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Examiners' report

PHYSICS A

H556

For first teaching in 2015

H556/01 Summer 2024 series

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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.

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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.

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 are used in investigations • explained what they would do with data taken in investigations clearly - 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.

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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 1

1 Which row in the table shows two equivalent physical quantities?

A	0 °C	–273.15 K
B	$1\,\mathrm{kg\,m\,s^{-1}}$	1000 N s
C	10 kW	10 000 N m
D	1.0 mPa	$0.0010\,\mathrm{N\,m^{-2}}$

Your answer ☐ **[1]**

Option C can be eliminated here because N m is equivalent to the joule, which is not equivalent to kW, the unit of power.

Option A cannot be correct as it has a negative absolute temperature.

Option B cannot be correct - the units are equivalent however $1\,\mathrm{kg\,m\,s^{-1}}$ and 1 N s are equivalent.

Question 2

2 What are the SI base units of the Boltzmann constant *k*?

A $\mathrm{J\,K^{-1}}$

B $\mathrm{kg\,m\,s^{-2}\,K^{-1}}$

C $\mathrm{kg\,m^{2}\,s^{-2}\,K^{-1}}$

D $\mathrm{N\,m\,K^{-1}}$

Your answer ☐ **[1]**

Neither option A nor option D can be correct since they contain units that are not base units.

Option B cannot be correct as $\mathrm{kg\,m\,s^{-2}}$ is equivalent to the newton, not the joule.

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Question 3

3 A rubber bung is attached to a string. The bung is whirled around in a horizontal circle of radius *r*. The rotational period of the bung is *T*. The tension in the string is kept constant as the bung is whirled around at different speeds.

Which relationship is correct for this whirling bung?

A $T \propto r$

B $T^2 \propto r$

C $T \propto r^2$

D $T \propto \sqrt{r}$

Your answer ☐ **[1]**

Many candidates used their knowledge of circular motion to select either option B or option D, both of which were acceptable, being mathematically equivalent.

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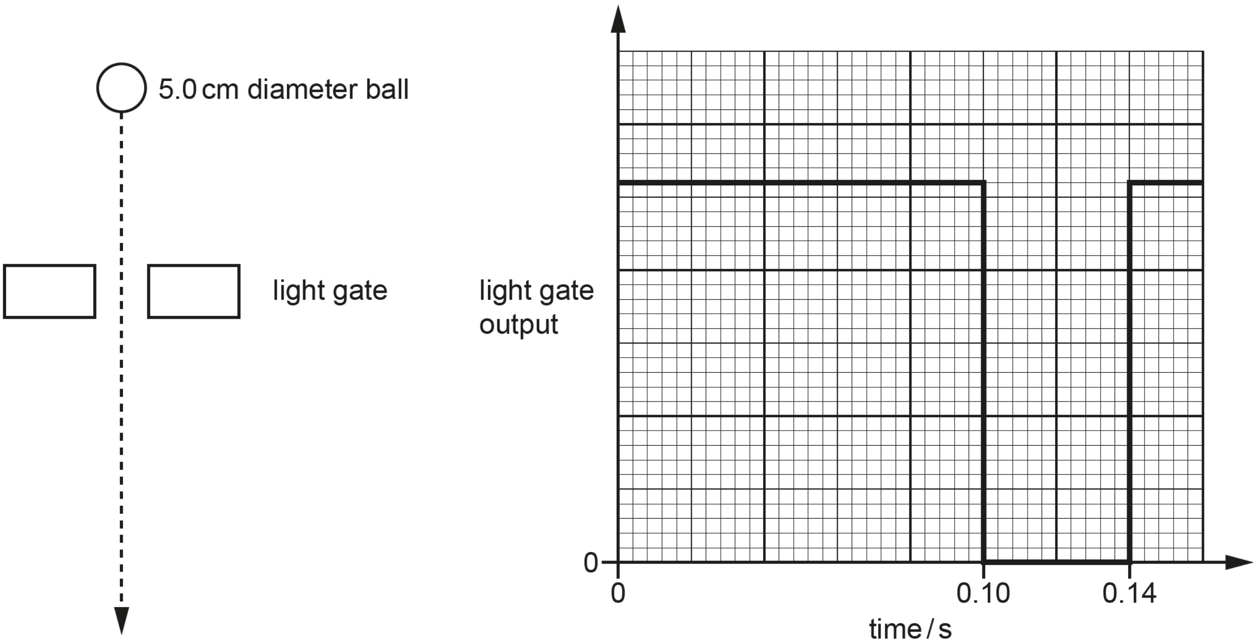
Question 4

4 To determine the acceleration of free fall *g*, a ball is dropped from rest from a point vertically above a light gate.

The ball has a diameter of 5.0 cm. It is dropped at time $t = 0$.

The light gate output shows that the ball passes through the gate between times $t = 0.10$ s and $t = 0.14$ s.

The graph shows the output from the light gate.



Air resistance has negligible effect on the motion of the ball.

What is the value of *g* in $m\,s^{-2}$ from these measurements?

