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A LEVEL

Examiners' report

PHYSICS A

H556

For first teaching in 2015

H556/01 Summer 2023 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Paper 1 series overview

H556/01 (Modelling Physics) is one of three examination components for the A Level Physics A specification. This component focuses on:

- mechanics
- properties of matter
- thermal physics
- simple harmonic motion
- Astrophysics

To do well on this paper, candidates need to be comfortable with performing both simple and multi-step calculations, describing and explaining ideas and phenomena as well as experimental techniques and data analysis.

Where candidates had extensive practical experience, this clearly allowed them to answer both planning investigations and data evaluation questions.

This paper was notably more challenging than equivalent papers in previous seasons.

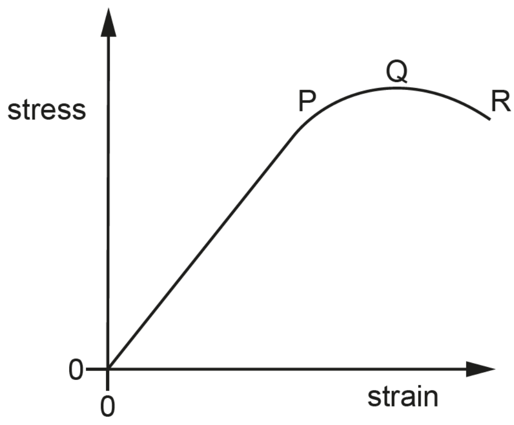
Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• made their working in calculations clear • showed each step in 'show that' questions carefully • made clear which instruments would be used in investigations • explained what they would do with data taken in investigations clearly. This would often be in the form of a graph, stating what the graph would show and how the gradient and/or the y-intercept of that graph was relevant to the investigation • used the data and relationships book wisely • worked through the multiple choice questions logically having removed unlikely answers first • moved on from challenging multiple choice questions if they were taking too long • remembered definitions of important terms and could reproduce them correctly • performed calculator operations accurately.	• showed their thinking in a disorganised way • forgot ideas about how investigative work is performed and reported, including the almost universal need for a relevant graph • muddled trigonometric functions • forgot some aspects of GCSE Physics, such as ideas about resultant force, experimental details regarding Hooke's Law and conservation of momentum • used the data and relationships book sparingly if at all • misread the question • did not address all aspects of a Level of Response question • re-used answers from previous mark schemes without thinking about how to apply them to an unfamiliar question or context.

Section A overview

Candidates answered Section A questions well. In this series, very few multiple choice questions were left blank. As ever there was a broad range of challenges here. Candidates should allot their time, accordingly, given that each Section A question is only worth 1 mark.

Question 4

4 Which row in the table correctly identifies the elastic limit, fracture and ultimate tensile strength in the graph below?



	Elastic limit	Fracture	Ultimate tensile strength
A	P	Q	R
B	P	R	Q
C	P	R	R
D	Q	R	P

Your answer [ ] **[1]**

Most candidates deduced the correct answer by remembering that the ultimate tensile strength is given by the highest point on the graph, in this case, point Q.

Question 5

5 A wire of cross-sectional area $3.9 \times 10^{-6}\,m^2$ carries a load of 240 N. The strain in the wire is 0.30%.

Which value of the Young modulus, in Pa, is correct and expressed to an appropriate number of significant figures?

A 2.05×10^8

B 2.1×10^8

C 2.05×10^{10}

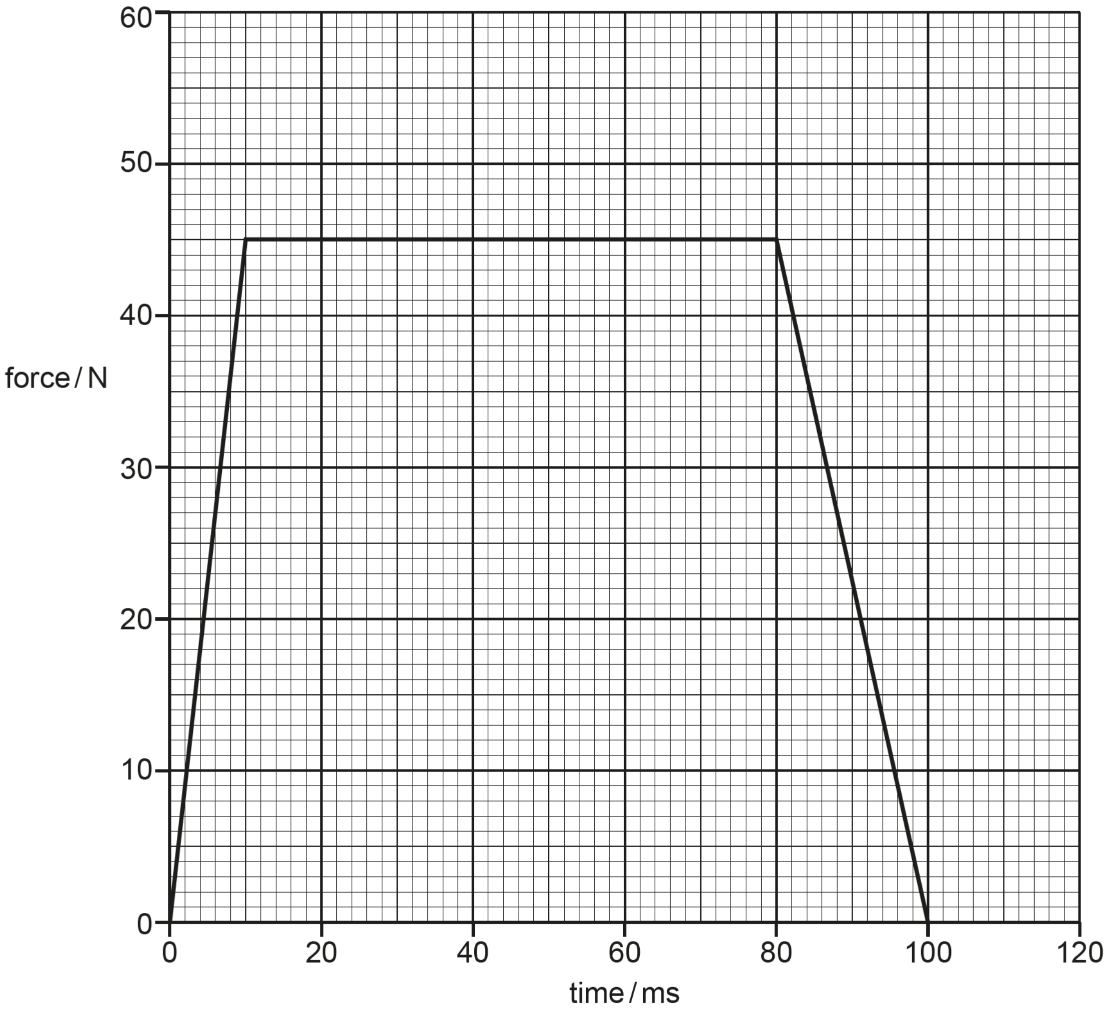
D 2.1×10^{10}

Your answer ☐ **[1]**

Just under half of all candidates got this correct. While the stress, given by force/area was straightforward to calculate, the strain was given as a percentage. This should have been converted to a decimal, i.e. 0.0030 to get the correct value of Young modulus.

