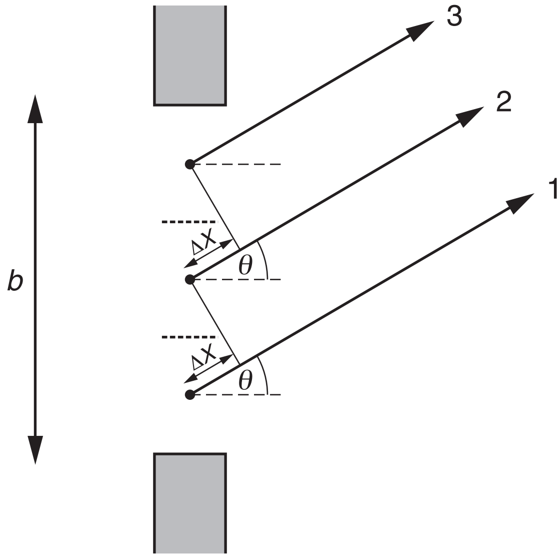


Fig. 10.3

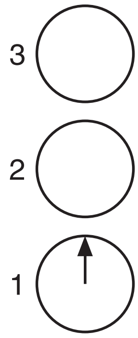


Fig. 10.4

(i) Explain why the phasor for path 1 has rotated 120° more than the phasor for path 2, when $\Delta x = \frac{1}{3}\lambda$, where λ is the wavelength of the waves.

[2]

(ii) Draw arrows on Fig. 10.4 above to represent the phasors for waves 2 and 3.
Explain, using a diagram, why the three phasors have a zero resultant.
Label your phasors in the diagram 1, 2 and 3.

[2]

(iii) Use Fig. 10.3 and the fact that $\Delta x = \frac{1}{3}\lambda$ to show that $\lambda = b \sin \theta$ where b is the total width of the gap. Show your working clearly in this space.

[2]

(c) Use the equation $\lambda = b \sin \theta$ to calculate the angle θ at which a minimum signal occurs when microwaves of wavelength 2.4 cm are incident on a gap of width 6.0 cm.

θ = ... ° **[2]**

[Total: 10]

11 This question is about firing an arrow using a longbow.
In Fig. 11.1, the archer has pulled back the bowstring to hold the arrow at rest with a force F. The tension in the bowstring is T.

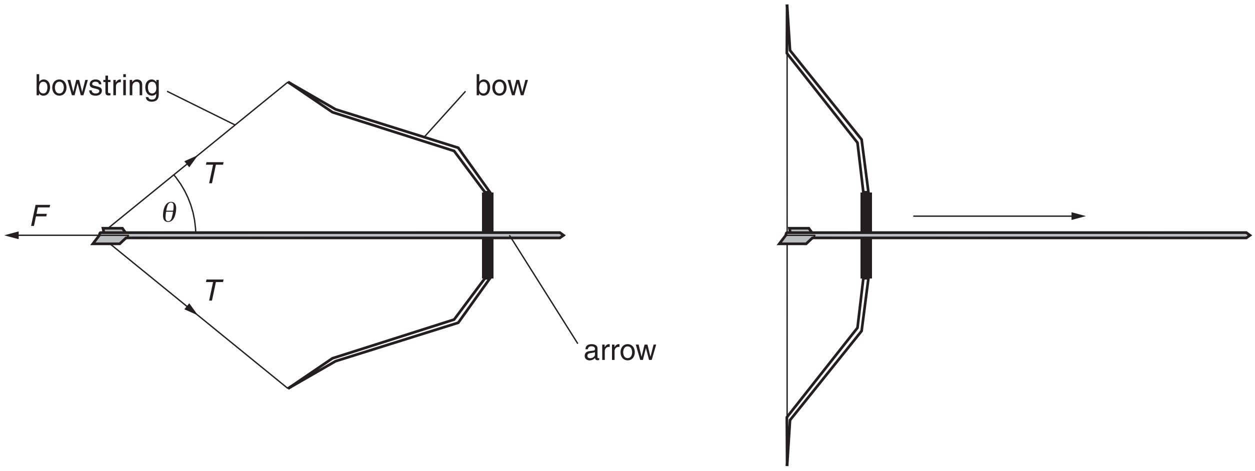


Fig. 11.1

(a) (i) Explain why the horizontal component of T is equal to ½F.

[2]

(ii) When the archer is pulling back the bowstring with a force F of 140 N, the angle $\theta = 36°$.
Show that the tension is the bowstring is about 90 N.

[2]

(b) When the arrow is released, it is accelerated by the string over a distance of 0.80 m.

(i) Assume the arrow is accelerated by an average force of 85 N.
Calculate the kinetic energy gained by the arrow when it is released.

kinetic energy gained = ... J **[1]**

(ii) Explain why the accelerating force changes from 140 N as the bowstring moves forward.

