LONDON SCIENCE COLLEGE

MARK SCHEME

PHYSICS

AS-Level

WAVES

TEST 2

Mark schemes

1 The marking scheme for this question includes an overall assessment for the quality of written communication (QWC). There are no discrete marks for the assessment of QWC but the candidate's QWC in this answer will be one of the criteria used to assign a level and award the marks for this question.

Descriptor – an answer will be expected to meet most of the criteria in the level descriptor.
Level 3 – good
-claims supported by an appropriate range of evidence
-good use of information or ideas about physics, going beyond those given in the question
-argument well structured with minimal repetition or irrelevant points
-accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling
Level 2 – modest
-claims partly supported by evidence,
-good use of information or ideas about physics given in the question but limited beyond this the argument shows some attempt at structure
-the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling
Level 1 – limited
-valid points but not clearly linked to an argument structure
-limited use of information about physics
-unstructured
-errors in spelling, punctuation and grammar or lack of fluency
Level 0
-incorrect, inappropriate or no response

Level 3
Response will give a sensible diagram, suggestion of length of string and sensible range details of range of tension, the procedure to obtain data and the analysis of the data. The response may include a calculation of *f* for the chosen apparatus.

Level 2
All bullet points will be addressed but may lack essential detail. The response will include a sensible diagram and procedure but the procedure may be poorly explained. It should include how the data is analysed to demonstrate the relationship.

Level 1
Attempt will contain some relevant detail of a sensible experiment. The diagram may be poorly drawn. The range for the tension may be given but not be sensible. Their procedure and analysis may be only superficially described.

Level 0
Response will contain no relevant information about an appropriate experiment.

Points that may be included

- *Labelled diagram including string , weights, pulley, metre rule,*
- *method using signal generator (calibrated) and magnets to cause oscillation of the string*
- *method using tuning forks*
- *Length 1-2 m*
- *e.g Weights up to 12 N in 2 N increments (range of at least 6)*
- *Frequencies different by detectable amount on sig gen / use of range of tuning forks*
- *Calculation to show approx f value for selected T and l*
- *Method of changing T*
- *How frequency is determined for each T*
- *Graph of f against $\sqrt{T}$*

[6]

2 **The student's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The student's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

Answers may cover some of the following points:

- *(1) a wave and its reflection / waves travelling in opposite directions meet / interact / overlap / cross / pass through etc*

  point (1) must be stated together i.e it should not be necessary to search the whole script to find the two parts namely the directions of the waves and their meeting
- *(2) same wavelength (or frequency)*
- *(3) node − point of minimum or no disturbance*

  points (3) may come from a diagram but only if the node is written in full and the y-axis is labelled amplitude or displacement
- *(4) antinode − is a point of maximum amplitude*

  point (4) may come from a diagram but only if the antinode is written in full and the y-axis is labelled amplitude or displacement
- *(5) node - two waves (always) cancel / destructive interference / 180° phase difference / in antiphase [out of phase is not enough] (of the two waves at the node) [not peak meets trough]*
- *(6) antinode − reinforcement / constructive interference occurs / (displacements) in phase*
- *(7) mention of <u>superposition</u> [not superimpose] of the two waves*
- *(8) energy is not transferred (along in a standing wave).*

  if any point made appears to be contradicted elsewhere the point is lost − no bod's

High Level (Good to excellent): 5 or 6 marks
The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

6 marks: points (1) ***AND*** *(2)* ***with*** *4 other points which must include point (4) or the passage must indicate that the wave is oscillating at an antinode*

5 marks: points (1) ***AND*** *(2)* ***with*** *any three other points*

although point (1) may not be given as a mark the script can be searched to see if its meaning has been conveyed as a whole before restricting the mark and not allowing 5 or 6 marks

Intermediate Level (Modest to adequate): 3 or 4 marks
The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

4 marks: (1) ***OR*** *(2)* ***AND*** *any three other points*
3 marks: any three points

Low Level (Poor to limited): 1 or 2 marks
The information conveyed by the answer is poorly organised and may not be relevant or

coherent. There is little correct use of specialist vocabulary.
The form and style of writing may be only partly appropriate.