Question 6

6 A tennis ball is hit with a racket. The graph shows the force the ball exerts on the racket.



What is the magnitude of the change in momentum of the ball?

A 2.3 kg m s^{-1}

B 3.8 kg m s^{-1}

C 2300 kg m s^{-1}

D 3800 kg m s^{-1}

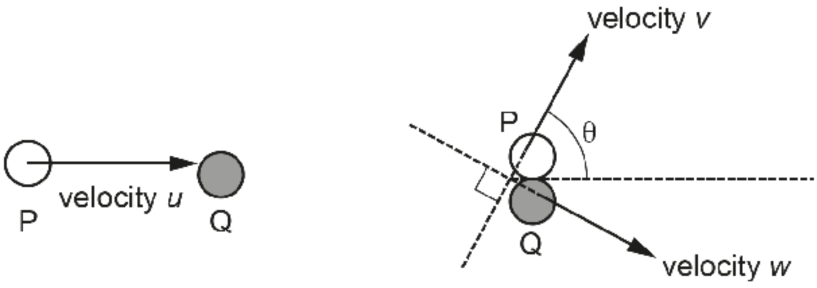
Your answer **[1]**

While virtually all candidates calculated the area of the trapezium correctly, candidates that forget that the time was measured in milliseconds picked answer D rather than the correct answer, B.

Question 8

8 A particle P of mass m and moving at velocity u collides **elastically** with a stationary particle Q also of mass m.

After the collision particle P moves with velocity v at an acute angle θ to the direction of the original motion. Particle Q moves in a perpendicular direction to P with velocity w.
The velocities u, v and w are constant.



Before collision After collision

Which of the following equations is/are correct?

1. $u = w\cos\theta + v\cos\theta$
2. $w\cos\theta = v\sin\theta$
3. $u^2 = w^2 + v^2$

A 1 only

B 1 and 2

C 2 and 3

D 1, 2 and 3

Your answer **[1]**

A good number of candidates answered this correctly. As this collision is elastic, the total kinetic energy (KE) for the collision, ½mu^2 remains unchanged. The total KE after the collision is ½mv^2 + ½mw^2. Equating these expressions gives statement 3 as correct, eliminating answers A and B. Statement 2 must also be correct and comes from conservation of momentum at right angles to the dashed line.

Looking along the dashed line, the momentum is mu before the collision. After the collision, the component of momentum along the dashed line for P is $mv\cos\theta$. The angle Q makes with the dashed line is not θ, so the component of momentum along that dashed line for Q cannot be $mw\cos\theta$. This makes statement 1 false and so the correct answer is C.

Question 11

11 A satellite is in geostationary orbit 36 000 km above the Earth's surface. The Earth has a radius of 6400 km.

At what speed is the satellite moving relative to the centre of the Earth?

A $0\,\text{m}\,\text{s}^{-1}$

B $490\,\text{m}\,\text{s}^{-1}$

C $2.6\,\text{km}\,\text{s}^{-1}$

D $3.1\,\text{km}\,\text{s}^{-1}$

Your answer **[1]**

The question is asking for the candidate to calculate the speed of an object in a circular orbit with radius 42 400 km, i.e. 42.4×10^6 m.

To do this, the candidate equates the gravitational force, $F_G = GMm/r^2$. with the centripetal force required for that orbit, $F_C = mv^2/r$, where M is the mass of the Earth and m is the mass of the satellite.

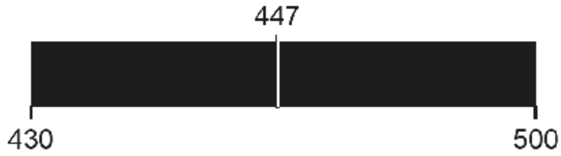
Rearranging gives $v = \sqrt{GM/r}$. Substituting the correct values for G, M and r will give answer D.

Question 14

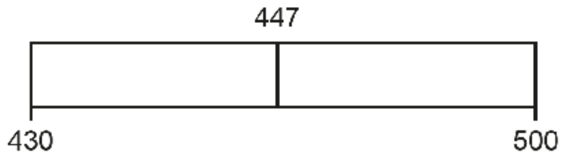
14 Part of the emission spectrum for hydrogen in a laboratory is shown. All wavelengths are given in nm.

Which diagram shows the corresponding part of the absorption spectrum observed from Earth emitted from a galaxy moving away with a velocity of 0.031 c?

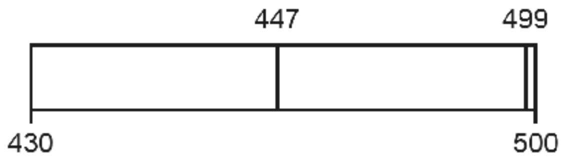
A



B



C



D

Your answer **[1]**

The spectrum in the question and those for answers A and B depict emission spectra. Spectra C and D are absorption spectra. The question asks for the absorption spectrum from distant galaxies so only answers C and D could be correct.

With the recession velocity of 0.031*c*, both wavelengths will be increased by 3.1 percent.

The laboratory wavelength of 434 nm becomes 447 nm after the redshift. The laboratory wavelength of 486 nm becomes 501 nm and so lies outside the range for these diagrams. This makes the correct answer C.

Section B overview

Questions in this section covered a broad range of topics from the specification as well as a broad spectrum of intended levels of challenge.

Question 16 (b) (i)

(b) A vehicle with mass 1600 kg is travelling at 110 km / hr.
The driver sees an obstruction and applies the brakes to bring the vehicle to rest in 5.6 s.

(i) Estimate the magnitude of the average resultant force *F* required to bring the vehicle to rest.

F = ... N **[2]**

Question 16 (b) (ii)

(ii) Explain the effect on the distance required to bring the vehicle to rest if the road has an upwards slope.

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.... **[2]**

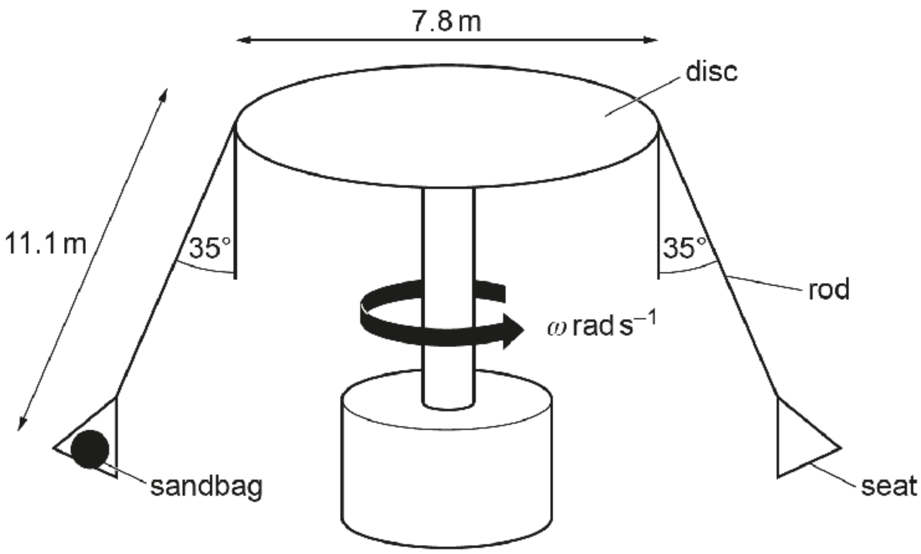
In Question 16 (b) (i), most candidates used the data available in the question to calculate an acceleration and hence a resultant force. In part (b) (ii), rather fewer used acceptable technical language to communicate their ideas. Useful phrases for explanations on this idea were 'resultant force' and 'component of weight parallel to the slope' rather than 'extra force' or 'some of the vehicle's gravity helped'.

