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 for this question paper) (inserted)
- Data, Formulae and Relationship Booklet

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

Monday 6 June 2011
Afternoon

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. 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. If additional space is required, you should use the blank pages at the end of this booklet. The question number(s) must be clearly shown.
- 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 **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.

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

(a) Choose the correct unit for force.

.... **[1]**

(b) Which two are units of energy?

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

2 Here is a list of magnitudes.

10^{-9} 10^{-6} 10^{-3} 1 10^{3} 10^{6}

(a) Choose the value closest to the wavelength of visible light in m.

.... **[1]**

(b) Choose the value closest to the weight of a person in N.

.... **[1]**

3 Fig. 3.1 shows three different paths for a photon travelling from a source **S** to a point **P** on a distant screen.

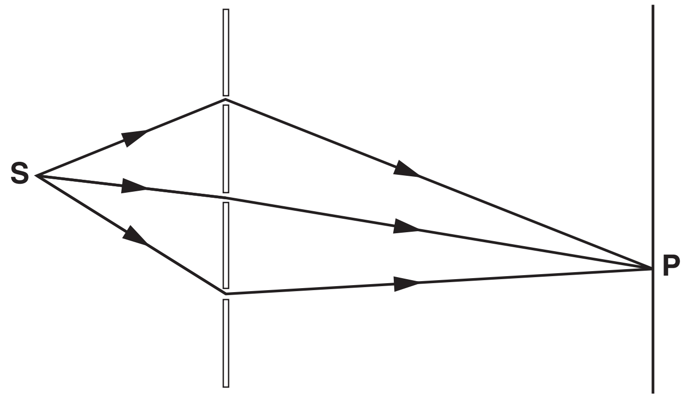


Fig. 3.1

At **P**, the phasor for each path has the same amplitude as shown by this arrow:

Draw a diagram to show a combination of the three phasors which would give zero light intensity at **P**.

[2]

4 Diffraction causes light passing though a narrow aperture to spread out.
Which of the following changes, on its own, would **decrease** the amount of diffraction?
Put a tick (✓) in the box next to **each** correct change.

increasing the amplitude of the light	☐
increasing the frequency of the light	☐
increasing the intensity of the light	☐
increasing the wavelength of the light	☐
increasing the width of the aperture	☐

[2]

5 A diffraction grating has 400 lines per millimetre.

(a) Calculate the grating spacing *d*.

d = ... m **[1]**

(b) Another diffraction grating, of grating spacing $d = 1.6 \times 10^{-6}$ m, is illuminated by light of wavelength 5.0×10^{-7} m.
Calculate the angle θ_2 of the **second-order** maximum in the spectrum.

θ_2 = ... ° **[2]**

6 A car of mass 850 kg can accelerate from 0 to 27 m s^{-1} in 15 s.

(a) Show that the mean accelerating force is about 1500 N.

[2]

(b) The car moves along a straight, horizontal road at a constant speed of 27 m s^{-1}. The engine provides a constant driving force of 1100 N.
Calculate the power dissipated against friction.

power = ... W **[1]**

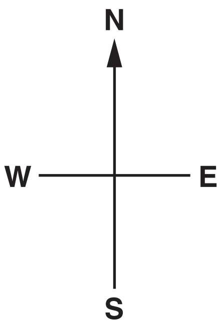
7 A treasure map states:

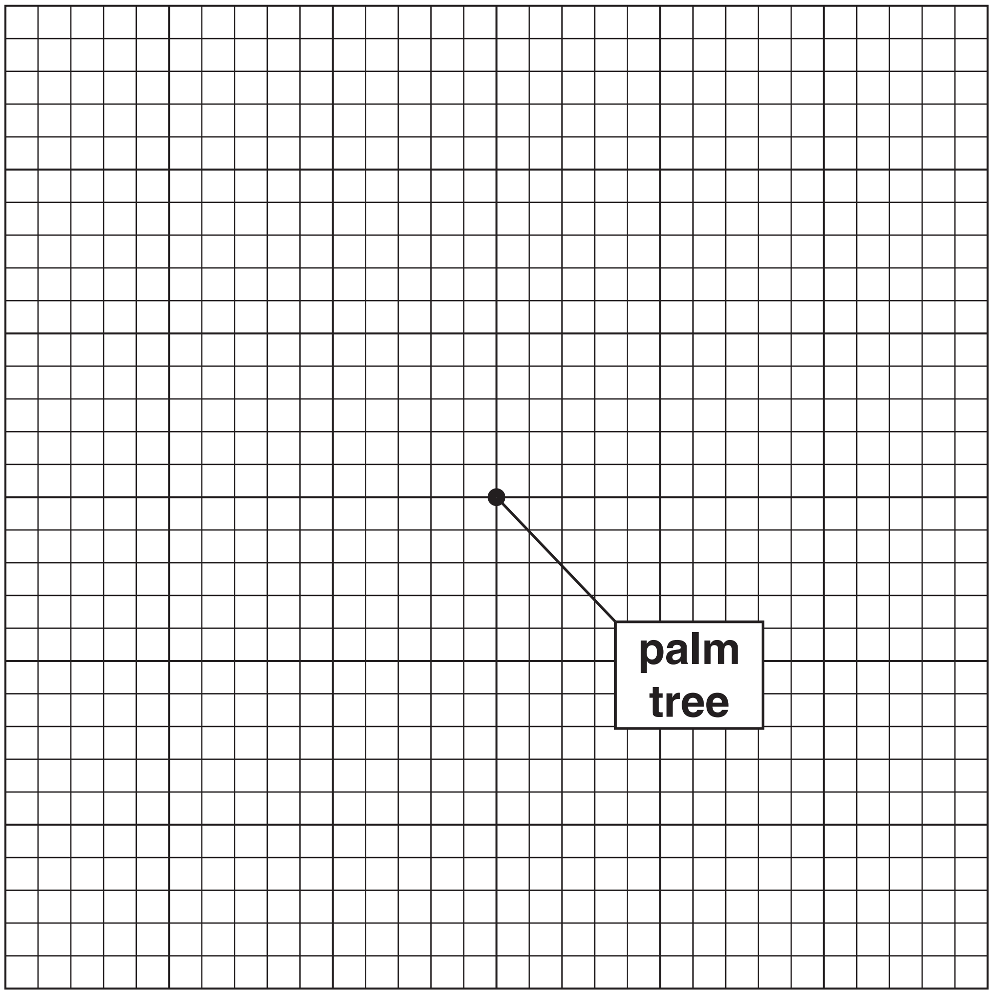
- from the palm tree, go 15 paces north,
- then go 7 paces west
- the treasure is buried 3 paces south.