2 marks: any two points
1 marks: any point or a reference is made to both nodes and antinodes

[6]

3 (a) number of (complete) waves (passing a point) in 1 second
OR
number of waves / time (for the waves to pass a point)
OR
(complete number of) oscillations \ vibrations per second
OR
1 / T with T defined as time for 1 (complete) oscillation ✓

Allow: cycles

Allow: unit time

1

(b) For two marks:
oscillation of particles \ medium \ material etc, but not oscillation of wave is parallel to \ in same direction as
the direction wave (travels) ✓ ✓

For one mark:
particles \ material \ medium move(s) \ disturbance \ displacement
parallel to \ in same direction as
the direction wave travels
OR
(oscillations) parallel to direction of wave travel ✓

the one mark answer with:
mention of compressions and rarefactions
OR
(longitudinal waves) cannot be polarised

gets **two** marks
✓

Allow
Vibration

Allow direction of energy transfer \ wave propagation

2

(c) ($f = 1540 / 0.50 \times 10^{-3}$)
= 3 100 000 (Hz) ✓ (3 080 000)
2sf ✓

2

(d) no more than two points from either list (max 3):

Description

- mention of nodes and antinodes
- particles not moving at a node
- maximum displacement at antinode
- particles either side of node in antiphase / between two nodes in phase
- variation of amplitude between nodes

Explanation

- a stationary wave (forms)
- two waves are of equal frequency or wavelength (and amplitude in the same medium)
- reflected and transmitted waves \ waves travelling in opposite directions, pass through each other
- superpose / interference occurs
- constructive interference at antinodes
- destructive interference at nodes

✓ ✓ ✓

Allow 'standing wave'

3

[8]

4 (a) (i) π / 2 (radians) or 90 (degrees) ✓

No path differences
Penalise contradictions
No fractions of a cycle

1

(ii) 3π / 2 (rad) or 270 (degrees) ✓

No path differences
Penalise contradictions
No fractions of a cycle

1

(b) (oscillation or motion) perpendicular to direction of wave (travel / velocity / energy transfer) ✓
(oscillates from equilibrium to maximum positive displacement, back to equilibrium, then to max negative displacement) and back to equilibrium / starting position / rest position ✓

do not allow 'up and down' for first mark
allow 'up and down', or 'down then up', 'side to side', 'rise and fall' in place of oscillates
Allow 'rest position', 'starting position' ,'middle', 'centre line'
ref to nodes / antinodes not allowed for 2 nd mark

2

(c) (the wave is) transverse **OR** not longitudinal ✓

accept it is an S wave or secondary wave

only transverse can be polarised **OR** longitudinal waves cannot be polarised **OR** oscillations are in one plane ✓

2

(d) (i) number of waves / complete cycles / wavelengths (passing a point / produced) per second ✓

or 'unit time'

allow: (number of) oscillations / vibrations / cycles per second

allow f=1 / T only if T is correctly defined

do not allow references to f=c / λ

1

(ii) ($v = f / \lambda$ $\lambda = v / f =$) $4.5 \times 10^3 / 6.0$ ✓

= 750 (m) ✓

correct answer only gets 2 marks

2

[9]

5 (a) (i) oscillates / vibrates ✓

(allow goes up and down / side to side / etc, repeatedly, continuously, etc)

about equilibrium position / perpendicularly to central line ✓

2

(ii) X and Y: antiphase / 180 (degrees out of phase) / π (radians out of phase) ✓

X and Z: in phase / zero (degrees) / 2π (radians) ✓

2

(b) (i) $v = f\lambda$

= 780 x 0.32 / 2 or **780 x 0.16 OR 780 x 320 / 2** or **780 x 160** ✓

THIS IS AN INDEPENDENT MARK

= 124.8 ✓ (m s^{-1}) correct 4 sig fig answer must be seen

2

(ii) ¼ cycle ✓

$T = 1 / 780$ OR $= 1.28 \times 10^{-3}$ ✓

$0.25 \times 1.28 \times 10^{-3}$

$= 3.2 \times 10^{-4}$ (s) ✓

Allow correct alternative approach using distance of 0.04m ✓

travelled by progressive wave in ¼ cycle divided by speed.