Question 17 (a)

17 The diagram below shows a fairground ride. Each rider is secured in a seat suspended by a rod.

The distance from the top of the rod to the base of the seat is 11.1 m.

The rod is attached to the edge of a disc of diameter 7.8 m.



(not to scale)

To test the equipment a sandbag is attached to the seat and the ride is started.

The combined mass of the seat and the sandbag is 12 kg.

The rod makes an angle of 35° with the vertical.

(a) **(i)** Draw an arrow labelled T on the diagram to represent the tension in the rod. **[1]**

(ii) Show that the radius of the circular path followed by the sandbag is about 10 m.

[2]

(iii) Calculate the tension *T* in the rod.

(iv) Show that the angular velocity of the ride is about 0.8 radians per second.

[2]

In Question 17 (a) (i) of this question, the phrase 'tension in the rod' can mean several different things, all of which were given in the mark scheme. Many candidates approached part (ii) with some confidence, spotting that the horizontal portion of the rod was 11.1 sin(35) and that it should be added to the radius of the disc.

Parts (a) (iii) and (iv) were more challenging, requiring good knowledge of both circular motion and how to calculate components of forces. Again there were several legitimate routes to the right answer, all of which were mentioned in the mark scheme. Very logical approaches were in part (a) (iii), to equate the vertical component of the tension with the weight of the sandbag. In part (a) (iv), the quickest approach was to equate the horizontal component of the tension with the centripetal force. The data booklet provides a convenient expression for the centripetal force in terms of the angular velocity, without the need for finding the tangential velocity.

Question 17 (b)

(b) When the seat is at its highest point the sandbag is 17 m above the ground. The sandbag is released from the seat to model an object being dropped by a rider.

(i) Calculate t, the time taken for the sandbag to reach the ground.

t = ... s **[2]**

(ii) Using your answer to **(a)(iv)**, determine the horizontal displacement s travelled by the sandbag before hitting the ground.

s = ... m **[3]**

(iii) Determine, with reasons, the effect on the horizontal displacement travelled if the object released from the ride was a shoe from a rider.

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.... **[3]**

Question 17 (b) explored ideas about parabolic flight due to gravitation. The only force acting on the sandbag and the shoe after they have been released is the weight force, which acts vertically downwards.

Many candidates realised that the vertical velocity of the sandbag when it left the swing was zero, enabling them to calculate the time for the bag to fall 17m vertically downwards (using $s = ½gt^2$)

To calculate the horizontal distance travelled required both the horizontal velocity (from $v = r\omega$) and the time of flight from part (b) (iii). There was lots of scope for applying error carried forward rules as mentioned in the mark scheme.

Misconception

?

In lots of questions, candidates make assumptions when trying to use formulae to justify their ideas. In this case, it was that for the same radius, the shoe must leave the seat faster than the sandbag, purely because the shoe had less mass.

Often, what is constant is as important to consider as what is changing. Here, if the radius for the sandbag and the shoe are the same, then the horizontal velocity at release must be the same, since the radius and angular speed for both are the same, using $v = r\omega$.

Question 18*

18* A student is attempting to determine the value of *g*, the acceleration due to gravity, by two different methods.

Method 1. Vertical drop method

Measuring the time of fall of a small dense ball being dropped from rest from different heights.

Method 2. Rolling ball method

Measuring the time it takes for the same ball to roll 1.900 m down a ramp, set at different angles.

Single sets of results are shown below. The times were measured using a standard stopwatch operated by the student.

Compare and discuss the uncertainties of the two values of *g* that could be obtained using these single measurements.

Describe how the student would analyse both sets of data when a full range of results has been taken.

Vertical drop method

Drop height / m	Time taken / s
1.20	0.50

Rolling ball method

Length of ramp / m	Angle / °	Time taken / s
1.900	30	0.90

[6]

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The easiest way to score well on this question was to look carefully at what was required. There is no mention of calculating *g* using either set of data nor any mention of steps the candidate could take to minimise the uncertainties. It is largely a question of what analysis *would be* used if there was a full range of results and how the uncertainties in both experiments can be compared.

Almost all experiments and investigations at A2 Level require the use of an appropriate graph to represent and analyse data. Here there are two graphs: s against t^2 for the falling object and t^2 against $\sin\theta$ for the rolling object. By rearranging the equations relating the variables, it is possible to work out the relevance of the gradient in both graphs.

The data tables gave significant clues about how uncertain these experiments are, such as the number of significant figures for the raw data and the instruments with which these measurements would have been taken. Very successful candidates took the information and correctly propagated the instrumental uncertainties, even remembering to double the uncertainty in the time measurement because of the appearance of t^2 in the analysis. Once they did this, they had a valid way of comparing the uncertainties in both experiments, coming to a valid conclusion.

Misconception

Candidates in this paper mistook the percentage *difference* for the percentage *uncertainty* in this question. To calculate the percentage difference here required an experimental value for g and the 'accepted' value of g, namely 9.81 m s^{-2}.

Exemplar 1

Single sets of results are shown below. The times were measured using a standard stopwatch operated by the student.

Compare and discuss the uncertainties of the two values of g that could be obtained using these single measurements.