By calculation or drawing, find the magnitude and direction of the displacement of the treasure from the palm tree.

The central dot represents the palm tree.

Each small square on the grid below represents one pace.





displacement = ... paces

in a direction .... **[3]**

8 A standing wave is set up on a string as shown in Fig. 8.1.

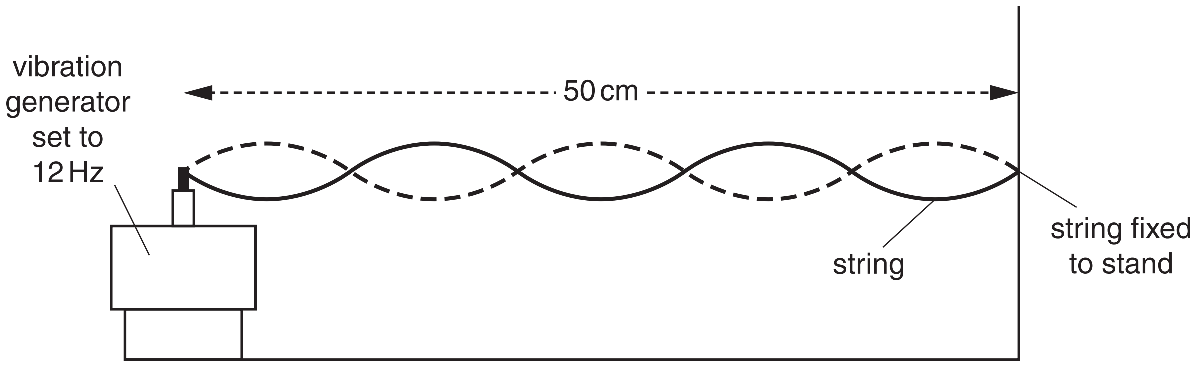


Fig. 8.1

(a) Explain how the diagram shows that the wavelength of waves along the string is 20 cm.

[1]

(b) When the tension in the string is increased, the frequency must also be increased to keep five loops in the string. The length is unchanged. The table below shows three values of frequency f and tension T which give the standing wave pattern shown in Fig. 8.1.

f/Hz	T/N
12	10
17	20
21	30

Theory suggests that the frequency should be directly proportional to the square root of the tension, $f \propto \sqrt{T}$.

Propose and carry out a test using these data to see whether they fit this relationship.

[3]

[Section A Total: 21]

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Section B

9 This question is about a small rocket taking off.
The rocket has a **constant** upward thrust T provided by the rocket engines, which work by ejecting gases at high velocity.
As gas is ejected, the weight W of the rocket decreases.

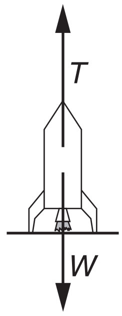


Fig. 9.1

The velocity-time graph for this rocket is shown in Fig. 9.2.
The rocket engines start at time $t = 0$ s.