In your answer, consider different factors which may affect the accelerating force, and how they change during the release of the arrow.

You should organise your answer clearly and coherently.

[3]

[Total: 8]

[Section B Total: 40]

Section C

12 This question is based on the article *Uncertainty, range bars and best-fit lines.*

A student used the arrangement in Fig. 12.1 to investigate how the change in gravitational potential energy is related to the gain in kinetic energy.

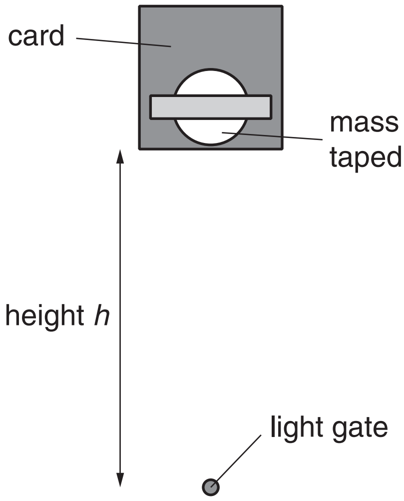


Fig. 12.1

He dropped the weighted card five times from eight different heights above the light gate, and recorded the speed of the card as it passed through the gate.
He used the principle of conservation of energy to write:

$$\tfrac{1}{2}mv^2 = mgh \qquad \text{and so} \qquad v^2 = 2gh$$

From his readings of v, he found the range in the value of v^2 for each height, and plotted the graph of Fig. 12.2.

(a) The table below shows five values for v when $h = 0.30$ m.
Use these values to confirm the range bar in v^2 for $h = 0.30$ m on the graph of Fig. 12.2 opposite.

v / m s^{-1}	2.70	2.52	2.68	2.72	2.54

[3]

(b) The student measured the position of the bottom of the card to ± 0.5 mm.
Suggest and explain a reason why he did not include range bars for *h* on the graph.

[2]