A 8.93

B 9.81

C 10.4

D 12.5

Your answer [ ] **[1]**

This question boils down to what acceleration is required for a displacement of 0.05 m between t = 0.10 s and 0.14 s.

i.e. 0.05 = ½ a (0.14)2 - ½ a (0.10)2 from which the acceleration can be calculated.

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Question 5

5 A block of wood is floating in calm water.

The density of the wood is $700\,kg\,m^{-3}$. The density of water is $1000\,kg\,m^{-3}$.

What percentage of the volume of the block is **above** the waterline?

A 30

B 50

C 70

D 89

Your answer ☐ **[1]**

For the block to float, its weight (700 x V x g) must equal the weight of water displaced (1000 x k x V x g) where k is the fraction of the block under water. Equating these two expressions gives k as 0.7.

The question, however, asks for the percentage of the block **above** the waterline, which is clearly 0.3, making A the correct answer.

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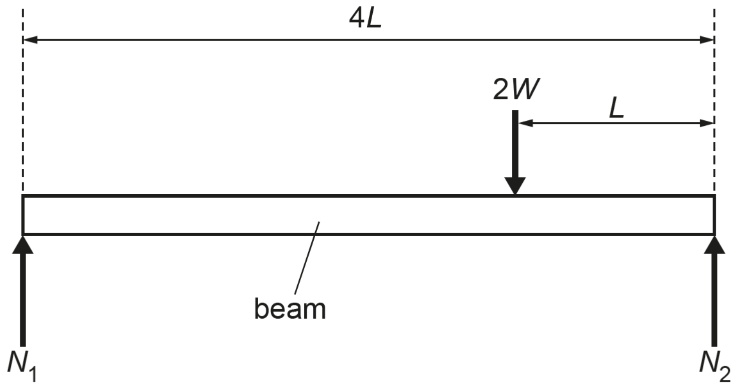
Question 6

6 A horizontal uniform beam of length $4L$ and weight W is supported at both ends.

An object weighing $2W$ is placed on the beam at a distance L from one end.



What are the magnitudes of the normal reactions N_1 and N_2 on the supports at the ends of the beam?

A $N_1 = 0.5W$, $N_2 = 1.5W$

B $N_1 = W$, $N_2 = 2W$

C $N_1 = 1.5W$, $N_2 = 1.5W$

D $N_1 = 2W$, $N_2 = W$

Your answer [ ] **[1]**

This question was made more challenging by not including the weight of the beam on the diagram. The correct approach is to take moments about the left hand end of the beam.

Omitting the weight of the beam gives N1 = 0.5W and N2 = 1.5 W.

When the weight of the beam is included, (2L x W) + (3L x 2W) = (4L x N2), giving N2 = 2 W and N1 = 2 W, i.e. option B.

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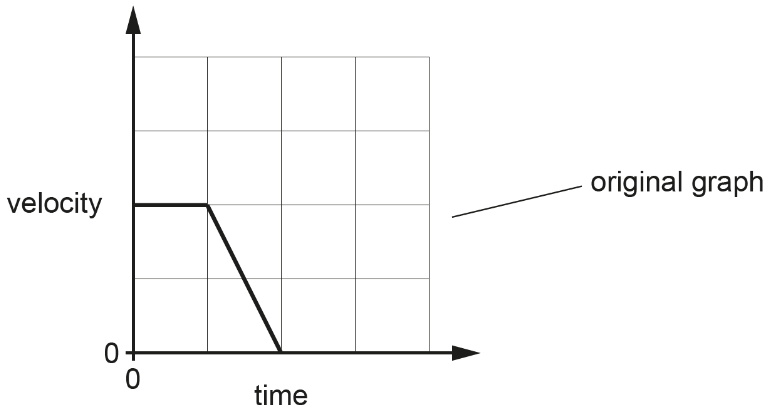
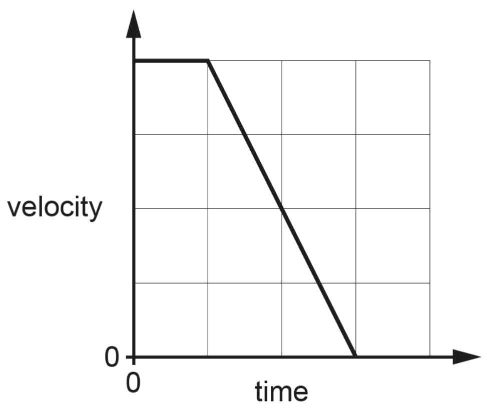
Question 7

7 The graph shows a velocity-time graph for a vehicle. At time $t = 0$ the driver observes an obstruction in the road. A short time later the brakes are applied, and the vehicle stops. The braking force remains constant.

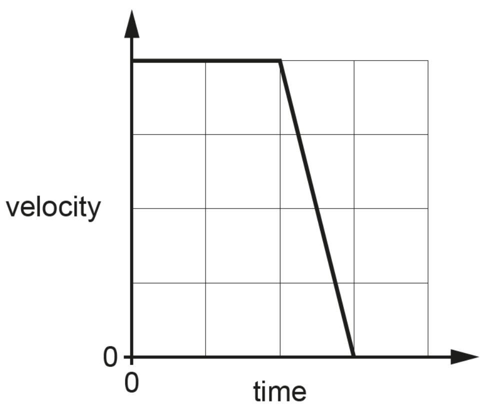


The situation is repeated. This time the vehicle starts with twice the original velocity. All other variables remain the same.