Describe how the student would analyse both sets of data when a full range of results has been taken.

i.e. better average time

Vertical drop method

Drop height / m	Time taken / s
1.20	0.50

Rolling ball method

Length of ramp / m	Angle / °	Time taken / s
1.900	30	0.90

[6]

• The absolute uncertainties in the time taken and either drop height or length of ramp are equal

• However in experiment 1, the drop height is shorter than the length of ramp, and the time taken is less, leading to larger % uncertainties (as [illegible] 1.58 × % unc in drop height, and 1.8× unc in time taken) so with these two factors, rolling ball has smaller uncertainty

• But rolling ball also measures an angle, introducing a further uncertainty from the protractor, which has a small absolute uncertainty compared to stopwatch

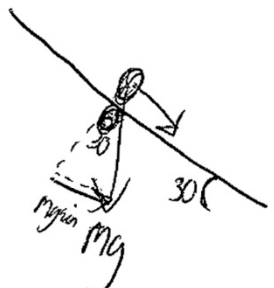
· Using lightgates would reduce % uncertainty in time, as would dropping from greater heights
· Since the stopwatch relies on human reaction, this will have an absolute uncertainty comparable to the time taken, so will have largest % uncertainty
∴ despite the angle being an uncertainty, the rolling ball is likely to have the smallest % uncertainty
· Repeating to get more t values and averaging will reduce % the uncertainty
· For vertical ball method, $s = ut + \frac{1}{2}at^2 \Rightarrow 1.2 = \frac{1}{2}g(0.5)^2$

Additional space if required ∴ $g = 9.6\,ms^{-2}$, which is only 2.1% off true value

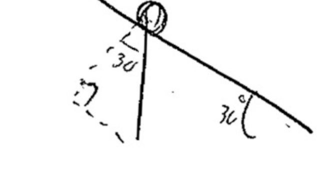
· With full range, find the average t and plug in to formula

· For rolling ball $s = ut + \frac{1}{2}at^2 \Rightarrow 1.9 = \frac{1}{2}(g\sin(30))0.9^2$
∴ $g = 9.382... = 9.4\,ms^{-2}$, which is further from true value of 9.81, with a 4.4% error

$s = 1.2$
$u = 0$
~~v~~
$a = g$
$t = 0.5$



$s = 1.9$
$u = 0$
~~$v = ?$~~
$a = g\sin(30)$
t



· For vertical drop:

$$g = \frac{2s}{t^2}$$

· For rolling ball: $$g = \frac{2s}{t^2\sin(\theta)}$$

· Despite the larger % unc. in time, the ave value of g from vertical drop method is closer to true value

The exemplar 1 response came from an otherwise successful candidate. Their first statement about the uncertainty in the time values is true yet not true regarding the uncertainty in the distance measurements. There is some discussion about the percentage uncertainties in the length due to the differences in size of those length measurements and extra uncertainty due to the use of a protractor. Crucially, there is not much discussion about the actual values of those uncertainties.

The candidate proceeds to calculate *g* from the single data points provided in the question. While this has been done correctly, it does not answer the question. There is no reference to graphical analysis at all. This resulted in this response being marked as a Level 1 response.

Exemplar 2

V S = 51.2
u = 0
a = g
t = time = 0.5

18* A student is attempting to determine the value of *g*, the acceleration due to gravity, by two different methods.

$g = -\frac{GM}{r^2}$

Method 1. Vertical drop method   t=

Measuring the time of fall of a small dense ball being dropped from rest from different heights.

Method 2. Rolling ball method   1.9m   t=   s a v [illegible]

Measuring the time it takes for the same ball to roll 1.900 m down a ramp, set at different angles.

Single sets of results are shown below. The times were measured using a standard stopwatch operated by the student.

Compare and discuss the uncertainties of the two values of *g* that could be obtained using these single measurements.

Describe how the student would analyse both sets of data when a full range of results has been taken.

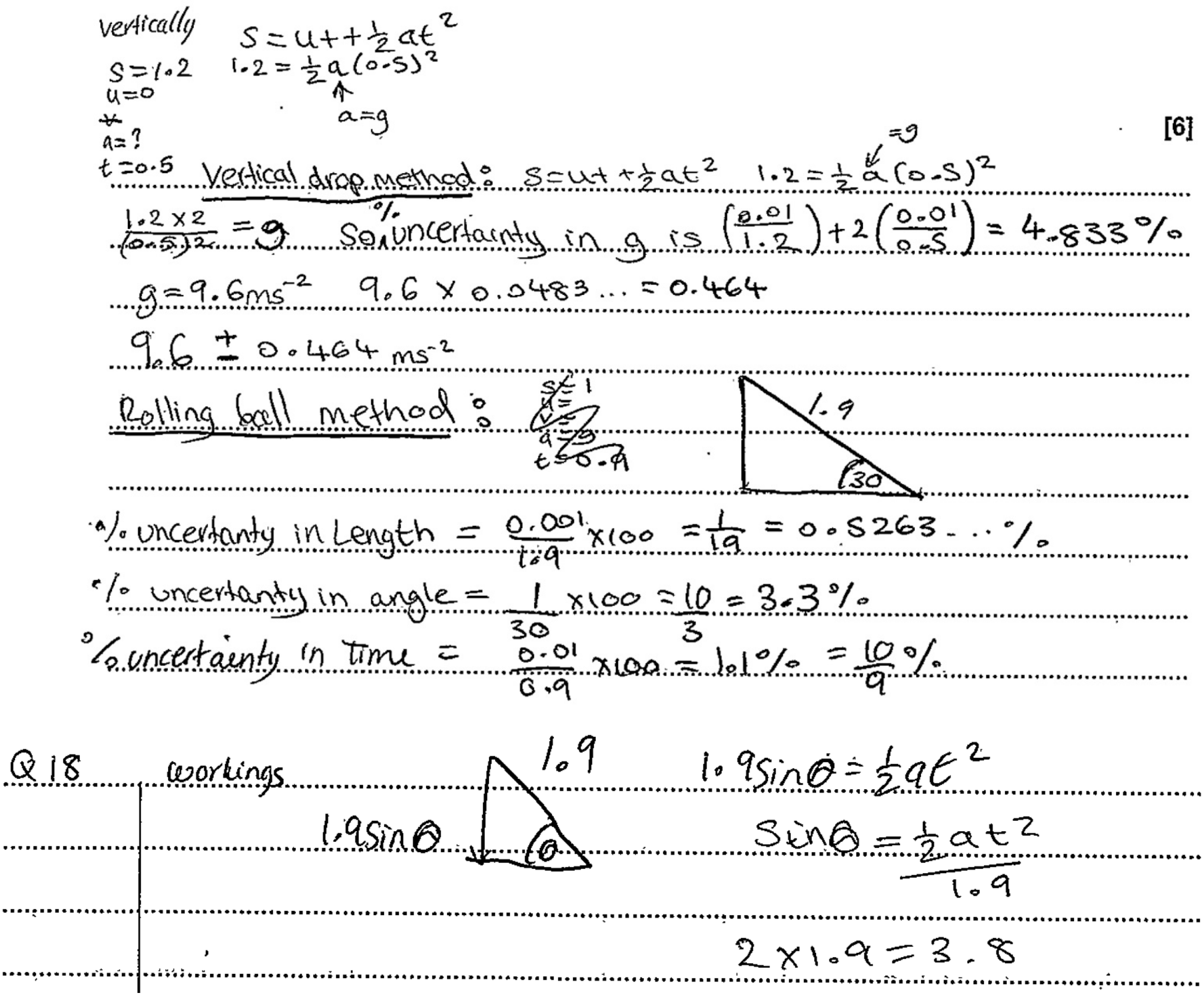
Vertical drop method

Drop height / m	Time taken / s
1.20	0.50

Rolling ball method

more values that could have error

Length of ramp / m	Angle / °	Time taken / s
1.900	30	0.90



vertically $s = ut + \frac{1}{2}at^2$

$s = 1.2$ $1.2 = \frac{1}{2}a(0.5)^2$

$u = 0$ $a = g$

$a = ?$

$t = 0.5$

[6]