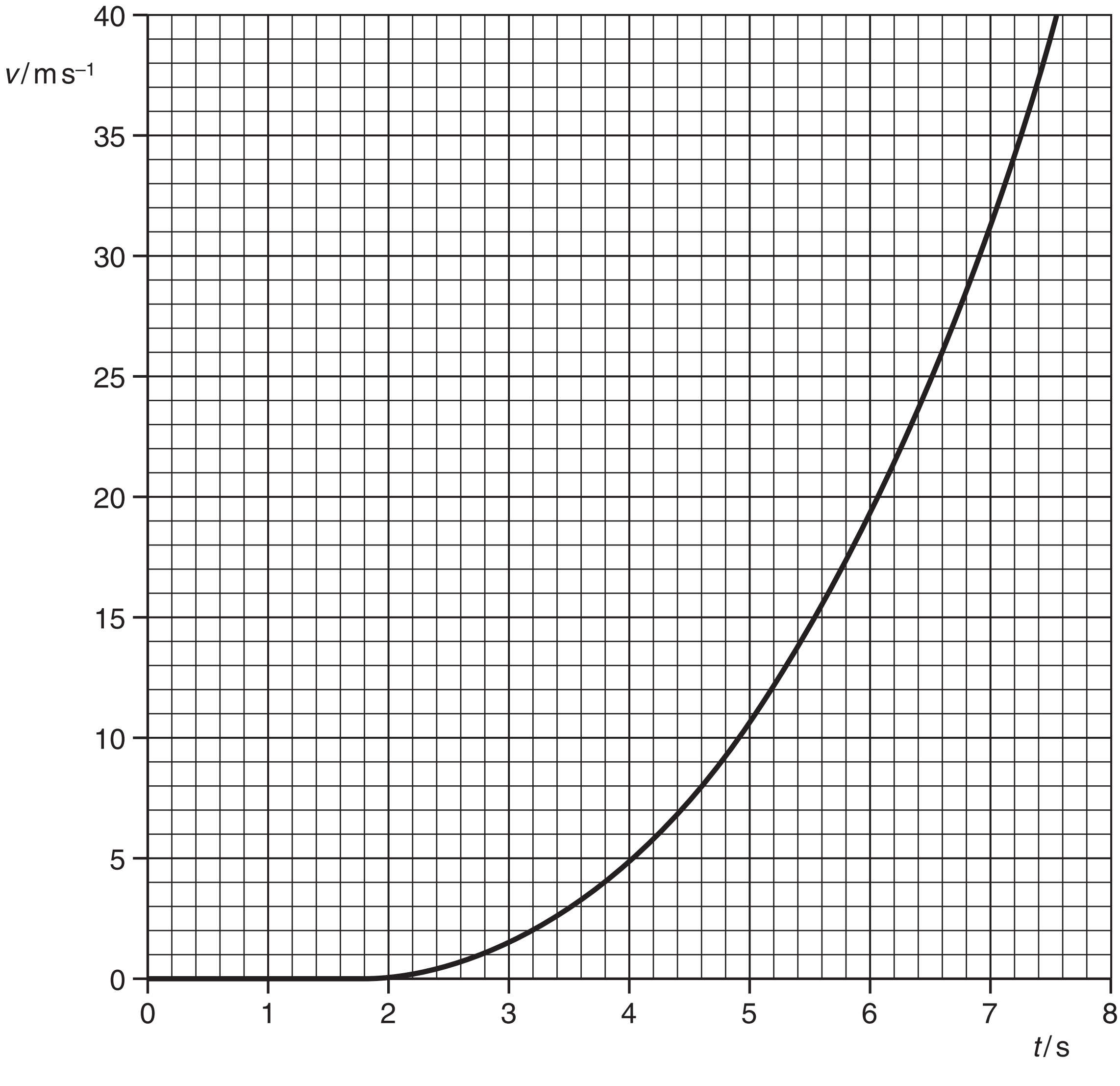


Fig. 9.2

(a) **(i)** State how the graph of Fig. 9.2 shows that the rocket remains stationary for a short while after the rocket engines start.

[1]

(ii) Explain in terms of the forces *T* and *W* why the rocket remains stationary for a short while, then begins to rise.

[2]

(b) **(i)** Use the graph of Fig. 9.2 to show that the acceleration of the rocket at the time $t = 6.0\,\text{s}$ is about $10\,\text{m}\,\text{s}^{-2}$.
Show your working clearly on the graph and in this space.

[3]

(ii) Show that at time $t = 6.0\,\text{s}$, the weight *W* of the rocket is about half the thrust *T* of the rocket engines.

mass of rocket at this time = 6.9 kg

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

[2]

(c) On Fig. 9.2 opposite, sketch the graph you would expect if the rocket had taken off with a slightly greater mass of gas ejected each second, giving a slightly larger thrust, *T*.

[2]

[Total: 10]

10 When light illuminates a clean surface of potassium, electrons can be emitted. This is the photoelectric effect. Fig. 10.1 shows a section of the surface at a microscopic scale.

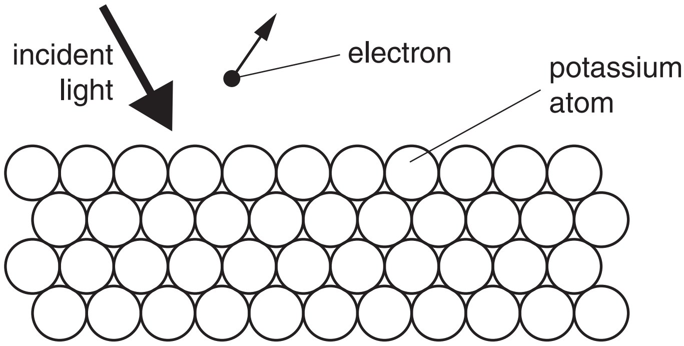


Fig. 10.1

(a) Electrons are emitted when the incident light is violet, but not when the incident light is red. Increasing the intensity of violet light causes more electrons to be emitted. Increasing the intensity of red light has no effect.

Explain how this is evidence for the quantum behaviour of light.

In your answer, you should link the quantum behavi ef

[4]

(b) Einstein explained the photoelectric effect by suggesting that there is a minimum energy ϕ, the work function, which must be supplied to remove an electron from the surface of a metal. The work function for potassium is 3.7×10^{-19} J.
Show that photons of frequency less than 5.6×10^{14} Hz cannot remove electrons from a potassium surface.

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

[2]

(c) Fig. 10.2 shows how the maximum energy of electrons emitted by potassium depends on the energy of the incident photons.