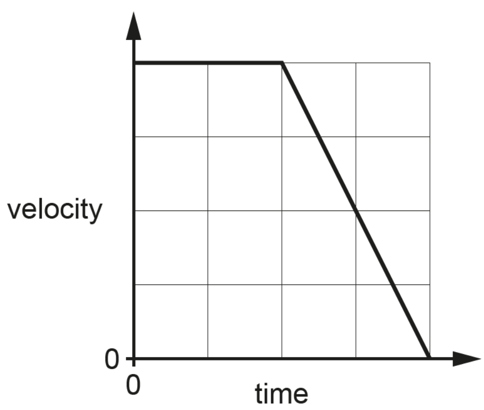
Which diagram shows the correct velocity-time graph for this new situation? The same scales are used on all graphs.



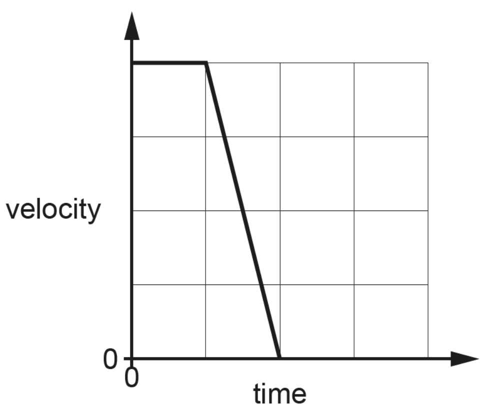
A



B



C



D

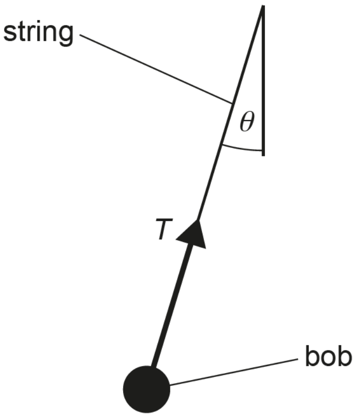
Your answer [ ] **[1]**

With all variables the same apart from the initial speed, there should only be one change to the graph, i.e. the initial speed. The gradient of the second phase should be the same, as the mass and braking force are the same. This gives option A.

Question 8

8 The bob of a pendulum is displaced slightly so that the string forms a small angle $\theta < 10°$ with the vertical.

The tension in the string is *T*. The small angle approximation applies.



Which of the following pairs of quantities would give approximately, within 2 significant figures, the same value for the horizontal component of *T*?

1 $T\cos\theta$ and $T\sin\theta$

2 $T\cos\theta$ and $T\tan\theta$

3 $T\sin\theta$ and $T\tan\theta$

A 1 only

B 1 and 3

C 3 only

D 2 and 3

Your answer [ ] **[1]**

For small angles, sinθ and tanθ are relatively close to each other and small. cosθ, however, is close to 1, which eliminates options 1 and 2. The only correct pair is option 3, making C the correct answer.

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Question 9

9 A mass suspended from a spring is pulled down 0.05 m from the equilibrium point and released.

It oscillates in simple harmonic motion. The frequency of the motion is 2 Hz.

At time $t = 0$ the mass passes through the equilibrium point.

What is the displacement in metres from the equilibrium point at time t?

A $0.05 \cos 2t$

B $0.05 \cos 4\pi t$

C $0.05 \sin 2t$

D $0.05 \sin 4\pi t$

Your answer **[1]**

Many candidates missed the third line of the question which states that the mass passes through the equilibrium point when t=0. This would indicate the correct function here is sine, rather than cosine. The argument of the function here (the expression inside the brackets) must be omega-t or 2πft. f here is 2 Hz, so the correct expression is 4πt.

Question 10

10 The natural frequency of an oscillator vibrating in air is 20 Hz.

Which statement is correct about this oscillator?

A The natural period of the vibrating oscillator is 5.0 ms.

B The oscillator can be forced to vibrate at maximum amplitude at a frequency of about 20 Hz.

C The oscillator can be made to resonate at a frequency of about 40 Hz.

D The period of the freely vibrating oscillator gets smaller as its amplitude decreases.

Your answer **[1]**

Option D is plainly false. Option A here is wrong by a factor of 10, as the correct period is 50 ms.

Option C applies to stationary waves not in forced oscillations as in this case.

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Question 11

11 A car drives over a bridge at speed v. The path of the car is part of a vertical circle of radius r. The mass of the driver is m.

At the top of the bridge the driver of the car experiences apparent weightlessness and no normal contact force from the car seat.

The acceleration of free fall is g.

Which statement is correct?

A $mg = 0$

B $v \geqslant gr$

C $v^2 \geqslant gr$

D $mv^2 \geqslant gr$

Your answer ☐ **[1]**

The condition for circular motion is that the centripetal force is equal to the resultant force. In this case, the resultant force is the weight - normal contact force so $W - R = mv^2/r$.