0.04 /125 ✓ $= 3.2 \times 10^{-4}$ (s) ✓

3

(c) (i) antinode ✓

1

(ii) 2 x 0.240 ✓

= 0.48 m ✓ '480m' gets 1 mark out of 2

2

(iii) ($f = v/\lambda$ = 124.8 or 125 / 0.48) = **260** (Hz) ecf from cii ✓

1

[13]

6 (a) (wave) **B** ✓

(the parts of the) spring oscillate / move back and forth **in direction of / parallel to** wave travel
OR
mention of compressions and rarefactions ✓

Second mark can only be scored if first mark is scored

2

(b) (i) (double ended arrow / line / brackets) from between two points in phase ✓

1

(ii) wave A: arrow vertically upwards ✓

wave B: arrow horizontally to the left ✓

2

(c) (transmitted radio waves are often) polarised ✓

aerial (rods) must be aligned in the same plane (of polarisation / electric field) of the wave ✓

2

[7]

7 (a) the **maximum displacement** (of the wave or medium) ✓

from the equilibrium position ✓

accept 'rest position', 'undisturbed position', 'mean position'

2

(b) (vertically) **down**wards (¼ cycle to maximum negative displacement) ✓

then **upwards** (¼ cycle to equilibrium position and ¼ cycle to maximum positive displacement) ✓

down (¼ cycle) to **equilibrium position/zero** displacement **and** correct reference to either **maximum** positive **or** negative displacement or correct reference to fractions of the cycle ✓

candidate who correctly describes the motion of a knot 180 degrees out of phase with the one shown can gain maximum two marks
(ie knot initially moving upwards)

3

(c) **max 3 from**

stationary wave formed ✓

by **superposition or interference** (of two progressive waves) ✓

knot is at a **node** ✓

waves (always) cancel **where the knot is** ✓

allow 'standing wave'

3

[8]

8 (a) **max 2 from**

in progressive waves, all points have the same amplitude (in turn), in stationary waves, they do not

B1

in stationary waves, points between nodes are in phase, in progressive waves, all points within one wavelength are out of phase with each other

B1

in stationary waves, there is no energy transfer along the wave, in progressive waves, there is

B1

stationary waves have nodes and antinodes but progressive waves do not

B1

where there are single relevant statements but no clear comparison between stationary and compressive waves, award 1 mark for two such statements

2

(b) $f \propto 1/l$ or $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ *or* fl = const

C1

657/660 (Hz)

A1

2

[4]

9 (a) **maximum displacement** from equilibrium/mean position/mid-point/etc **(1)**

1

(b) (i) any **one** from:

surface of water/water waves/in ripple tank **(1)**

rope **(1)**

slinky clearly qualified as transverse **(1)**

secondary ('s') waves **(1)**

max 1

(ii) transverse wave: oscillation (of medium) is perpendicular to wave travel

or transverse can be polarised

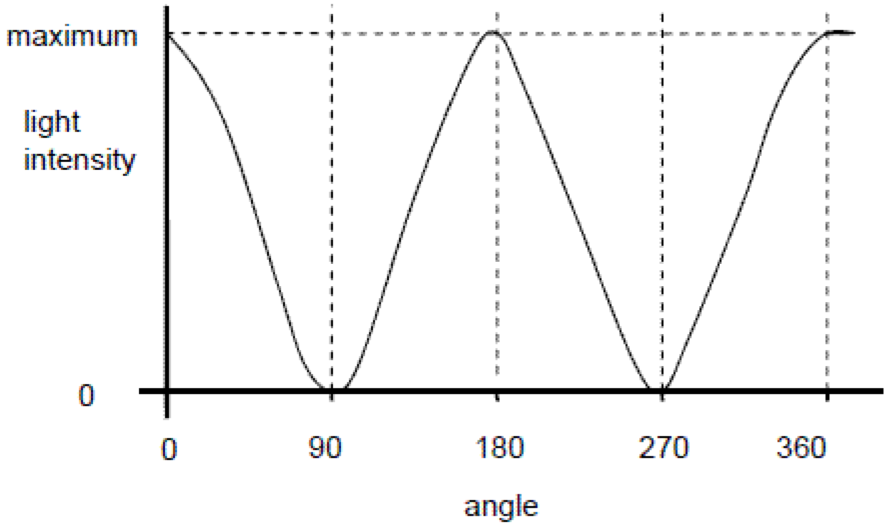
or **all** longitudinal require a medium **(1)**