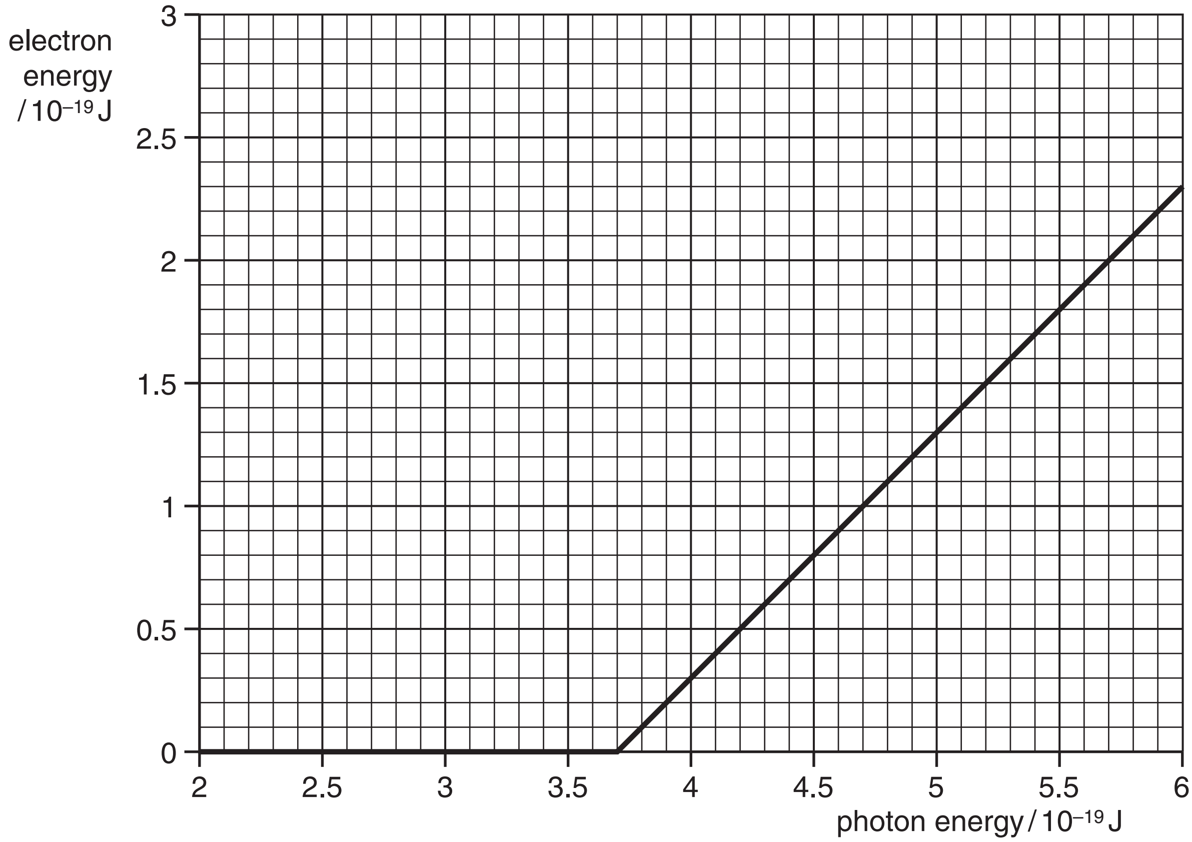


Fig. 10.2

Explain the shape of the graph in Fig. 10.2.

[2]

(d) One early device using the photoelectric effect was the photoelectric cell. This cell sets up a current in an external circuit when light falls on it.

Suggest one use for a photoelectric cell containing a potassium surface and any limitations it may have in practice.

[2]
[Total: 10]

11 This question is about the first measurement of the speed of light by the Danish astronomer Ole Rømer in 1676.
He found that there were two times in the year when Jupiter and Io were at the same point in the sky, relative to the stars. The two positions of the Earth at these two times are shown as **A** and **B**, a distance *d* apart, in Fig. 11.1.

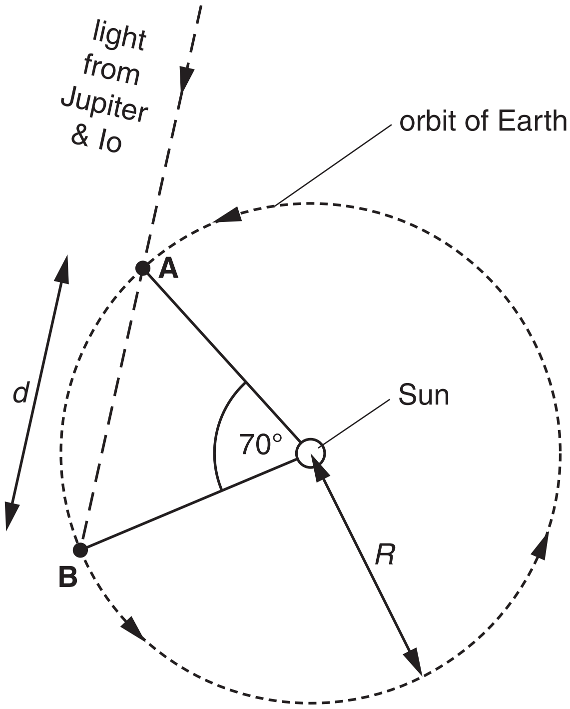


Fig. 11.1

(a) **(i)** Use data from Fig. 11.1 to show that the Earth took 71 days to move from **A** to **B**.
1 year = 365 days

[2]

(ii) During the time it took the Earth to move from **A** to **B**, the moon Io made 40 orbits around Jupiter.
Calculate the time for one orbit of Io in minutes.

time = ... minutes **[2]**

(b) Knowing the time for one orbit of Io, Rømer was able to calculate that the time taken for light to travel from **A** to **B** was 11 minutes.

(i) Use the geometry of Fig. 11.1 to show that

$$d = 2R\sin(35°)$$

where R is the radius of the Earth's orbit. Show your working clearly.

[2]

(ii) The radius R of the Earth's orbit was estimated in Rømer's time to be 1.4×10^{11} m. Use this value, together with the 11 minutes it took light to travel from **A** to **B**, to calculate the speed of light, c.

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

(iii) Suggest and explain one reason why the value for c obtained in **(ii)** is too low.

[2]

[Total: 10]

12 This question is about a game in which each player must throw a hard wooden ball into a bucket so that the ball stays in the bucket.
The thrower throws the ball, with initial velocity u at an angle θ to the horizontal, towards a bucket as shown in Fig. 12.1. The ball enters the bucket after time t.

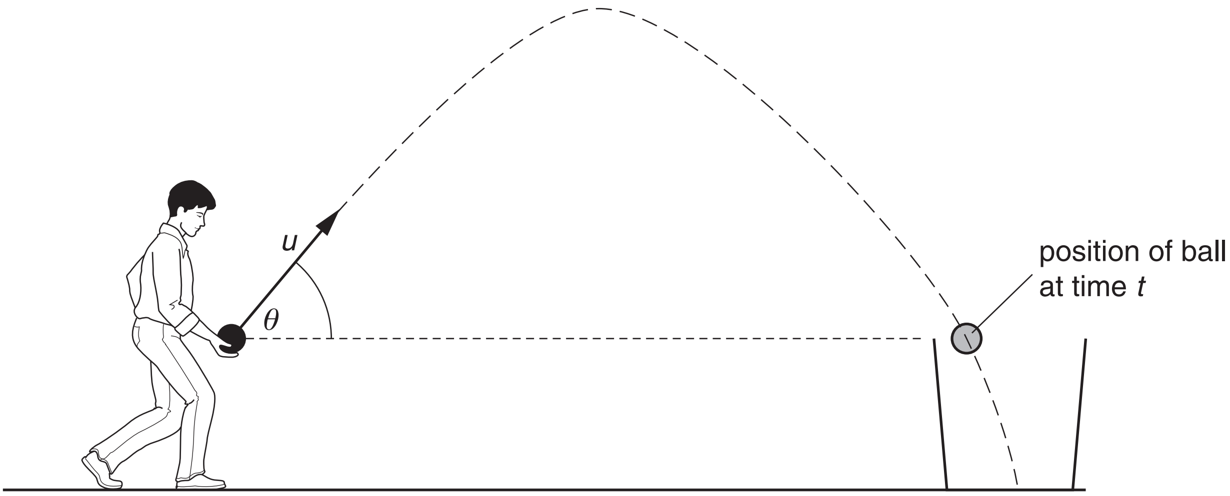


Fig. 12.1

(a) Write down expressions for the horizontal and vertical components of u.