Vertical drop method: $s = ut + \frac{1}{2}at^2$ $1.2 = \frac{1}{2}a(0.5)^2$ ($a = g$)

$\frac{1.2 \times 2}{(0.5)^2} = g$ So % uncertainty in g is $\left(\frac{0.01}{1.2}\right) + 2\left(\frac{0.01}{0.5}\right) = 4.833\%$

$g = 9.6\,ms^{-2}$ $9.6 \times 0.0483\ldots = 0.464$

$9.6 \pm 0.464\,ms^{-2}$

Rolling ball method: $s = 1$, $u = 0$, $t = 0.9$

1.9, 30

% uncertainty in Length $= \frac{0.001}{1.9} \times 100 = \frac{1}{19} = 0.5263\ldots\%$

% uncertainty in angle $= \frac{1}{30} \times 100 = \frac{10}{3} = 3.3\%$

% uncertainty in time $= \frac{0.01}{0.9} \times 100 = 1.1\% = \frac{10}{9}\%$

Q18 workings

1.9, $1.9\sin\theta$, θ

$1.9\sin\theta = \frac{1}{2}at^2$

$\sin\theta = \frac{\frac{1}{2}at^2}{1.9}$

$2 \times 1.9 = 3.8$

This candidate has gone to great trouble to calculate the uncertainties each measurement would contribute to the overall uncertainty in the value of *g* for both methods, allowing a valid comparison of the two.

In contrast to exemplar 1, there is a full description of the required graphical analysis, justifying which variable should be plotted on which axis and how a value of *g* could be obtained from such a graph in each case.

This response was therefore marked as a Level 3 response.

OCR support

Teachers and candidates all have access to the Practical Skills handbook which includes techniques and ideas that prove useful in answering Level of Response and other questions that check practical experience.

Question 19 (a)

19 (a) Describe how to find the centre of mass of a 2-dimensional shape, including any equipment required.

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.... **[3]**

This question was answered well by the majority of candidates, especially those that mentioned a good method of showing where the vertical was. Explicit use of the term 'plumb-bob' or 'plumbline' was not required i.e. 'mass on a string' or 'pendulum' or 'string with an object on the end' were all perfectly acceptable alternate wordings.

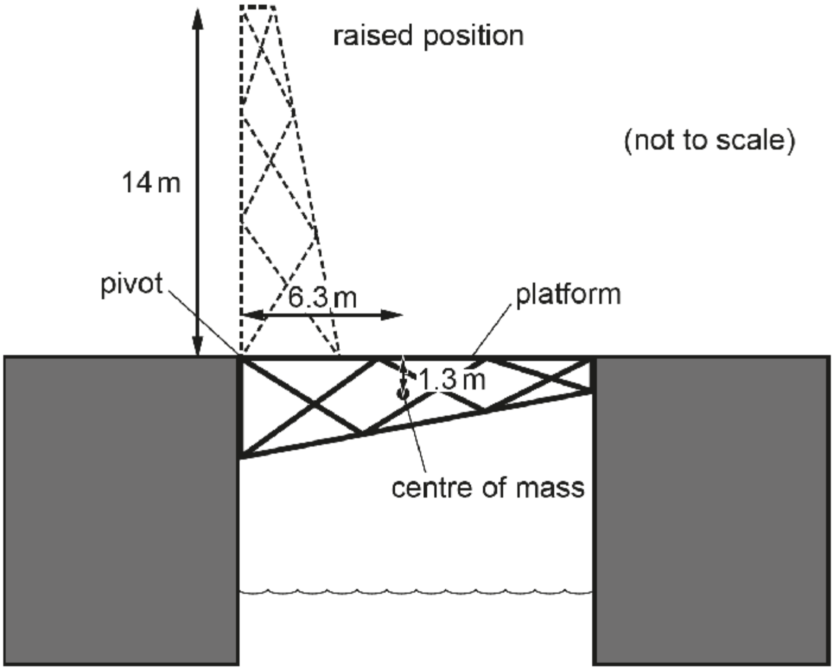
Methods that relied on balancing the 2-D shape horizontally on a point could only score a maximum of 1 mark, even though it is a viable way of checking the results of the more detailed and expected procedure.

Question 19 (b)

(b) **Fig. 19** shows a bridge.

The bridge can be raised by an electric motor to allow tall ships to pass underneath.

Fig. 19



The moving section of the bridge is 14 m long and has a weight of 120 kN.

The centre of mass of the structure is 6.3 m from the pivot.

(i) Calculate the average power required to raise the bridge to a vertical position in 90 s.

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

(ii) Suggest why the actual electric motor used to lift the bridge has a maximum power output several times larger than the value calculated in **(b)(i)**.

....

....

.... **[1]**

In Question 19 (b) (i), many candidates spotted the need to calculate the GPE required to raise the bridge using the relationship GPE = *mgh* although there was some confusion about the value of *h*.

The centre of mass goes from a position 1.3 m below the top of the grey boxes to a position 6.3m above those same grey boxes, making the total value of *h* 7.6 m.

Once the candidates had calculated the GPE, the successful ones divided by the time taken to lift the platform i.e. 90 seconds.

Candidates that forgot the extra 1.3 m but otherwise completed the calculation correctly scored 1 mark out of the 2 available. No other distances were given credit.

In part (b) (ii), there were lots of very sensible answers, many of which gained credit.

Question 20 (a)

20 (a) A sealed container contains *n* moles of an ideal gas. The gas has pressure *p*, absolute temperature *T* and occupies volume *V*.

The mass of one mole of the gas is *M*.

Use an ideal gas equation to show that the density ρ of the gas is given by the expression $\rho = \frac{pM}{RT}$.

Successful candidates correctly identified the starting point for this question as the ideal gas equation, $pV = nRT$.

Many candidates took the approach that $n = 1$ which was not sufficient. A more sufficient proof used the idea that the total mass of the gas was $n \times M$, allowing cancelling of the *n* in the ideal gas equation.

Question 20 (b)

(b) An airship has a cabin suspended underneath a gasbag inflated with helium.

The airship is floating above the ground and is stationary.

The volume of the gasbag is 12 000 m^3.
The temperature of the helium and the surrounding air is 20 °C.
Atmospheric pressure is 1.0×10^5 Pa.
The molar mass of air is 0.029 kg mol^{-1}.
The volume of the cabin is negligible compared to the volume of the gasbag.

(i) Show that the density of air under the conditions described is about 1.2 kg m^{-3}.

[1]

(ii) Calculate the weight of air displaced by the airship.

weight of air .... N **[2]**

(iii) Explain why the weight of air displaced by the airship has the same magnitude as the weight of the airship and its contents.

....

....

.... **[2]**

(iv) The pressure of the helium in the gasbag is maintained at a value only slightly greater than atmospheric pressure.
Suggest why a larger pressure is not used.

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.... **[2]**

The vast majority of candidates correctly substituted values into the given formula, also remembering to convert the temperature from celsius into kelvin. Good practice for "show that" questions is to calculate the quantity required to at least one more significant figure in the question. In this example, that would mean evaluating the density to 1.19 kg m^{-3}.