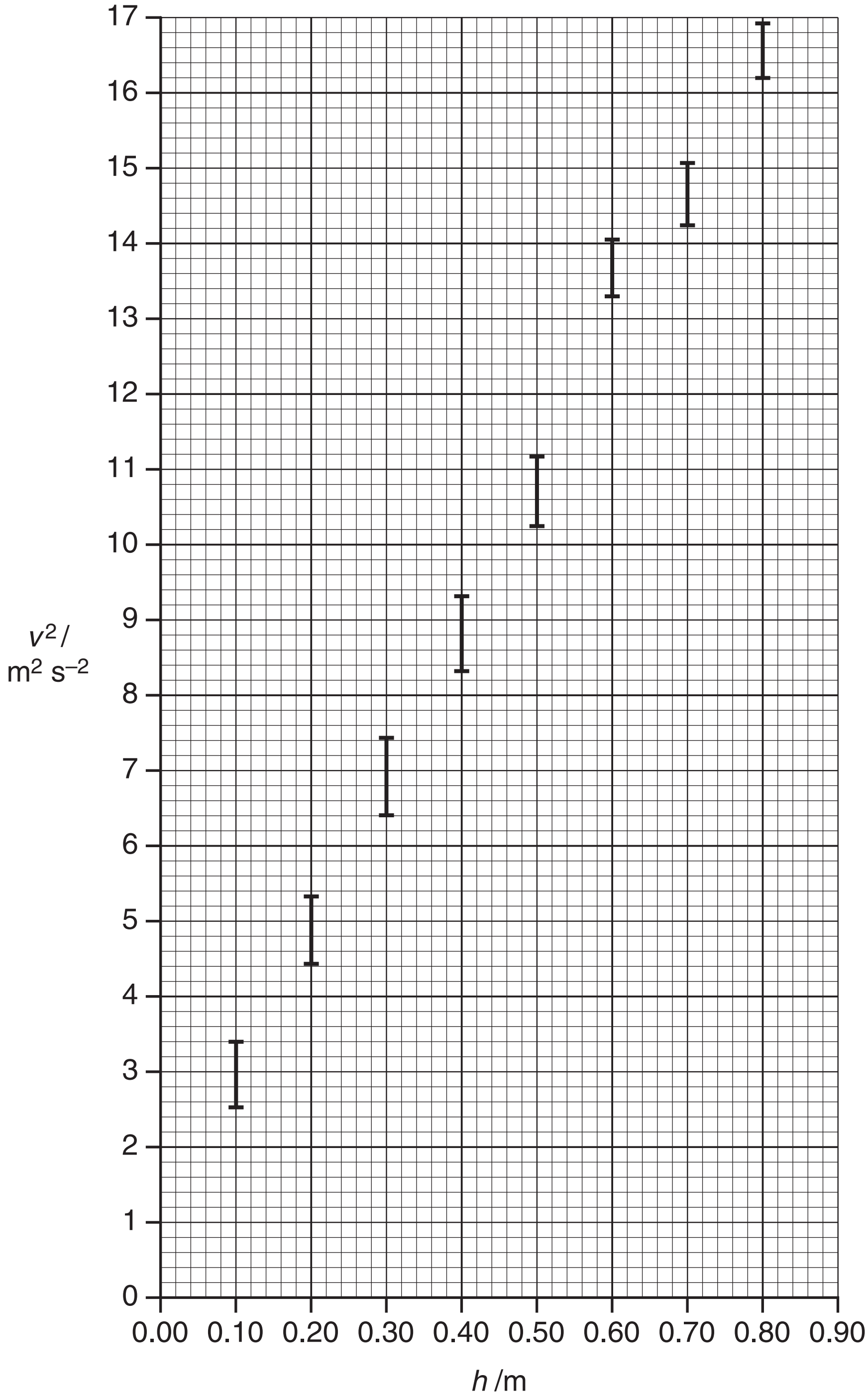


Fig. 12.2

(c) Draw a best-fit straight line for the data on the graph. Determine the gradient of your best-fit straight line. Write down any assumption that you make.

gradient = ... m s^{-2} **[4]**

(d) As $v^2 = 2gh$, the graph of v^2 against h should give a straight line through the origin. The graph is a straight line, but it does **not** go through the origin.

(i) The student suggests that energy losses as the weighted card fell are responsible. Explain why this cannot be correct.

[2]

(ii) By reference to the experimental arrangement (Fig. 12.1), suggest a possible systematic error, and explain why it would give a positive intercept on the v^2 axis.

[2]

[Total: 13]

13 This question is about the article *Young's Double-Slit experiment.*

(a) The Young's double-slit equation $\lambda = \frac{dx}{L}$ applies only if the angle θ is small enough so that $\sin\theta = \frac{x}{L}$ (Fig. 13.1).

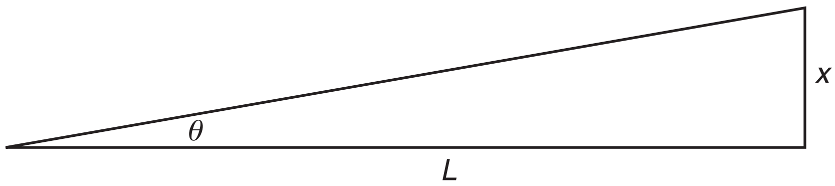


Fig. 13.1

Show that, for $x = 0.01$ m and $L = 1.0$ m, $\sin\theta = \frac{x}{L}$ is an extremely good approximation.

[2]

(b) Using the classroom arrangement shown in Fig. 2 in the article, a student observed the pattern of fringes in Fig. 13.2 on the screen when a yellow filter was placed in front of the lamp filament. She decided that there was an uncertainty of ±1 mm in determining the position of the centre of each maximum, giving an uncertainty of ±2 mm in the separation between two of them.

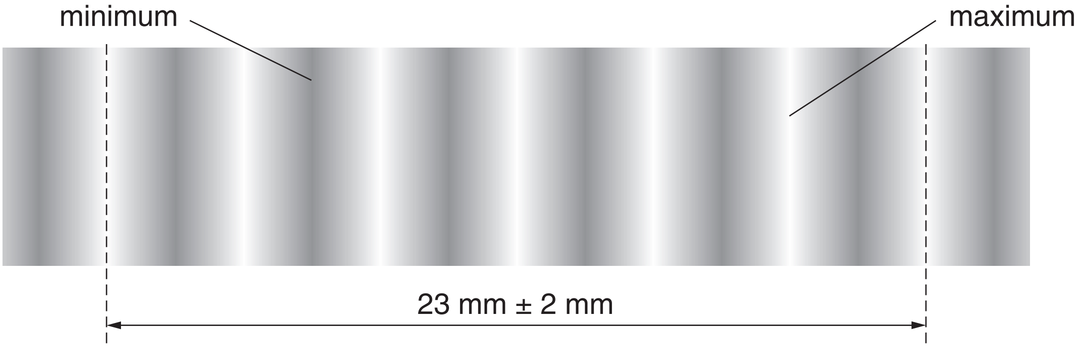


Fig. 13.2

(i) The measurements on the diagram give calculated values of 3.83333333 ± 0.33333333 mm for the mean value and uncertainty in the separation x between maxima.
Write down the mean value and uncertainty to an appropriate number of significant figures.

x = ... ± .... mm **[2]**

(ii) The distance d between the two slits was 0.25 ± 0.01 mm.
Which of the two measurements, d or x, contributes the greater uncertainty to a calculation of the wavelength, λ?
Justify your answer.