horizontal component of u = ...

vertical component of u = ... **[1]**

(b) The ball leaves the player's hand at the same height above the ground as the top of the bucket. The time t taken for the ball to reach the top of the bucket is given by the equation

$$0 = (u\sin\theta)t - \tfrac{1}{2}gt^2.$$

(i) Show that this equation arises from applying an equation for uniformly accelerated motion to the vertical motion of the ball.

[3]

(ii) Calculate the time taken for a ball thrown at 8.0 m s^{-1} at an angle of 50° to the horizontal to reach the top of the bucket.

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

t = ... s **[3]**

(c) When the hard wooden ball, thrown as shown at an angle of 50° to the horizontal, hits the **bottom** of the bucket, some kinetic energy is dissipated during the collision, but the remaining kinetic energy is usually enough to allow the ball to bounce back out.
Suggest and explain a strategy for **throwing** the given ball which might increase the chance of the ball staying in the bucket.

[2]

[Total: 9]

[Section B Total: 39]

Section C

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

13 This question is based on the article *Using the speed of water waves to determine g.*

(a) Student A does the experiment by making a wave with a ruler and starting the stop watch at the same time. He stops the watch when it reaches the end of the tank.

Student B makes the wave in the same way, but does not start the watch until the wave reaches the far end of the tank. She then allows the wave to travel up and down the tank several times, stopping the stopwatch when it reaches one end of the tank.

Give **one** reason why student B's method is better than student A's method.

[1]

(b) Systematic errors can affect the results obtained from this experiment.
Suggest one systematic error which might occur in making these measurements, and how it might be prevented.

[2]

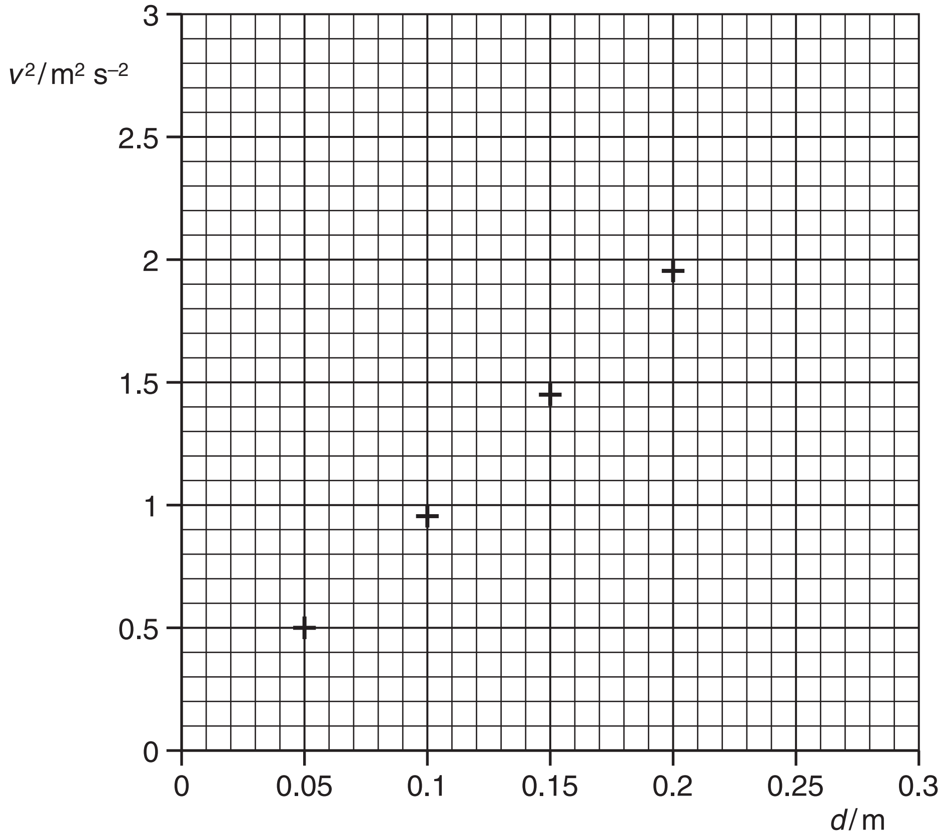
(c) The following data was obtained in an experiment in which the depth d and speed v were measured rather precisely.

(i) Complete the table.

d/m	v/m s^{-1}	v^2/m^2 s^{-2}
0.05	0.70	0.49
0.10	0.98	0.96
0.15	1.20	1.44
0.20	1.40	1.96
0.25	1.56	
0.30	1.71	

[1]

(ii) Plot your values from the table to complete the graph.
Draw a best-fit straight line.



[3]

(iii) Rearrange the equation $v = \sqrt{gd}$ to show that the gradient of the graph is g.

[1]

(iv) Use the graph to calculate a value for g.
Show all your working on the graph or in this space.

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

(d) Another, less carefully done experiment, gave the following measurements.

The student measured the time for a wave to travel from the near end of the tank to the far end and then back to the near end.

	measured value	uncertainty	percentage uncertainty
length of tank / m	0.62	±0.01	2%
time for return journey / s	0.7	±0.2	30%
depth of water / m	0.30	±0.01	

(i) Complete the table by calculating the percentage uncertainty for the depth of water. **[1]**

(ii) Suggest why the uncertainties in the length of the tank and the depth of the water can be ignored when estimating the percentage uncertainty in *g*.