The person leaves the seat when $R \leq 0$. When rearranged with $W = mg$ gives the correct answer C.

Question 12

12 An object is released from rest and oscillates with simple harmonic motion. The maximum kinetic energy is U.

The object is stopped and the process is repeated with the initial displacement doubled.

What is the new maximum kinetic energy?

A U

B $1.4U$

C $2U$

D $4U$

Your answer ☐ **[1]**

When the initial displacement is doubled, then the amplitude and hence maximum speed is also doubled.

If the maximum speed is doubles, the maximum KE is quadrupled, since $KE = ½mv^2$.

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Question 13

13 An object of mass 1.0 kg is moving in a straight line at velocity 10 m s^{-1}.

It collides with an identical object also travelling at 10 m s^{-1} in a straight line. Their initial velocities are perpendicular.

The two objects stick together.

What is the magnitude in m s^{-1} of the new combined velocity?

A 7.1

B 10

C 14

D 20

Your answer **[1]**

This is a conservation of momentum question. The momentum of each object is 10 kg m s^{-1}. The combined momentum has two components at right angles to each other of 10 kg ms-1. The magnitude of this momentum is √ (200). To find the speed, divide this by 2.0 kg, giving 7.1 m s^{-1}, so the answer is A.

Question 14

14 At the surface of a planet with radius *r* the magnitude of the gravitational field strength is *g*.

What is the escape velocity from the surface of the planet?

A $\sqrt{rg}$

B $\sqrt{2g}$

C $\sqrt{2rg}$

D $2rg$

Your answer **[1]**

By considering the GPE at the planet's surface of -GMm / r and the KE of ½ m v^2, the condition for 'escape' is that the total energy is zero at infinity. This gives the condition GMm / r = ½ mv^2. The gravitational field strength at the surface of the planet is GMm / r^2 i.e. gr, giving gr = ½ mv^2. When rearranged this gives answer C.

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Question 15

15 Stars rotate around the centre of their galaxy.

Observations suggest that the stars at the edges of galaxies are moving at much higher velocities than expected.

What is the name given to the current explanation for these observations?

A Chandrasekhar limit

B Dark matter

C The Cosmological principle

D Wien's displacement law

Your answer [ ] **[1]**

The Chandrasekhar limit relates to white dwarf stars and their evolution. Wien's displacement law relates the surface temperature of a star and λ_{max}. The Cosmological principle has nothing to do with stars' velocity in a galaxy, hence the correct answer is B.

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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. Candidates should look through the entire question as parts often flow into each other and are designed to scaffold into the harder questions.

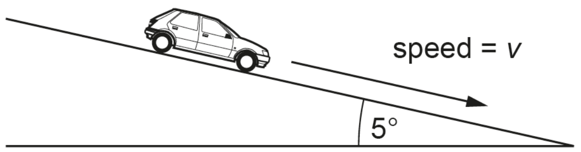
Question 16 (a) (i)

16 A car of weight 9300 N is moving at speed v. The total resistive force, F, acting against the motion of the car is given by the formula

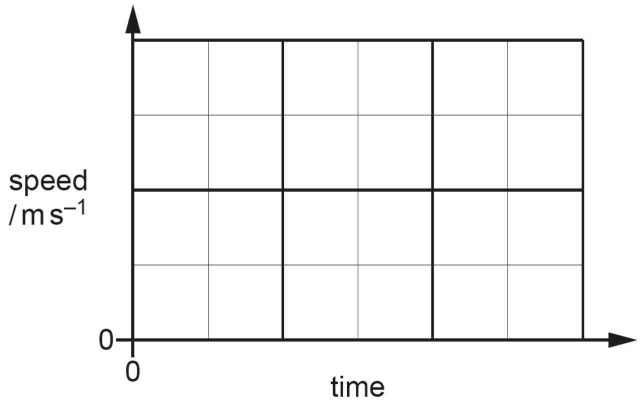
$F = kv^2$

where k is a constant.

(a) The car is allowed to roll from rest down a slope of 5° to the horizontal. The engine of the car is not switched on. The car reaches a maximum speed of $30\,\text{m}\,\text{s}^{-1}$.



(i) Sketch a graph on the axes below to show how the speed of the car changes over time. Add a suitable value to the vertical axis.



[2]

Most candidates used the grid effectively to put a suitable scale on the speed axis. They also communicated that the maximum speed was $30\,\text{m}\,\text{s}^{-1}$. Many candidates also got the shape of the curve correct, which starts with maximum gradient and then flattens out.

Question 16 (a) (ii)

(ii) Explain why the car reaches a maximum speed.

....

....

.... **[2]**

While many candidates appreciated that the car reached a maximum speed because the resultant force was zero, some contradicted this by saying that the weight = drag (as it would be in vertical motion) or something else incorrect. Far fewer candidates stated that the drag increases with speed effectively. Quoting the given expression $F = kv^2$ was deemed insufficient.

Examination Tip

Repeating information given in the question is rarely creditworthy by itself.

Question 16 (a) (iii)

(iii) Show that the value of k in the equation $F = kv^2$ is about 1.