[3]

(iii) The distance L from slits to screen was 1.72 m, measured to the nearest cm.
Although the uncertainty in L was much larger than the uncertainties in d and x, it has less effect on the uncertainty in the final result. Explain why.

[1]

(iv) Use the equation $\lambda = \frac{dx}{L}$ to calculate the **smallest** possible value for the wavelength of yellow light.
Take $L = 1.72$ m together with the mean values and uncertainties for d and x from **(b)(i)** and **(ii)**.

smallest wavelength = ... m **[3]**

(v) The mean value for the wavelength of the yellow light calculated from the data in **(b)(i)** and **(ii)** is 5.60×10^{-7} m.
Use you answer to **(b)(iv)** to write down the uncertainty in wavelength $\Delta\lambda$.

$\Delta\lambda$ = ... m **[1]**

(c) It is difficult to scratch two slits very close together on the blackened microscope slide. If the slit separation d were doubled to 0.50 mm, the separation x of the fringes would fall to half the value in **(b)(i)**. The uncertainties in the measured values d and x would not be changed.
Explain why this would result in an increased uncertainty in the wavelength calculated.

[3]

[Total: 15]

14 This question is about the article *Tycho Brahe: pushing the bounds of measurement*.

(a) Show that Tycho's quadrant of radius 2.0 m had nearly 6 mm between its 10 arc-minute (sixths of a degree) divisions.

[2]

(b) Fig. 14.1 shows part of the scale of Brahe's large quadrant with the sight aimed at a planet.

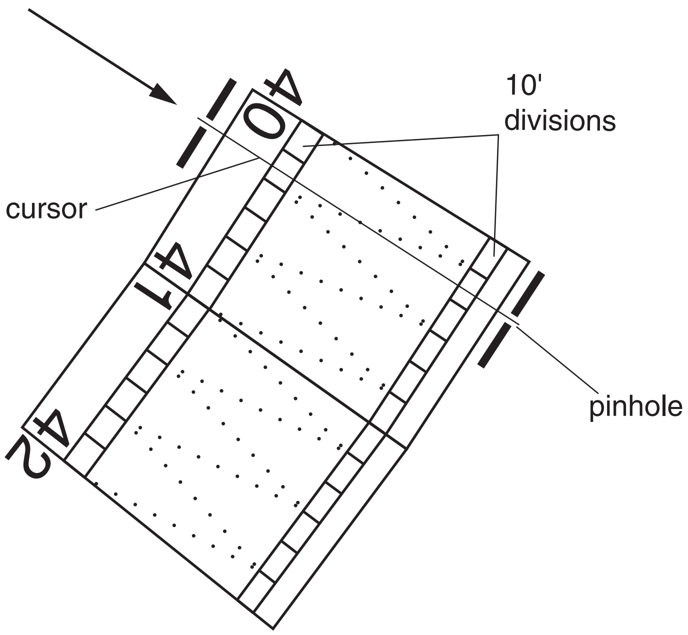


Fig 14.1

(i) Calculate the reading shown in Fig. 14.1 in degrees. Express your answer to an appropriate number of significant figures.

reading = ... ° **[3]**

(ii) The scale can be read to the nearest minute of arc ($\frac{1}{60}°$).

Calculate the percentage uncertainty in the reading in Fig. 14.1.

percentage uncertainty = ... **[2]**

(c) Brahe repeated his observations a number of times.
Explain the advantages of repeating readings.

[3]

(d) Although Brahe was primarily interested in the movements of the planets, he made a number of observations of fixed stars. Suggest reasons why he did this.

[2]

[Total: 12]

[Section C Total: 40]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE

ADVANCED SUBSIDIARY GCE

PHYSICS B (ADVANCING PHYSICS) G492

Unit G492: Understanding Processes/
Experimentation and Data Handling

INSERT

Monday 17 January 2011
Afternoon

Duration: 2 hours

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.

INSTRUCTION TO EXAMS OFFICER/INVIGILATOR

- Do not send this Insert for marking; it should be retained in the centre or destroyed.

1. Uncertainty, range bars and best-fit lines

When you plot data on a graph, it is useful to be able to show the uncertainties in the values. If a best-fit line or curve is to be drawn, the size of the range bars gives a good indication how close the line ought to go to the points in question.

As an example, look at the graph of Fig. 1, showing the kinetic energy gained by a falling object after dropping through a height *h*.