[1]

(iii) Using the measured values in the table gives a value for *g* of 10.5 m s^{-2}.

Use the maximum possible value of the time for a return journey, together with the measured values of the length of the tank and the depth of water, to calculate the percentage uncertainty in *g*.

percentage uncertainty in *g* = ... % **[3]**

[Total: 15]

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Question 14 on next page.

14 This question is about the article *Rolling Friction in Bicycle Tyres – interpreting trends in data*.

(a) Explain why comparing the performance of different tyres is difficult.

[1]

(b) The table of results shows a comparison of type A and type B tyres.

inflation pressure / N cm^{-2}	**rolling friction / N**					
	type A tyres			**type B tyres**		
	tyre 1	**tyre 2**	**tyre 3**	**tyre 1**	**tyre 2**	**tyre 3**
35	5.76	5.96	5.75	4.80	4.83	4.82
40	5.22	5.40	5.20	4.37	4.37	4.36
45	4.83	5.03	4.80	3.99	4.01	3.98
50	4.52	4.74	4.55	3.73	3.72	3.73
55	4.27	4.49	4.29	3.51	3.50	3.50
60	4.02	4.20	4.02	3.34	3.33	**3.65**
65	3.79	3.99	3.77	3.20	3.22	3.18
70	3.62	3.79	3.62	3.09	3.06	3.09
75	3.48	3.65	3.46	2.97	2.97	2.95
80	3.35	3.55	3.36	2.86	2.85	2.86

The tests on one tyre had a systematic error in the collection of the data.

(i) State the test which was faulty.

test for tyre .... of type .... **[1]**

(ii) Justify your answer to **(i)**.

[1]

(iii) Suggest and explain what might have been done in the test, illustrated in Fig. 2 in the article, to give rise to this systematic error.

[2]

(c) (i) Using evidence from the variations between tests, explain why it would be justifiable to give the values of rolling friction to 3 significant figures.

[2]

(ii) The value of 3.65 N for the third type B tyres at 60 N cm^{-2} has been highlighted in the table. Give **two** reasons, supported by data from the table, why it is reasonable to be suspicious of this value, and to consider checking it or eliminating it from the data.

[2]

(d) Use the table to suggest and explain which type of tyre would be the more suitable to achieve a high speed, and the best inflation pressure for that tyre.

[2]

[Total: 11]

15 This question is about the article *Eratosthenes' measurement of the Earth's circumference*.

(a) The unit of distance used by Eratosthenes was the stadion. In his original calculation he estimated the circumference of the Earth to be 252 000 stadia.

Describe how he reached this value from his initial measurement of the angle of the shadow of a vertical post (Fig. 3 in the article).

In your answer, you should make the steps in his calculation clear.

[4]

(b) Suggest one disadvantage to people in Ancient Egypt of measuring distances in terms of the number of days taken for camel caravans to travel them.

[1]

(c) **(i)** The stadion was commonly used at the time but its actual value was not consistent or exact.
An estimate of the value used by Eratosthenes is 1 stadion = 170 m, with an uncertainty of 5%.
Calculate the minimum and maximum values of 1 stadion. Express your answers to two significant figures.

minimum value = ... m

maximum value = ... m **[2]**

(ii) Eratosthenes measured the angle of the shadow at Alexandria as 7 ± 1°. He knew that this angle on the Earth's surface corresponded to 4900 stadia.
Use these data, together with the value of 170 m for a stadion, to calculate the maximum and minimum values for the circumference of the Earth.
Compare your results with the current accepted mean circumference of the Earth of 40 010 km (4.001×10^7 m).

maximum value = ... m

minimum value = ... m

[3]

(iii) Explain why the uncertainty in the length of a stadion was not used in **(c)(ii)** to calculate the maximum and minimum values of the circumference of the Earth.

[2]

Question 15 continues on the next page

(d) The article refers to an assumption made by Eratosthenes about the relative locations of Alexandria and Syene.

Eratosthenes thought that Syene was due south of Alexandria. In fact, it was some distance to the east, as shown in Fig. 15.1.