1

(c) (i) vertical line on B ± 5° **(1)**

1

(ii)



max 0, 180, 360 + min 90, 270 **(1)**

and line reaches same minimum and maximum every time and reasonable shape **(1)**

2

(d) appropriate use **(1)**

reason for Polaroid filter being used **(1)**

eg

Polaroid glasses/**sun**glasses/ windscreens	to reduce glare
camera	reduce glare/enhance image
(in a) microscope	to identify minerals/rocks
polarimeter	to analyse chemicals/concentration or type of sugar
stress analysis	reveals areas of high/low stress/ other relevant detail
LCD displays	very low power/other relevant detail
3D glasses	enhance viewing experience, etc

2

[8]

10

(a) (i) rearrangement of $f = \frac{1}{2l}\sqrt{\frac{T}{u}}$ to give $l = \frac{1}{2f}\sqrt{\frac{T}{u}}$ C1

correct subs $l = \frac{1}{2 \times 92.5}\sqrt{\frac{681}{1.87 \times 10^{-2}}}$ or 92.5 = $\frac{1}{2f}\sqrt{\frac{681}{1.87 \times 10^{-2}}}$

C1

1.0(3) (m) condone sf

A1

3

(ii) 2 loops roughly equal

B1

1

(iii) (lightly) stop (in centre) B1

pluck or bow B1 2

(b) keeps tension or mass per unit length constant

B1

way of measuring frequency or producing vibration of known *f*

B1

way of measuring length (at resonance)

B1

use of suitable graph (*f vs 1/l* or *l vs 1/f)* to display results

B1

marks may be awarded for information seen on diagram

4

[10]

Examiner reports

1 Responses to this part were very disappointing and very few seemed to have conducted or seen such an experiment performed. Diagrams of apparatus were very poor and many were quite inappropriate for the experiment. Descriptions included no way of fixing the tension in the string and those who had some idea usually quoted use of increments of 100 g masses. Many seemed to think the experiment had to be conducted in such a way as to use calculations to determine the tension. A few made sensible suggestions such as the use of a set of tuning forks, microphone and oscilloscope or a stroboscope but most responses gave no method at all or an impractical method such as timing a number of oscillations using a stopwatch. When a vibrating mechanism was suggested this was often stated to be driven by dc and / or moved to produce tension with the other end fixed. Relatively few gave a sensible way of using the data.

2 Almost all students made a good effort at answering this question and almost all of those knew that standing waves are constructed from two waves. This being the case it was appropriate that this question was the basis of the quality of written communication assessment in this examination. Weaker students often spent too long setting the scene. They gave details of the apparatus and explained how the string was plucked or vibrated before the bullet points were addressed. Often at this stage these were answered with very brief responses that gave very little detail. The middle ability group of students fared much better. They could describe what nodes and antinodes were and how they came about in terms of the interference of two waves. What was often missing was the fact that the two waves that superpose have the same frequency or wavelength. Many of this group and a large percentage of the top ability group understood that an antinode was a maximum of the motion but they referred to the maximum displacement rather than the maximum amplitude. A couple of points separated this top group from the middle students as well as the quality of the structure of their writing and spelling. First they referred to the waves superposing unlike the majority who thought the waves superimposed on each other. Secondly, they sometimes included a point about the lack of energy transmission in a standing wave.

3

(a) The majority of candidates got this mark and only a small number missed out the very important 'per second'.

(b) For 2 marks it was necessary to point out that the particles are oscillating rather than the wave oscillating. For example, some candidates said something like, '*waves oscillate parallel to direction of wave*', or '*the motion is in the direction of the wave*'.

Confusion between progressive waves and stationary waves was often seen and some candidates talked about '*energy not being transferred with the wave*'.

Many candidates talk about 'motion' of particles rather than oscillation. Part (a) and part (b) highlight the fact that simple descriptions and definitions need to be memorised.

(c) The first part was done well apart from some candidates who did not convert from mm to m. Many rounded to 3sf rather than 2. This was probably because they believed 0.50 mm was three significant figures.