[3]

As this question is a 'show that', all steps were required. Many candidates omitted the rearrangement stage, restricting their maximum score for this item to 1 mark. This approach was consistent throughout the paper for this type of question.

Examination Tip

Make sure that all steps of working are presented in 'show that' questions, especially the step that shows the relevant quantity as the subject of the equation. Always show your evaluation to at least 1 more significant figure than that shown in the question.

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Question 16 (b)

(b) The car is now moving along a straight, level track. The engine of the car delivers a maximum power of 75 kW.

Calculate the maximum speed of the car.

maximum speed of car = ... $m s^{-1}$ **[3]**

The key idea here is that the force from the engine (given by F = P / v) will equal the resistive forces (F = kv^2) when the car is at maximum speed. Candidates could choose which value of k they used here, either k = 1 from the question data or the value of k from the previous item. This gives an acceptable range of speeds as stated in the mark scheme.

Question 16 (c)

(c) Changes are made to the engine of the car so that it can produce double the original maximum power.

Explain why the maximum speed of the modified car is **not** doubled.

....

....

....

.... **[2]**

Even if they couldn't complete the calculation in the previous item, candidates needed to be able to state the idea qualitatively for the first mark. No further calculations were required, except the correct answer that the maximum speed would increase by a factor of cube root (2).

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Question 17 (a)

17
(a) State Newton's second law of motion.

....

.... **[1]**

Most candidates selected the right law of motion to state although a reasonable fraction missed out something vital. Often than was that the idea of resultant force.

Misconception

?

Common misconception that F = ma is Newton's second law, whereas it's a special case.

Question 17 (b) (i)

(b) A model of an aircraft is being tested in a wind tunnel. The model is fixed in position by a support, and air is blown horizontally towards it by fans.

In one second, 35 kg of air moving at $50\,\mathrm{m\,s^{-1}}$ hits the model. After flowing around the model, the airflow is diverted downwards at an angle of 30° to the horizontal. The speed of the diverted airflow remains at $50\,\mathrm{m\,s^{-1}}$.

(i) Calculate the horizontal and vertical components of the velocity of the diverted airflow.

horizontal component of velocity = ... $\mathrm{m\,s^{-1}}$

vertical component of velocity = ... $\mathrm{m\,s^{-1}}$
[2]

Most candidates got this correct. Some scored a single mark for confusing sine and cosine but otherwise completing the calculation correctly.

Examination Tip

Make sure to check whether your calculator should be in degrees or radians mode.

Also, practise which trigonometric function to use. If in doubt, draw a labelled right-angled triangle to help identify the correct function.

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Question 17 (b) (ii)

(ii) Explain how the airflow around the model produces a force on the model.

....

....

.... **[2]**

The key idea here was Newton's third law, with credit for some supporting information.

Question 17 (b) (iii)

(iii) Calculate the **vertical** lift force *F* acting on the model due to the airflow around it.

F = ... N **[3]**

Answers that clearly used F = ma with the acceleration of 25 ms^{-2} were deemed wrong Physics (as in previous series). Error Carried Forward (ECF) was clearly applied here also.

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Question 18 (a) (i)

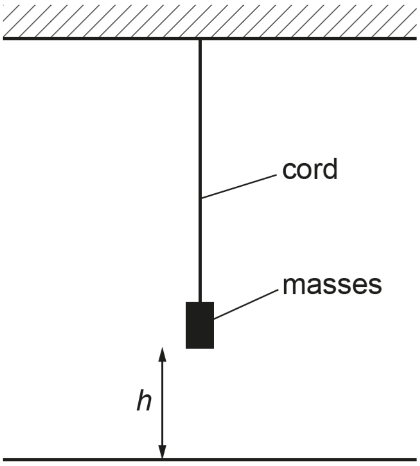
18 Mats made from rubber are often used in laboratories where heavy objects might be dropped.

A rubber cord is tested to determine the material's mechanical characteristics.

(a) The cord is suspended from a ceiling and masses can be attached to the free end.

The apparatus is set up as shown in **Fig. 18.1**.

Fig. 18.1



Masses are added and the height, *h*, of the base of the bottom mass from the floor is measured. The extension of the cord is *x* when the tension in the cord is *F*. After six masses have been added, they are removed one at a time and *h* measured each time.

The table shows the data collected.

***F* / N**	***h* / m**	***x* / m**
0.0	1.80	0.00
1.0	1.60	0.20
2.0	1.56	0.24
3.0	1.51	0.29
4.0	1.45	0.35
5.0	1.35	0.45
6.0	0.81	
5.0	1.13	0.67
4.0	1.37	0.53
3.0	1.30	0.50
2.0	1.34	0.46
1.0	1.45	0.35
0.0	1.75	0.05

(i) Complete the final column of the table. **[1]**

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As stated in the Mark Scheme, it was unclear whether all candidates had seen the erratum. As a result, all candidates were awarded this mark.

Erratum notice

Turn to **page 16** of the **question paper** and look at **question 18(a)**.

Go to the table showing the data collected.

In row 9 of the data, cross out '1.37' and replace with '1.27'.