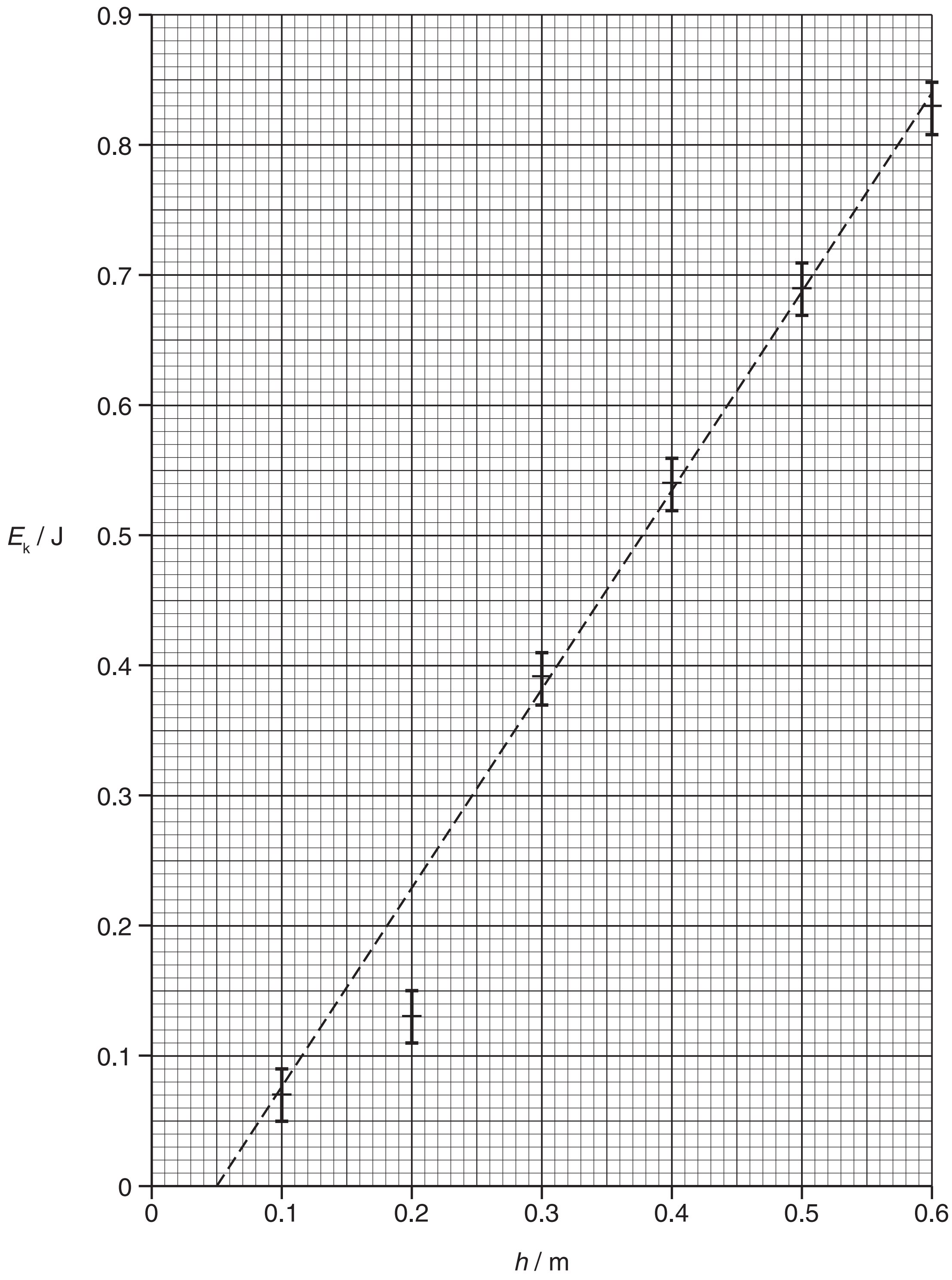


Fig. 1

The graph seems linear, but it has a point at h = 0.2 m, E_k = 0.13 J which is further than its estimated uncertainty from any straight line which could be drawn through the range bars of all the other points. This seems to be an outlier, and has been omitted in drawing the best-fit straight line shown.

Another problem is that the line would be expected to go through the origin, but this one clearly does not, even if the outlier is ignored. This may involve a systematic error in measurement of initial height or final velocity, or it may indicate energy losses. Deciding which is responsible will involve looking in detail at the experimental procedure used.

2. Young's Double-Slit Experiment

Historically, the first really serious challenge to Newton's particle theory of light was made by Thomas Young. Young knew that sound was a wave and displayed a phenomenon called *interference*. He reasoned that if light were actually a wave phenomenon, as he suspected, then a similar interference effect should also be observed for light. He observed exactly the effect he predicted.

One popular classroom arrangement for observing what Young discovered is shown in Fig. 2.