In part (b) (ii), finding the weight was a matter of finding the mass and then finding the weight, all by using data in the question.

Part (b) (iii) required understanding of Archimedes' principle, rather than merely referring to it. Most candidates successfully related the principle to this context, writing about the upthrust being equal to the weight of fluid or air displaced by the gasbag. This is *always* true, regardless of the other forces that may be in play. References to displacement of water at this point were rejected. Fewer candidates completed the explanation by mentioning that the upthrust must be equal to the weight of the gas bag because we know that the gas bag is in equilibrium.

Most candidates scored a mark in part (b) (iv) because they referred to some sort of structural failure if the pressure increased. Others delved a bit deeper, correctly stating that an increase in mass without an increase in volume (and hence upthrust) would cause the gas bag to sink.

Misconception

Some candidates confused the ideas of mass and weight. Remember that weight = mass × gravitational field strength.

Misconception

Some candidates suggested that an increase in pressure alone would cause a change in temperature in this question, using the ideal gas equation as supporting evidence. Here, the pressure change has been caused by an increase in the number of moles of gas. As previously mentioned, candidates should take care to think about what is constant in such relationships and what is not.

Question 20 (c)

(c) The airship engine drives a fan which moves 7.8 kg of air per second at a relative speed of 45 m s^{-1}, so the airship starts to move.

All other conditions given in **(b)** remain the same.

Calculate the thrust that the engine produces.

thrust .... N **[2]**

Question 20 (d)

(d) The airship has a higher maximum speed at high altitudes, but also produces less thrust from the engine.

Explain these observations.

....

....

....

....

.... **[2]**

Question 20 parts (c) and (d) group well here. Part (c) is similar in nature to previous questions about rate of change of momentum. We rejected the use of the idea *F=ma* as it is wrong physics, even though the numerical value is the same.

The idea of rate of momentum transfer carries on in part (d). Most candidates correctly assumed that the density of air at high altitudes is much lower than at low altitudes. Many candidates implied that this meant a reduction in drag, which is correct. Far fewer correctly described the reduction of rate of change of momentum, causing less thrust.

Assessment for learning

Candidates should take care to use technical language. In this question, responses that included ideas of 'less air to push' or 'less mass moved per second' are insufficient at A2 Level.

Question 21 (a)

21 (a) Fig. 21.1 shows a stationary glider of mass *m* on an air track.

The glider has identical springs with force constant *k* attached to each end which are secured to fixed posts.

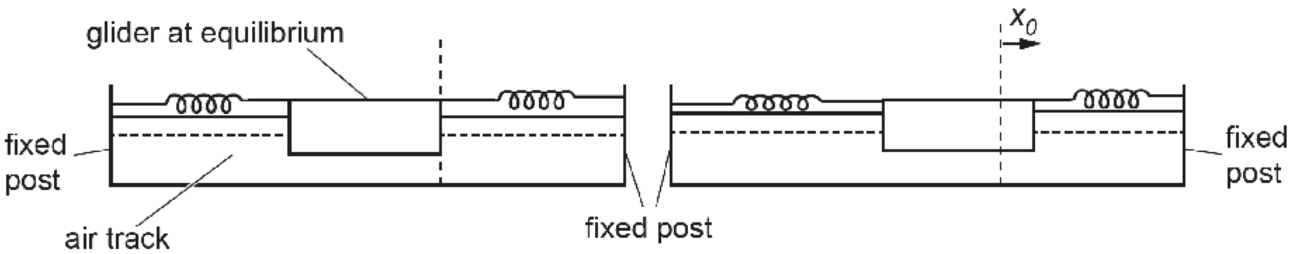
The air track blower is turned on and the glider is displaced a small distance x_0, as seen in **Fig. 21.2**. It is then released.

The glider moves horizontally in simple harmonic motion.

The springs remain in tension throughout the motion.

The time taken for 20 complete oscillations is measured, and the period *T* calculated.

Fig. 21.1 **Fig. 21.2**



The relationship between the period *T*, the mass of the glider *m* and the force constant *k* is described by the equation

$$T^2 = \frac{2\pi^2 m}{k}.$$

(i) Show that the equation above is homogeneous by reducing the equation to SI base units.

[2]

(ii) Explain why the magnitude of the resultant force F on the glider is given by $F = 2kx$ where x is the displacement at any time.

....

....

....

.... **[2]**

Many candidates successfully derived or remembered how to express the newton in SI base units. From there, working out the base units for the spring constant and cancelling kilograms proved straightforward for many.

Question 21 (a) (ii) is considerably more challenging. The two springs are not in series nor are they in parallel. When there is a displacement x one spring is extended by an *extra* amount x i.e. an extension of $(e + x)$ and the other is extended by a reduced amount x *i.e.* an extension of $(e – x)$ where e is the equilibrium extension. This meant that the resultant force was $k(e + x) – k(e – x)$, which is clearly $2kx$.

Neither spring goes into compression, although we condoned candidates who suggested that a reduction in extension meant the same as a compression.

Question 21 (a) (iii)

(iii) State and explain the effect, if any, of increasing the initial displacement on the period of the subsequent motion.

....

.... **[2]**

A reasonably large proportion of candidates did not link the idea of initial displacement to the amplitude of this motion. Those that did often scored both marks as they also recalled that SHM is isochronous.

Assessment for learning

Merely repeating the words in the question, in this case 'the initial displacement' instead of 'amplitude', is unlikely to give access to full marks. Think about which piece or pieces of technical language on the specification are the likely target of each question.

Question 21 (b) (i)

(b) Masses are added to the glider, and the measurement of $20T$ repeated.

The results table is below.

m / kg	$20T$ / s	T	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

(i) Describe **two** different errors in the table.

1 ....

....

2 ....

....