The row:

4.0	**1.37**	0.53

Should now read:

4.0	**1.27**	0.53

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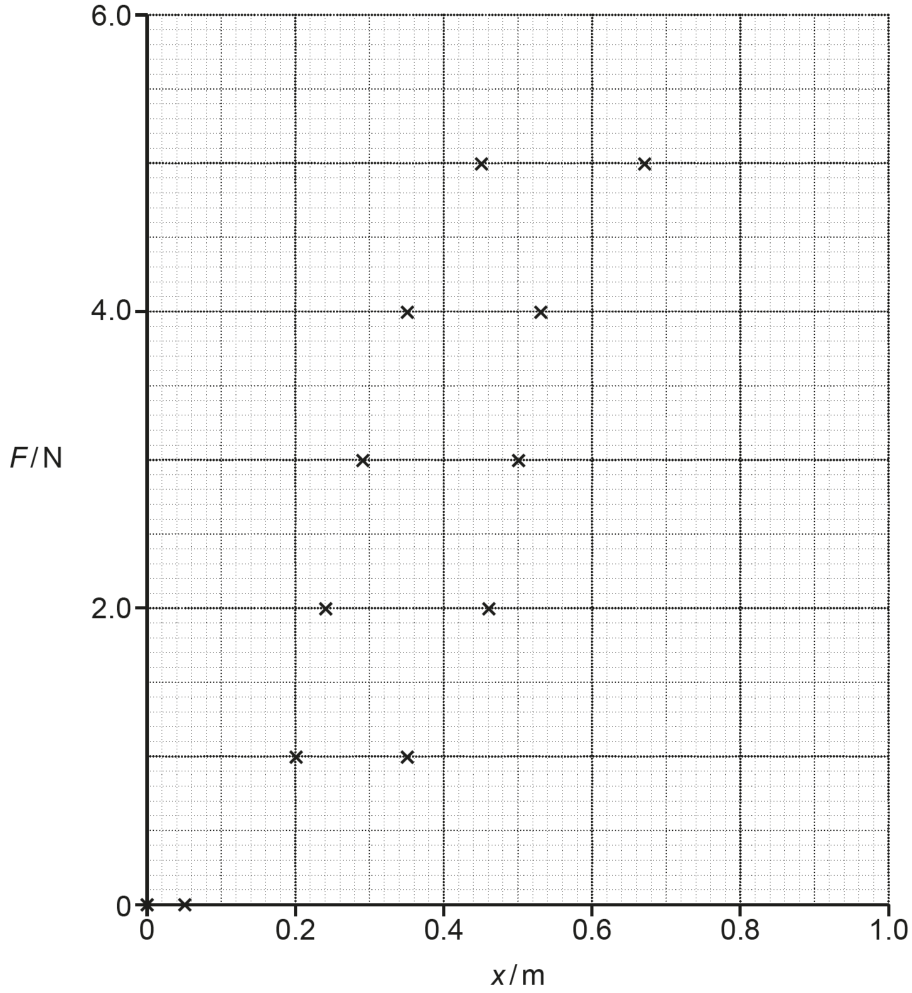
Question 18 (a) (ii)



(ii) Plot the data point for F = 6.0 N on the graph above. The other points have been plotted.

Draw and label **two** curves to show the loading and unloading of the cord. **[3]**

Almost all candidates scored the first mark here, correctly converting the data point they'd calculated in the previous part into graphical form. Candidates drew very good curves, although many lost the final mark for not indicating which curve was which.

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Question 18 (a) (iii)

(iii) Discuss whether Hooke's law can be applied to the cord.

....

.... **[2]**

The best way of answering this sort of question is to link what evidence there is in the question - in this case the graph - to what the candidate knows about Hooke's Law. Here, the lines are clearly not straight, so cannot support an idea that the extension and loading force are directly proportional.

Examination Tip

When answering questions of this nature, a good start is to describe the trend line (or the relevant graphical feature) and then move on to how this either supports or rejects a particular theory or relationship.

Question 18 (a) (iv) (1)

(iv) There is an area between the two curves that you have drawn on the graph.

1. State the **name** of the derived SI unit of this area.

.... **[1]**

Some candidates stated the quantity (energy) or the base units ($kg\,m^2\,s^{-2}$) or did both. The rubric in the mark scheme is clear: only the first answer is acceptable for this sort of question.

Assessment for learning

Teachers and candidates should be aware of not only the marking points in a mark scheme but also the large amount of guidance given to markers in the preceding pages of that mark scheme.

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Question 18 (a) (iv) (2)

2. Explain the significance of this area to the planned use of the rubber.

....

....

.... **[2]**

The scientific language is subtle here. The area between the two curves is not the work done (which is the area underneath any particular F-x graph) but it is the increase in the object's internal energy typically as thermal energy,

Similarly, the language needed to be suitably scientific for the second marking point, using A Level terminology.