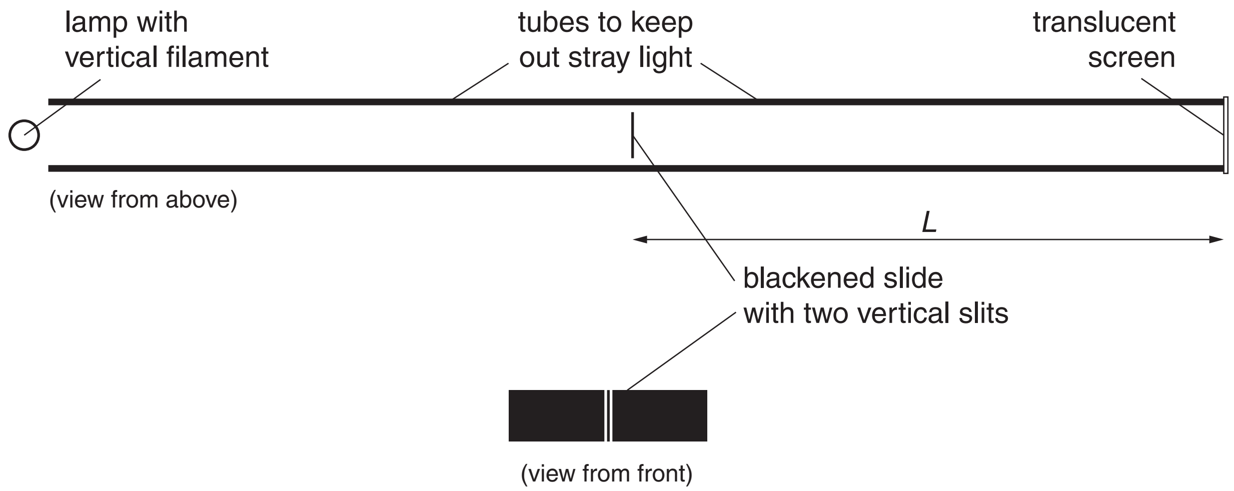


Fig. 2

The light from the filament of the lamp is incident on the blackened slide. This is a microscope slide blackened with graphite paint, with two slits scratched through the paint very close together. Each slit, scratched with a fine needle, is a fraction of a millimetre wide and the distance *d* between the centres of the two slits needs to be less than 1 mm. The interference fringes (maxima and minima) are viewed on a screen a distance *L* from the two slits as shown in Fig. 3, and are seen to be at a constant spacing *x*.

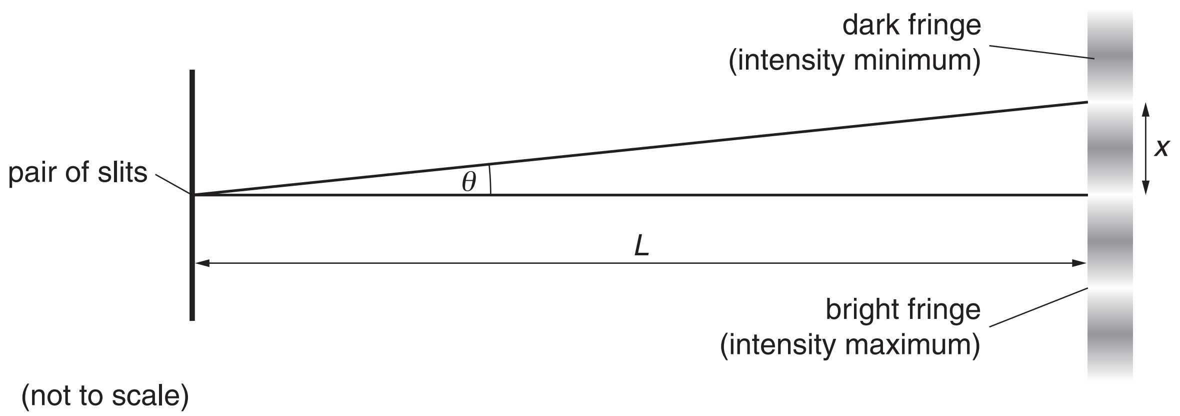


Fig. 3

The difference between the paths from the two slits to the first bright fringe from the centre is one wavelength. Fig. 4 shows that $\lambda = d \sin \theta$ where d is the separation between the centres of the two slits.

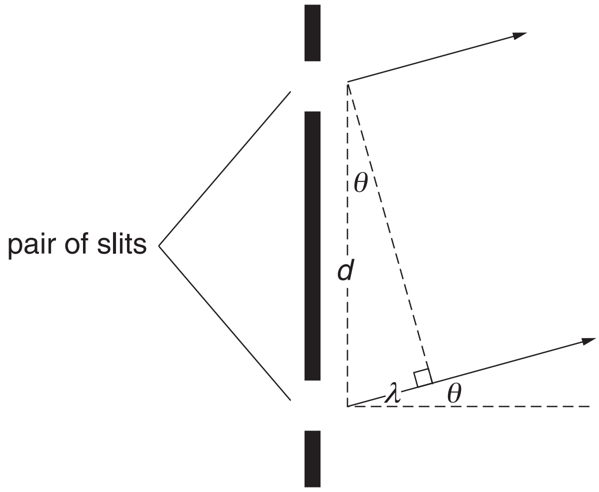


Fig. 4

To a very good approximation, $\sin \theta = \frac{x}{L}$ for the values of x and L met in this experiment, so that $\lambda = \frac{dx}{L}$.