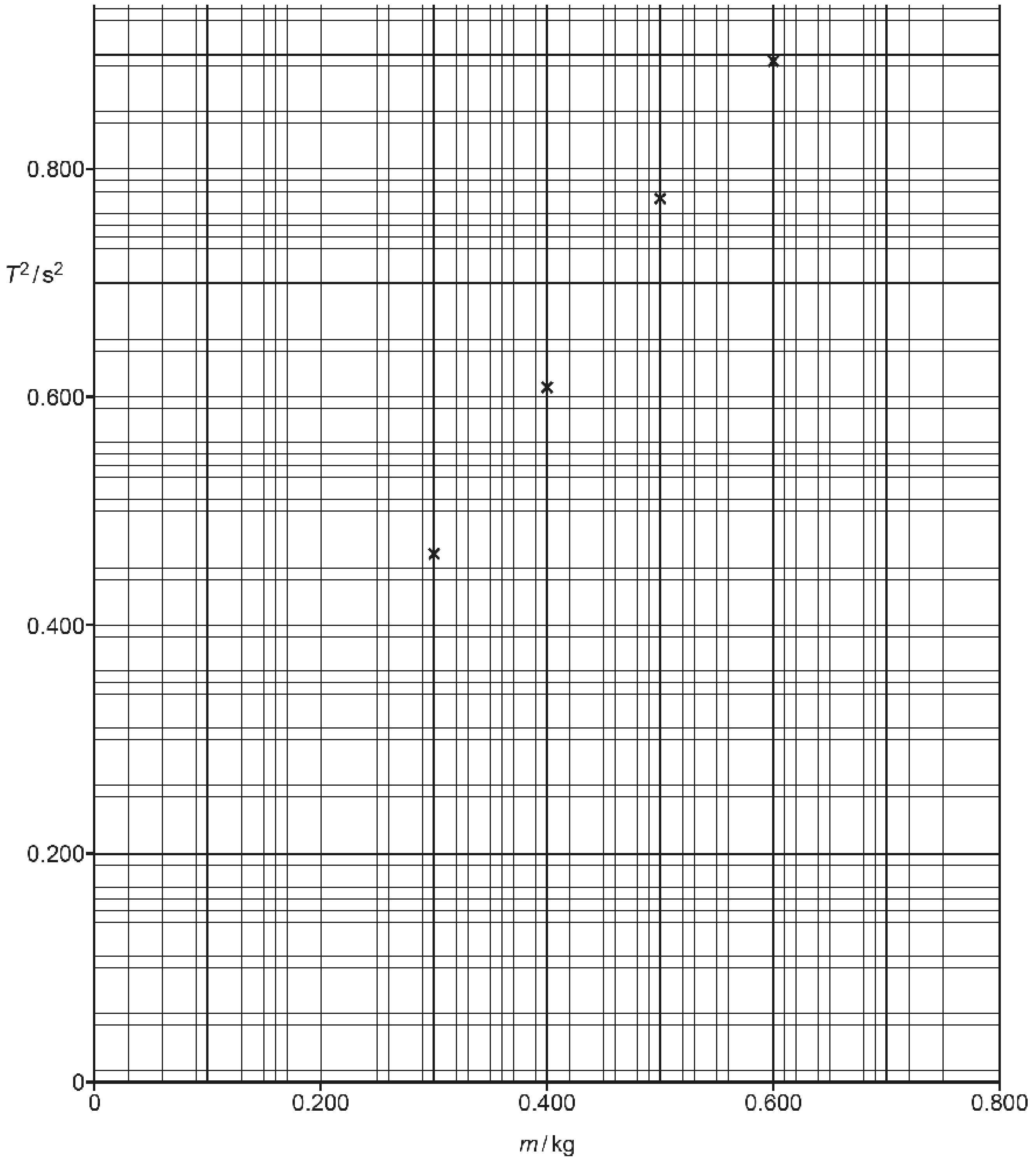
[2]

Most candidates spotted the two different errors namely the lack of units for both T and T^2 and the inconsistent presentation of the digits in the data.

Assessment for learning

The Practical Skills handbook has a section dedicated to the treatment of data in tables and how to get the number of significant figures (or decimal places) correct, even if there is a logarithmic column.

m / kg	$20T$ / s	T	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1



(iii) Use the graph to determine the value of k.

k = ... N m^{-1} **[3]**

Almost all candidates correctly plotted the data point at (0.200, 0.372). Most candidates constructed an acceptable line of best fit with a minority insisting that the best fit line should go through the origin.

Best fit lines are judged on two criteria: the number of points above and below the proposed line and a fair distribution of points away from the line. Consider the line that starts at the origin and has three points above and below it. The first and last points are some distance away from the line and the points get progressively closer towards the middle. This cannot happen with the best fit line.

Most candidates used the relationship correctly, recognising that the gradient = $2\pi^2/k$. Nearly all candidates correctly calculated the gradient, going on to evaluate k. Gradients from incorrect best fit lines were acceptable under error carried forward rules for all 3 marks. A minority of candidates misread their graphs or made algebraic errors.

Question 21 (c)

(c) When the initial displacement is increased, one spring increases its extension while the extension of the other spring decreases.

Explain why the **maximum** kinetic energy of the motion increases.

....

....

....

....

....

.... **[4]**

The language around energy and energy transfers is challenging and this question was pitched as a high demand question. Once more, the technical language needed to be relatively accurate for marks to be given.

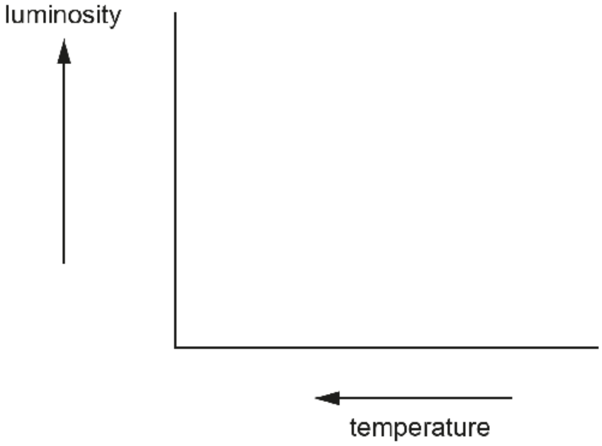
As soon as the glider is displaced, the total elastic potential energy (EPE) is increased. The spring that is longer than at equilibrium stores more energy than before and the spring that is shorter than at equilibrium stores less. Since the amount of EPE is given by $\frac{1}{2}kx^2$, the increase in EPE in the longer spring is larger than the decrease in EPE for the shorter spring. A few candidates attempted to prove this algebraically which was not required. Finally, the EPE at equilibrium position is not zero but a minimum. This is why the maximum KE occurs at this point.

Some candidates attempted the slightly more accessible route of comparing v_{max} with the amplitude yet did not mention that the angular velocity was the same, although there was still some credit available.

Question 22*

22* A star has a mass similar to that of the Sun.

Describe how the position of this star on a Hertzsprung-Russell (H-R) diagram changes as it evolves.

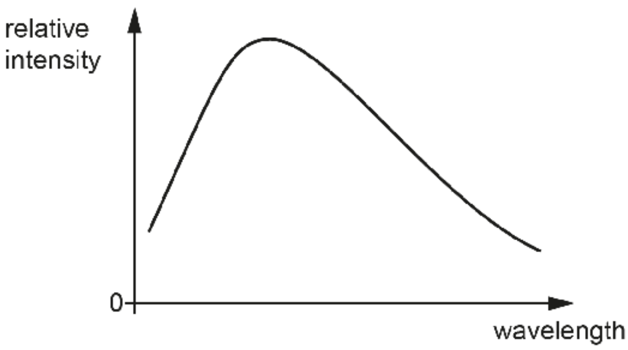


of a star.

of the

[6]

Fig. 22.2



....

....

....

....

Most Level of Response (LoR) questions have multiple parts to them. The first task the candidates are asked is to describe the life of a star similar to the Sun with the added complexity of showing or describing how that affects the star's position on the H-R diagram. Many candidates enjoyed considerable success here.

Fig 22.2 proved more challenging to interpret. As there are no scales on the axes, it is difficult to say what colour this star is, however λ_{max} is relatively low, which points in the direction of early-mid-life (yellow or yellow white). Candidates rightly suggested that Wien's law was applicable and that as the star grew older and expanded into a red giant, the curve's peak would move to the right.