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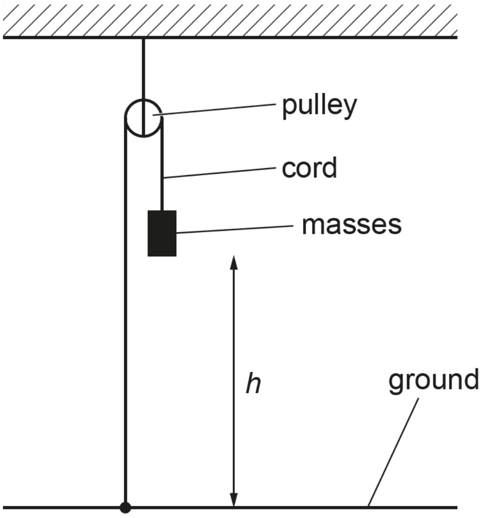
Question 18 (b)

(b) An alternative arrangement for the experiment is to use a pulley as shown in **Fig. 18.2**.

The arrangement makes it possible to cover a larger range of extensions.

Fig. 18.2



The cord is fixed to the ground.

Describe **two** factors that would affect the accuracy of the results obtained using this alternative arrangement.

1 ....

....

2 ....

.... **[2]**

The Mark Scheme lays out what was acceptable here. Just as in the previous item, credit would be given for suitably sufficient A Level Physics language.

Examination Tip

Practise using scientific terms and quantities learnt over the course to explain as many different phenomena as possible. This is equally applicable for theoretical or for experimental ideas.

Question 19*

19* Describe how to determine the wavelength λ of a monochromatic laser pointer using a diffraction grating.

As part of your answer, explain how to

- analyse the measurements collected using a graphical method.
- improve the accuracy of the measurements taken.

You are given the number of lines per mm for the diffraction grating.

[6]

This experiment is one of the suggested practicals to complete in the Practical Endorsement. The relevant formula was not on the question paper itself, however it is in the relationships and formulae booklet in the appropriate place.

Candidates that described the two-slit interference experiment could not, therefore, be awarded any more than Level 1 (2 marks).

As explained in previous series, approaches required a graphical element to find the wavelength (amongst other aspects) in order to achieve Level 2 (4 marks).

Finally, a key aspect that distinguished between candidates was their ability to describe and explain the necessary precautions for high quality data. A selection of these is listed in the Mark Scheme.

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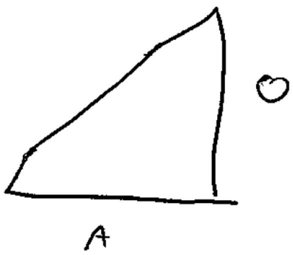
Exemplar 1



$d \sin\theta = n\lambda$

$n = \left(\frac{d}{\lambda}\right) \sin\theta$

$y \quad m \quad x$

using a monochromatic light, focus it towards the diffracting grating, and the order of maxima will be shown on the screen. d the distance between slits of grating can be found using 1/lines per m ensuring that to convert to lines per metre. Using a ruler, measure the distance between grating and screen, and measure the distance between the adjacent maximas, repeated measure to ensure the true value. Using trigonometry, the angle can be found $\theta = \tan^{-1}\left(\frac{a}{x}\right)$. Ensure the room is dark with limited light coming in, and find the angle for each n. Record in a table. Plot a graph of n against sin θ and draw a line of best fit. The gradient

Additional space if required

will be equal to $\frac{d}{\lambda}$ as shown above. Rearranged, d/gradient $= \lambda$.

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Exemplar 1 has satisfied all of the criteria for a Level 3 response, 6 marks.

The candidate has described the correct experiment and made it clear how they are going to measure the relevant quantities such as the distance of the maxima away from the centre and the distance to the screen so that they can later calculate theta and hence sin(theta). This already is promising for a Level 3 response.

The candidate has also completed the analysis correctly by using a graphical approach. It is clear what is going to be plotted on which axis and what the gradient of the line of best fit will represent. Finally, it is clear how the wavelength shall be calculated.

The candidate has used trigonometry to calculate theta and has stated that the room should be dark,

All of these factors taken together indicate Level 3 thinking.

Question 20 (a) (i)

20 (a) (i) Define the internal energy of an ideal gas.

....

....

.... **[1]**

This definition did not trouble the vast majority of candidates, although some did forget to mention about particles. References to potential energy were ignored.

Question 20 (a) (ii)

(ii) Use the formulae below to show that the average kinetic energy of a particle of an ideal gas is directly proportional to the absolute temperature of the gas.

$pV = \frac{1}{3}Nm\overline{c^2}$ $\qquad$ $pV = NkT$

[2]

Almost all candidates that responded successfully equated the two expressions here. Many then went on to successfully manipulate the equation to give the familiar relationship given in the Mark Scheme and in the formula sheet.

Question 20 (b) (i)

(b) The velocities of four gas particles at 290 K are given below in m s^{-1}.

310 370 440 550

(i) Show that the root-mean-square (r.m.s.) speed of the sample is about $430\,\text{m s}^{-1}$.

[2]

Most candidates completed this item successfully by squaring each number, adding those four results, dividing that by four and square rooting as shown in the Mark Scheme. Those that did not either made a numerical slip or calculated the simple mean of the four numbers.

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Question 20 (b) (ii)

(ii) Calculate the molar mass of the gas assuming an absolute temperature of 290 K and r.m.s. speed of 430 m s^{-1}.

molar mass = ... kg mol^{-1} **[3]**

This question proved rather more challenging than the 20(a)(ii), even though the formula was included in the formula booklet. The most common error was omitting the 'square' on the mean-squared-speed.