The separation d between the centres of the two slits is extremely hard to measure accurately. A travelling microscope – sometimes called a vernier microscope – allows measurement of separations to ± 0.01 mm. A larger value of the slit separation d reduces the percentage uncertainty in this measurement but makes it harder to measure the fringe separation x.

The fringes seen on the translucent screen are fuzzy, but it is possible to see about seven maxima. Measurement of the fringe separation x is difficult, because x is quite small, and it is difficult to see the middle of each bright fringe. Furthermore, the different colours in the white light from the filament lamp produce fringes of slightly different spacing, so that the maxima become broader and coloured at the edges as you move out from the centre. This problem can be reduced by using coloured filters, but this does make the faint fringes even fainter.

3. Tycho Brahe: pushing the bounds of measurement

An important measurement made by astronomers is the altitude of a star or planet when it passes due south of the observer. By recording this angle together with the exact time it occurs, maps of the heavens can be drawn. This observation can be done with the naked eye, but it needs a large quadrant (a protractor or angle measurer) to give readings to a precision better than 1°.

In the sixteenth century, before the invention of telescopes, the Danish nobleman and astronomer Tycho Brahe made famous measurements of the shifting positions of the planets.

He used a very large brass quadrant 2.0 m in radius, built into a wall. The wall was aligned north-south, and the centre of the quadrant was a narrow slit in the facing wall (Fig. 5).

The quadrant had two parallel scales with divisions of 10 arc-minutes (sixths of a degree) nearly 6 mm apart, with diagonal lines of nine dots between these markings as shown in Fig. 5 to allow the instrument to be read to the nearest minute of arc ($1' = \frac{1}{60}°$).