The most challenging aspect of this question is suggesting what limitations this approach has. The lack of scales has already been mentioned. The colour alone cannot uniquely define a star's position on the H-R diagram and thus the stage of life of the star. The graph only gives a relative intensity, which means that the total output of the star, or its luminosity cannot be measured.

Exemplar 3

Fig. 22.1

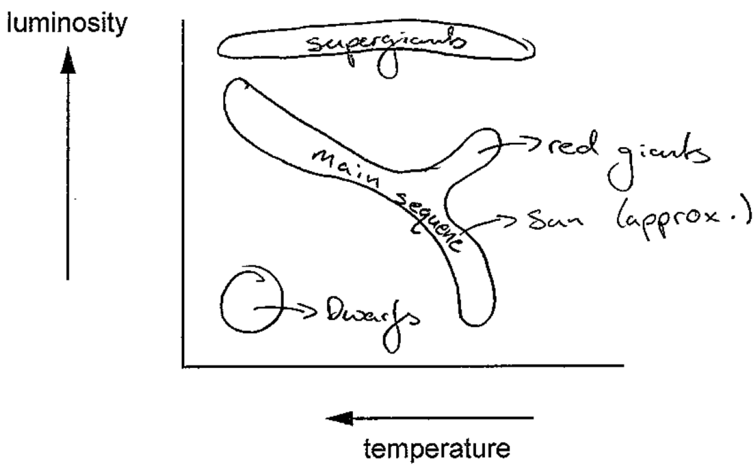
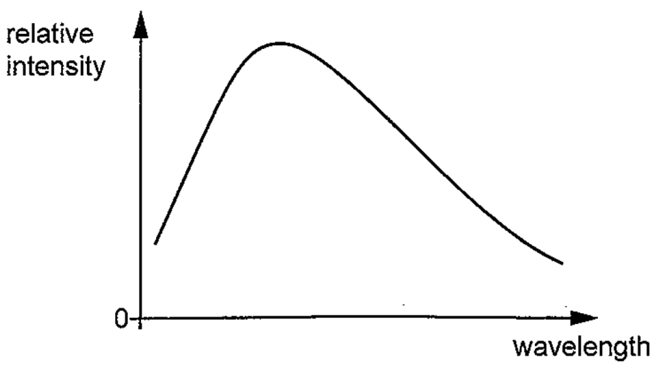


Fig. 22.2



When the star begins fusing, becoming a star from ~~the~~ a protostar in the nebula cloud it will be in the bottom right of the diagram and progress to around the position of the sun as it will be

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relatively low temperature and luminosity. Once it has fused all of its hydrogen, the unfusing core will collapse and the outer layers will expand and cool forming a red giant due to the radiation pressure of the fusing nuclei caused by the shockwaves in the collapse. The star won't get any hotter but surface area and ∴ luminosity will increase, shifting it's position up and right slightly to the red giant section. The outer layers drift off as planetary nebula into space leaving a blue dwarf which will cool to a black dwarf.

Additional space if required

The core will collapse until electron degeneracy pressure matches gravitational collapse. It's surface area is much smaller now ∴ luminosity is low but temperature is high due to gravitational collapse so it shifts to the bottom left of the diagram where white dwarves show.

Wein's displacement law can be used to calculate the temperature of a star ($\lambda \propto 1/T$) which can then be used to locate its "x-coordinate" on the HR diagram. However we don't know the star's surface area so luminosity is unknown and so it can be hard to tell apart a white dwarf or high luminosity main sequence star for example as they are the same temperature.

This candidate described the life cycle of sun-like stars in great depth, completed an excellent HR diagram and in the text described the path of the star on the H-R diagram throughout its lifetime. The references in the last paragraph are what makes this response worthy of a Level 3. The candidate has answered all aspects of the question, explaining both Wien's law and how the luminosity (and hence position on the H-R diagram) is impossible from the data presented.

Question 23 (a)

23 The Hipparcos space telescope used stellar parallax with a precision of 9.7×10^{-4} arcseconds to determine the distance to stars.

One of the stars studied was Polaris A. Data about this star is in the table below.

Parallax angle	7.5×10^{-3} arcseconds
Radius	2.1×10^{10} m
Mass	1.1×10^{31} kg
Surface temperature	6000 K
Temperature of the atmosphere of the star	4.0×10^{6} K

(a) (i) Estimate the maximum stellar distance in parsecs that could be measured using Hipparcos.

maximum stellar distance = ...pc **[1]**

(ii) Calculate the percentage uncertainty in the calculated value of the distance to Polaris A.

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

The maximum stellar distance is given by the smallest parallax Hipparcos can measure, i.e. 9.7×10^{-4} arcsec. The distance corresponding to this parallax is $1/9.7 \times 10^{-4}$ = 1030 pc.

To find the percentage uncertainty in the distance, candidates needed to divide the smallest detectable change in the parallax by the parallax itself. This is equivalent to the percentage uncertainty in the distance because of the reciprocal relationship of distance with parallax.

Many candidates correctly determined both quantities. A minority of candidates confused the two similar sounding quantities.

Question 23 (b) (i)

(b) A continuous stream of particles called a solar wind flows from the surface of the star into the surrounding space.

These particles include helium nuclei of mass 6.6×10^{-27} kg.

Assume that the atmosphere is modelled as an ideal gas.

(i) Show that the typical kinetic energy of a helium nucleus in the atmosphere is about 10^{-16} J.

[2]

Question 23 (b) (ii)

(ii) The gravitational potential energy of a helium nucleus in the outer layer of the star is -2.3×10^{-16} J.

Calculate the gravitational potential energy *U* at the maximum distance from the star that a helium nucleus could reach.

U = ... J **[1]**

Question 23 (b) (iii)

(iii) Calculate the distance from the centre of the star reached by this helium nucleus.

distance = ... m **[3]**

Question 23 (b) (iv)

(iv) Explain why the star has a solar wind that reaches a much greater distance from the star than found in **(iii)**.

....

.... **[1]**

Candidates answered Question 23 (b) (i) well, provided that they used the correct temperature i.e. that of the stellar atmosphere and not the surface temperature.

The helium nucleus in parts (b) (ii) and (b) (iii) has a KE of 10^{-16} J and a GPE of -2.3 × 10^{-16} J. This helium nucleus cannot therefore escape and so the GPE at the further possible point of the helium nucleus must be negative. The GPE at this furthest possible point is where the KE is zero and there has been a gain of 10^{-16} J of GPE, giving the GPE = –1.3 × 10^{-16} J, using the values in the question. Of course, we used the exact value calculated in part (b) (i) instead of 10^{-16} J, giving U = –1.5 × 10^{-16} J as the 'correct' answer.

Question 23 (b) (iv) has several acceptable responses yet the predominant correct candidate answers were that the solar wind particles might be lighter (i.e. hydrogen) or that the Maxwell-Boltzmann distribution of KE values in a gas of particles would mean that some particles would have greater than average KE.

Assessment for learning

Usually in physics calculations, we use the calculator value all the way through the calculation. Any rounding should take place at the very end of the calculation.

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