(d) This type of question is asking the student to apply their knowledge in a context that may be unfamiliar (assessment objective AO2 – see specification).

A simple explanation describing the formation of a stationary wave was therefore needed here.

However, many students did not spot that the question was about stationary waves. Candidates could mention how nodes and antinodes are formed by superposition, etc.

4 (a) (i) Some candidates thought this was a stationary wave and thus stated incorrect phase differences. See (a)(ii).

(ii) Phase difference is generally not well understood by candidates. Phase differences were often wrongly given in fractions of a wavelength e.g. λ / 4 rather than angles, e.g. 90°. Ninety degrees was often also given as π / 4 radians or π radians rather than π / 2 radians. Two hundred and seventy degrees was often thought to be equivalent to π rather than 3 / 2 π radians.

Many said 'in phase' or 'out of phase' rather than stating the phase difference.

Many marks were lost here due to contradictions, where candidates attempting to embellish their answers only succeeded in talking themselves out of the mark. E.g.' *90° (π / 4)*' or *'90° (antiphase)*'. Where a question says 'state' and there is one mark available, the candidate should try to give just the answer that they are confident is correct and not try to expand upon it.

(b) A high proportion of candidates thought that point **B** was going to go 'downwards'. Candidates must be clearer when stating directions. It is always advisable to say 'vertically upwards' or 'move upwards perpendicularly to the equilibrium line'. When a description of a complete cycle is required, marks will be lost if the whole cycle is not described including, in this case, the return to the equilibrium position.

(c) Many came up with interesting hypotheses such as, that the wave must have passed through a 'crack' in the rock to become polarised. However, in a question like this we are only expecting the candidate to apply the physics that they know. Here we were only looking for the link between polarisation and transverse waves, and not an in depth knowledge of seismology.

(d) This was very well done. A few candidates defined time period (*T*) rather than frequency. There was a tendency for some to say *'number of waves that pass a point in a <u>given time</u>'* rather than <u>*per second*</u>. A rather odd response to this question that was seen quite often was: *'The frequency doesn't change'* . Quite a few stated the equation f = c/λ but this is not the accepted definition of frequency.

5 Part (a)(i) was almost universally misinterpreted due to a similar question appearing on a previous paper. Many students interpreted the question as ‘describe the motion over the next cycle’. Those who did this often failed to point out that there was a continuing oscillation taking place. Part (a)(ii) was very poorly answered which was a surprise. A common answer was ‘out of phase’ for X and Y which is not equivalent to ‘antiphase’. Phase was often given in terms of number of wavelengths, e.g. ½λ. There was little understanding of the difference between phase difference along a progressive wave and a stationary wave. Many had measured the fraction of a wavelength between the points and converted this into an angle as you would for a progressive wave. It is suggested that phase difference along a stationary wave be demonstrated by referring to the many simulations available.

Part (b)(i) presented few problems for students. In part (b)(ii) many students did 1/780 and obtained the time for one complete cycle but did not recognise that they needed to divide by 4 to get the time for ¼ of a cycle. A significant number thought that the time between maximum displacement and reaching the equilibrium position was half a cycle. Some divided 780 by 4 which makes the answer 8 times greater than it should be.

For part (c)(i) most students got ‘antinode’ but a significant number put ‘node’/ ‘amplitude’/ ‘max displacement’ / ‘stationary wave’ / ‘equilibrium’ / ‘maxima’. Part (c)(ii) presented few problems for students. In part (c)(iii) quite a few students left this blank because they were unable to answer the previous question. However, many of those who scored the mark did so by using an incorrect answer to (c)(ii). Students should be encouraged not to give up; the final part of a question is not necessarily the hardest.

6 Most did well in part (b)(i) and indicated a complete wavelength very precisely, though a generous tolerance was allowed. A significant number thought the coils constituted the waveform and gave the spacing between one or two coils as the wavelength and some chose the compression or the rarefaction or the whole length of the spring. In part (b)(ii) many believed point P would move downwards. This is a very common misconception and a similar question has appeared in a past paper. The behaviour of point Q is more difficult to understand. The particle changes direction when the centre of a rarefaction or compression reaches it. If the wave is moving to the right, then as the compression gets closer to the particle, the particle will move left towards the compression.