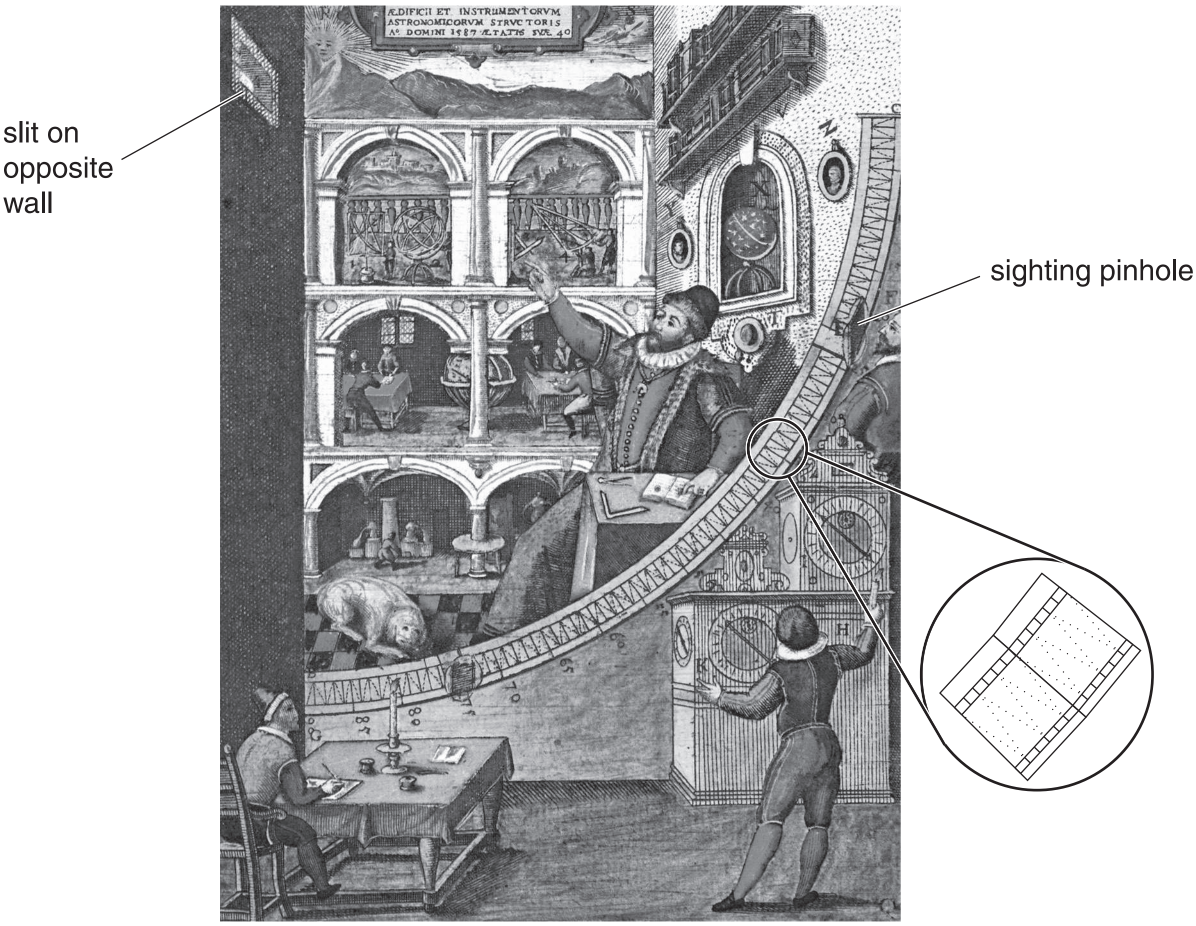


Fig. 5

The observer would line up the sighting pinhole on the star or planet, seen through the slit in the opposite wall, and then find the angle by counting along the line of dots to find how many minutes of arc to add to the main scale reading.

Brahe also improved the sighting pinhole. The observer had to put his eye close to the pinhole to be able to see the star or planet, and slight movements of the observer's head would be possible while still keeping the object in view. This introduces an uncertainty, known as parallax, of eight arc-minutes (± 0.13°).

Brahe found that using two pinholes, one on each side of the quadrant scale, reduced this uncertainty to about one arc-minute (±0.017°). The two pinholes were mounted on the **cursor**, a moveable straight-edge used to take the reading from the quadrant scale. When the pinholes were aligned with the star or planet, the number of dots between the last scale division and the cursor were counted to give the number of minutes of arc to add to that scale reading. In Fig. 6 below, the angle would be $41° + (2 \times 10') + 6' = 41° 26' = 41.43°$.

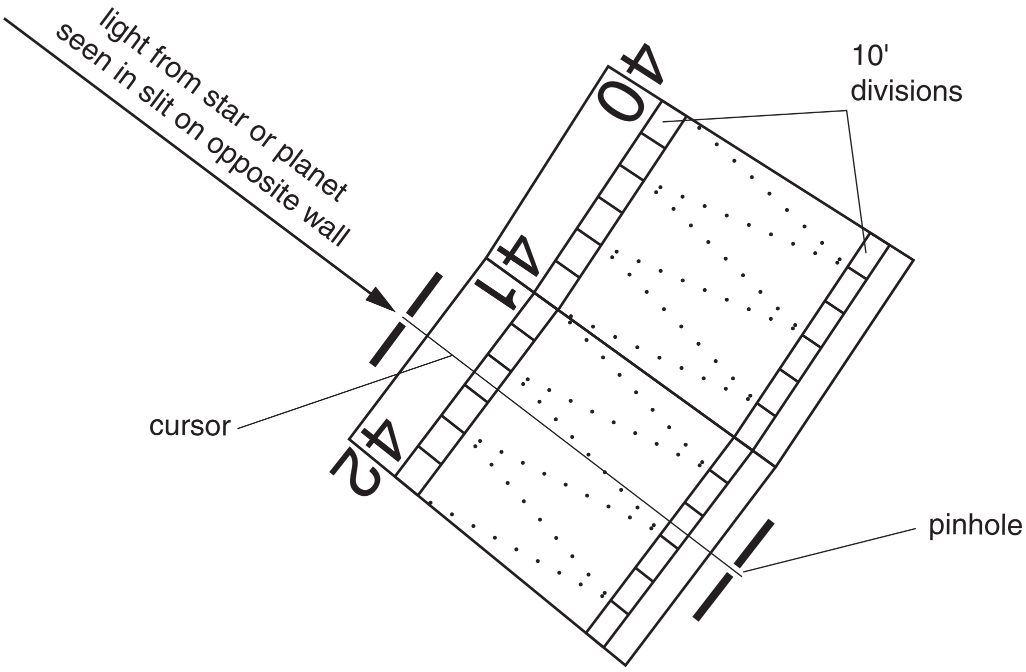


Fig. 6

Brahe checked on this instrument itself by comparison with other quadrants he had built, and repeatedly calibrated his instruments by measuring the positions of fixed stars, which do not change their positions in the sky the way that planets do. He also introduced an idea which is now fundamental to all experimental science: he repeated his readings, which improved his confidence in the angles obtained. So good were Brahe's readings that, some years later, the astronomer Kepler used them to deduce the way in which planets move.

The advances in measurement made by Tycho Brahe were not without cost. It has been estimated that getting the King of Denmark to finance the building of his great observatory cost 1% of the entire Danish state budget. In comparison, the UK's share of costs in the LHC (Large Hadron Collider), one of the most costly modern scientific developments, is about 0.003% of the UK's state budget. Many people feel that the money spent on the LHC would be better spent elsewhere; this simple comparison suggests that Brahe's observatory was 300 times more expensive!

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