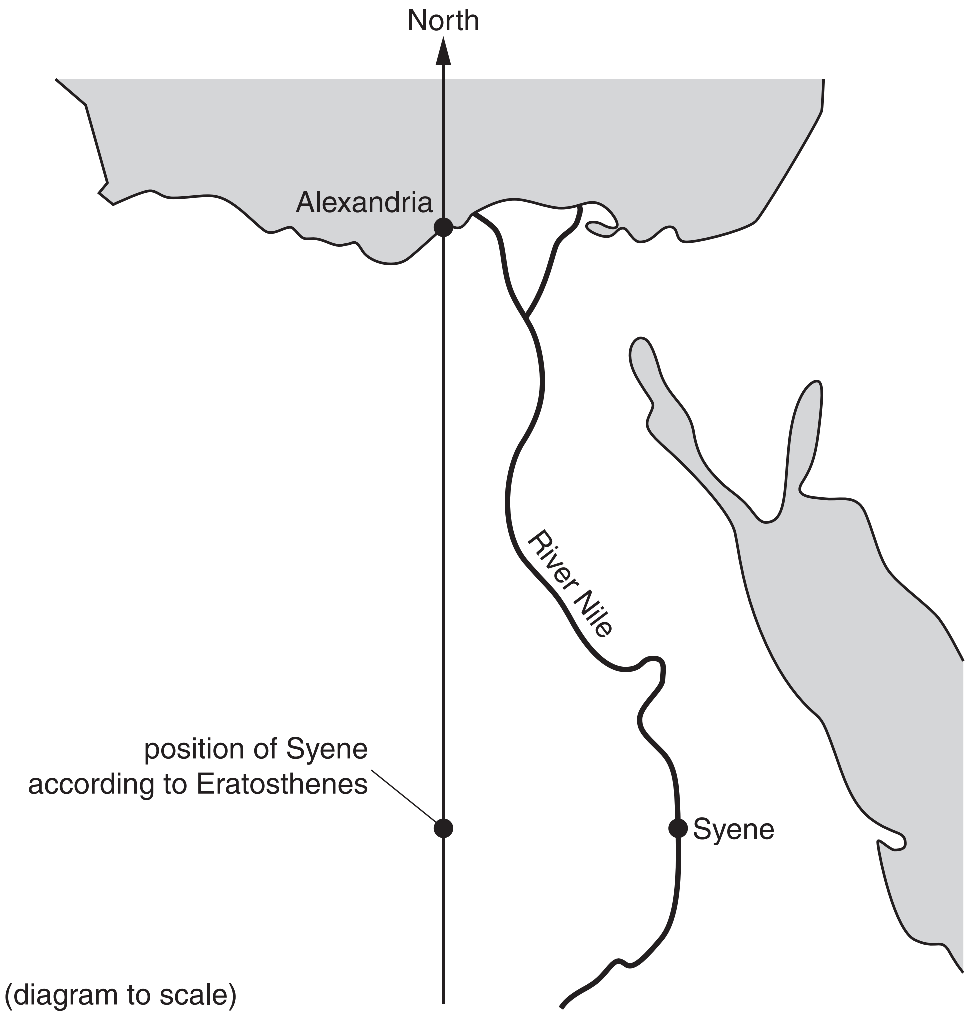

Fig. 15.1

Suggest and explain how this systematic error might affect his calculated value for the circumference of the Earth.

[2]
[Total: 14]
[Section C Total: 40]

END OF QUESTION PAPER

ADDITIONAL PAGE

If additional space is required, you should use the blank pages below. The question number(s) must be clearly shown.

ADDITIONAL PAGE

ADDITIONAL PAGE

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ADVANCED SUBSIDIARY GCE

PHYSICS B (ADVANCING PHYSICS) G492

Unit G492: Understanding Processes / Experimentation and Data Handling

INSERT

Monday 6 June 2011
Afternoon

Duration: 2 hours

G410610611

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 Using the speed of water waves to determine *g*

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.

The simple arrangement of Fig. 1 can be used to carry out the practical task.

v = velocity of the waves
d = depth of water

Fig. 1

Waves can be generated in a number of ways, such as pushing a ruler to and fro in the water, or just simply lifting one end of the tank about 1 cm and then lowering it quickly onto the bench.

The depth of water can be easily changed, but the velocity of the wave can prove to be problematic to measure. Although simple, the most practical way of measuring the speed is to use a stop watch to time how long the waves take to travel the length of the tank and back again. The velocity can then be calculated. In making these measurements, it is important to consider possible systematic errors.

The relationship $v = \sqrt{gd}$ can be applied to the experimental data and used to determine a value for g, the acceleration due to gravity.

2 Rolling Friction in Bicycle Tyres – interpreting trends in data

In the competitive world of bicycle manufacturing, it is widely recognised that it is very difficult to compare the performance of different tyres due to the fact that there are many unwanted variables such as differing tyre constructions, sizes, widths, treads and designed running pressures.

One simplified way of looking at the performance of tyres is to attempt to measure the relationship between rolling friction and inflation pressure for different tyres. The greater the rolling friction, the greater the energy losses in travelling.

The rolling friction for two types of tyres was measured in the same apparatus under the same conditions. In the test, a bicycle wheel rotating at a fixed speed was placed on rollers and the time taken for it to slow down to a stop was measured (Fig. 2).

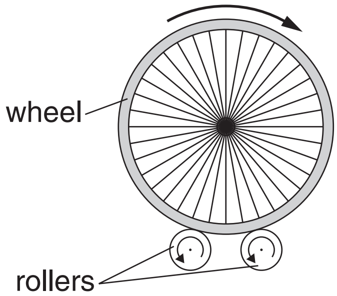

Fig. 2

From this time, the force of rolling friction could be calculated. The test was repeated at a range of inflation pressures for three examples of each tyre.

The table below gives the data produced in the measurements.

inflation pressure / $N\,cm^{-2}$	rolling friction / N					
	type A tyres			type B tyres		
	tyre 1	tyre 2	tyre 3	tyre 1	tyre 2	tyre 3
35	5.76	5.96	5.75	4.80	4.83	4.82
40	5.22	5.40	5.20	4.37	4.37	4.36
45	4.83	5.03	4.80	3.99	4.01	3.98
50	4.52	4.74	4.55	3.73	3.72	3.73
55	4.27	4.49	4.29	3.51	3.50	3.50
60	4.02	4.20	4.02	3.34	3.33	3.65
65	3.79	3.99	3.77	3.20	3.22	3.18
70	3.62	3.79	3.62	3.09	3.06	3.09
75	3.48	3.65	3.46	2.97	2.97	2.95
80	3.35	3.55	3.36	2.86	2.85	2.86

Inspection of the data, without any calculation, suggests that the tests on one tyre were subject to a systematic error.

Furthermore, patterns can be seen which reveal characteristics of the different types of tyre.

3 Eratosthenes' measurement of the Earth's circumference

Eratosthenes, a Greek mathematician, poet, athlete, geographer, and astronomer, was born in 276 BC. He lived in Egypt, which then belonged to Greece. He made several discoveries and inventions including a system of latitude and longitude. In about 240 BC he was the first person to calculate the circumference of the Earth (with remarkable accuracy), using trigonometry and knowledge of the angle of elevation of the Sun.

The calculation was based on the assumption that the Earth is spherical and that the Sun is so far away that its rays can be taken as parallel.

At Syene (now Aswan), the Sun would appear at noon on the summer solstice at the zenith, directly overhead, as its reflection could be seen at the bottom of a deep well. Eratosthenes also knew, from measurement of the length of a shadow cast by a vertical post, that in his hometown of Alexandria, at noon on the same date, sunlight fell at an angle of about 7° from the vertical. This is shown in a sectional view through the Earth in Fig. 3.