In (c) the majority of students surprisingly did not recognise that this was about polarisation. Those who did point this out did not describe the aerial being aligned with the plane of polarisation.

7 Many students had learned the correct definition in part (a) but some gave a description, for example 'the greatest height of the wave from the middle'. This did not gain marks.

Surprisingly in answer to part (b), many students referred to the equilibrium position as the 'node' and maximum amplitude as the 'antinode' on a progressive wave. Many use fractions of a cycle to describe the position of the knot but some use angles or fractions of a wavelength which are not appropriate. The biggest loss of marks occurred in the first mark where a large number thought that the knot would be travelling upwards initially.

Part (c) was a fairly easy question with students only needing to state that the 'knot is at a node on a stationary wave which is caused by superposition' to get three marks. Most students managed to get two of the marking points. Many did not understand how a node is formed, believing it is the sum of a peak and a trough only, or that the whole rope is stationary, or that the rope is only stationary at a node when cancellation occurs between waves that are 180° out of phase. The two waves that form a stationary wave are not always 180° out of phase in order to cancel at the nodes. Nodes are where the wave always cancels but the phase difference between the waves repeatedly varies from zero to 2π. Cancellation everywhere on the stationary wave only occurs when the waves are in antiphase but cancellation always happens at the nodes because the displacements of the waves are always equal and opposite at those points (or displacements are both zero when in phase and in antiphase). This is a complex situation but there are many simulations available on the internet that help to get these ideas across.

8 In part (a), many students could not make a distinction between progressive and stationary waves, instead making generalised, unspecific and often inaccurate descriptions of aspects of waves. For example, some thought that all stationary waves were transverse. References to phase and amplitude were rare and confused.

Part (b) was done more effectively by many. Those that failed to gain credit tended to invert the ratios. Students could get the correct numerical answer using the general wave equation but this approach was not credited.

9 In part (a), the strict definition of amplitude was expected. Candidates needed to say 'maximum displacement' and then indicate in some way that this was relative to the equilibrium position.

The majority, however, chose to define amplitude as the **distance** between the centre and the peak.

For part (b) (i), the majority of candidates could not give an example of a transverse wave other than electromagnetic waves. Most gave a form of electromagnetic radiation (most commonly 'light') or even sound. Common answers that were accepted included 'water waves', 'waves on strings' or 's-waves'.

Most candidates realised that a comparison between the direction of wave travel and the oscillation of the medium was a good way to answer part (b) (ii). It was common, however, for candidates to struggle to express this clearly. The most common error was to say that a transverse wave 'moves' perpendicular to the direction of wave travel rather than 'oscillation is perpendicular to direction of wave travel'.

The vast majority of candidates found part (c) (ii) very straight forward.

The majority of candidates had no problem with part (c) (ii). The exact shape of the line was not important as long as the maximum and minimum intensities appeared in the right place.

There were many very good answers to part (d), such as ‘sunglasses/ski goggles reduce glare from light reflected from water/snow’ and ‘a camera filter reduces unwanted reflections’. Common inadequate responses included saying that polarising sunglasses ‘reduce light intensity’ because the lenses are ‘darker’, or that polarising filters reduce UV.

10 Most candidates did the calculation well. Those that did not usually did not correctly rearrange the equation. Once again, those who set out calculations well tend to be more successful than who are untidy or who miss out steps. Candidate’s drawings of the oscillation tended to be correct. A few got it wrong because they could not identify the correct oscillation but more lost the mark because their loops were obviously far from equal in size. Candidates should be advised to take care with their answers. Measuring the sixes of loops would not be inappropriate. Few candidates answered part (a) (iii) well. Stopping was mentioned and allowed even when the candidates did not indicate that this should be done lightly.

Part (b) was extremely badly done. There were some diagrams that showed more or less appropriate experimental apparatus but more that showed unfamiliarity with any sensible experiment. Candidates tended not to know the names of apparatus such as oscillators or signal generators. Very few mentioned that the length of the vibrating string should be measured using a metre rule or suitable alternative. Those that mentioned that a graph should be drawn almost always failed to suggest an appropriate graph that would yield a straight line. When describing experiments, candidates should be aware of the need to state the measurements that should be made; the measuring equipment used; which variables to control and how; how to display the results in a straight line graph.