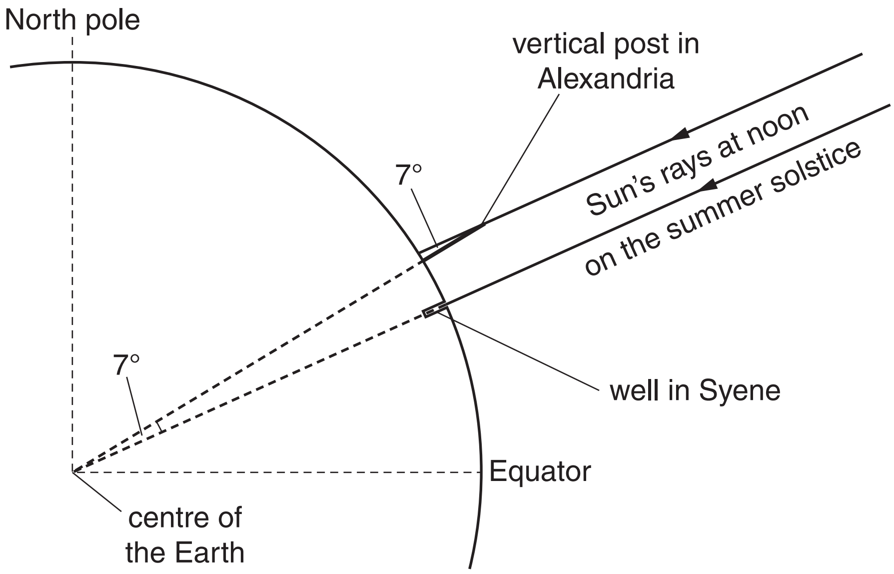

Fig. 3

Eratosthenes concluded that the distance from Alexandria to Syene must be 7/360 of the total circumference of the Earth.

It is believed that Eratosthenes calculated the distance between Syene and Alexandria from the time taken for a caravan of camels to travel between them. The Greek unit of distance was the *stadion* (plural *stadia*). This was originally the length of an athletics field. A camel caravan travelled about 100 stadia each day, and took 50 days to travel between Syene and Alexandria, implying that they are 5000 stadia apart.

Eratosthenes calculated the distance along the Earth's surface corresponding to one degree of longitude, and rounded his result to 700 stadia per degree. This gave him a value for the Earth's circumference of 252 000 stadia. The Greek stadion and Egyptian stadion were slightly different and it is not certain which Eratosthenes used. Combining them gives a value of 170 m with an uncertainty of about 5%.

In his calculations, Eratosthenes assumed that Syene was due south of Alexandria. In fact, it is east of south, as shown in Fig. 4. This systematic error would not have greatly affected his accuracy, as the percentage uncertainty involved in his measurement of the angle of the shadow to ±1° was much greater.

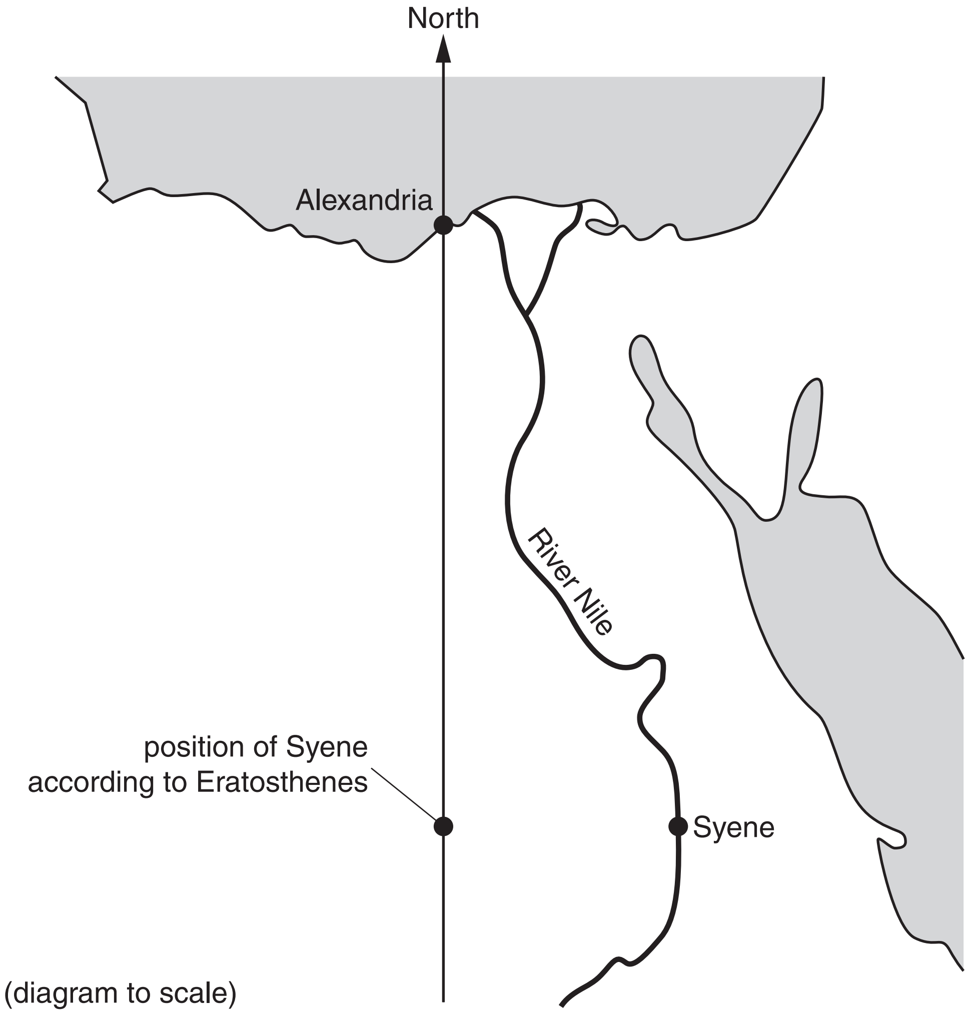

Fig. 4

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