The conversion from the mass of a single particle to the molar mass proved challenging.

Examination Tip

Quantities and units in Physics can be of either or mixed case. In this question, n, N, m and M are all valid quantities and can be muddled easily.

Also, as a check, the mass of a mole of a substance in grams is equal to the relative formula mass, i.e. one mole of iodine-128 has a mass of 128 g or 0.128 kg.

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Question 20 (c) (i)

(c) Spherical filament lamps are manufactured by a process where they are filled with a gas at 290 K and low pressure.

When the filament lamp is switched on, the filament reaches a constant temperature of 2400 K. At this temperature, the pressure inside the filament lamp is 120 kPa.

(i) Explain, in terms of energy transfers, why the temperature of the filament does **not** increase beyond 2400 K. You are **not** expected to refer to the electrical characteristics of the filament lamp.

....

....

....

....

.... **[3]**

Again, the language required to suitably communicate the correct Physics was challenging here. Respones which described gas law physics had missed the point. The principal reasons why the temperature of the filament does not increase above any given temperature is that the energy in = energy out in a given time period. Further marks were for describing the energy process for supplying energy to the filament and the transfer of energy away from the filament.

Examination Tip

Quantities in Physics remain unchanged often because an idea of equilibrium or balancing two sides of an equation (see questions 16(a)(iii) or 16(b) for earlier examples). Explaining the physics of either side of that equation is often creditworthy.

Question 20 (c) (ii)

(ii) Calculate the pressure of the gas within the filament lamp during manufacture.

pressure = ... kPa **[2]**

Most candidates used the directly proportional relationship of pressure to absolute temperature successfully here.

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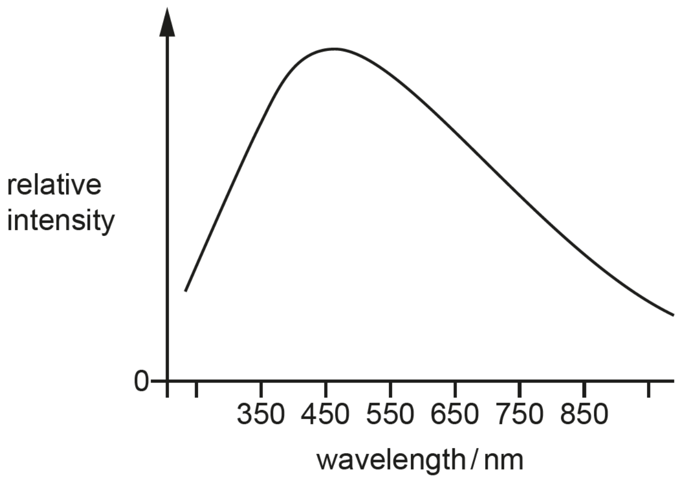
Question 21 (a) (i)

21 This question is about analysing the electromagnetic radiation from the star Nu Persei in the Milky Way galaxy.

Fig. 21.1 shows the relative intensities of different wavelengths of electromagnetic radiation from Nu Persei.

Fig. 21.1



The surface temperature of the Sun is 5800 K and its wavelength at which maximum intensity is emitted is 500 nm.

The luminosity of Nu Persei is 2.3×10^{29} W.

(a)
(i) Use **Fig. 21.1** to show that the surface temperature of Nu Persei is about 6300 K.

[2]

As in previous 'show that' questions, most candidates started this question well by obtaining λ_{max} from the graph and calculating the surface temperature. This was insufficient as a consistent approach to showing working for these questions was applied.

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Question 21 (a) (ii)

(ii) Estimate the radius of Nu Persei.

radius = ... m **[3]**

As long as candidates used the equation for Steffan's Law, they tended to score well on this item. There were some candidates that transcribed the power of 4 incorrect yet had ECF applied to their work to score most of the marks available.

Question 21 (b) (i)

(b) Electromagnetic radiation is collected from Nu Persei by a sensor with an efficiency of 11% and cross-sectional area $1.0 \times 10^{-4}\,m^2$.

The radiant power collected by the sensor is $7.0 \times 10^{-15}\,W$.

(i) Show that the radiant power per unit area arriving at the sensor is about $6 \times 10^{-10}\,W\,m^{-2}$.

[2]

Most candidates successfully manipulated the data given to show that the radiant power per unit as required.

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Question 21 (b) (ii)

(ii) By the time the electromagnetic radiation from Nu Persei reaches Earth, the radiation from Nu Persei is evenly distributed over a spherical area with radius equal to the distance between Nu Persei and Earth.

Calculate the distance of Nu Persei from Earth in light years.

distance = ... light years **[4]**

This is a challenging multi-step question. Essentially it tests understanding of the inverse-square relationship.

Some candidates simply used the formula given on the formula sheet. Others did not, however successfully manipulated the data to use the inverse-square rule and/or finding the intensity of radiation leaving the surface of the star.

Once the candidate arrived at the distance in metres, it was relatively simple to find the distance in light years.

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Question 21 (c)

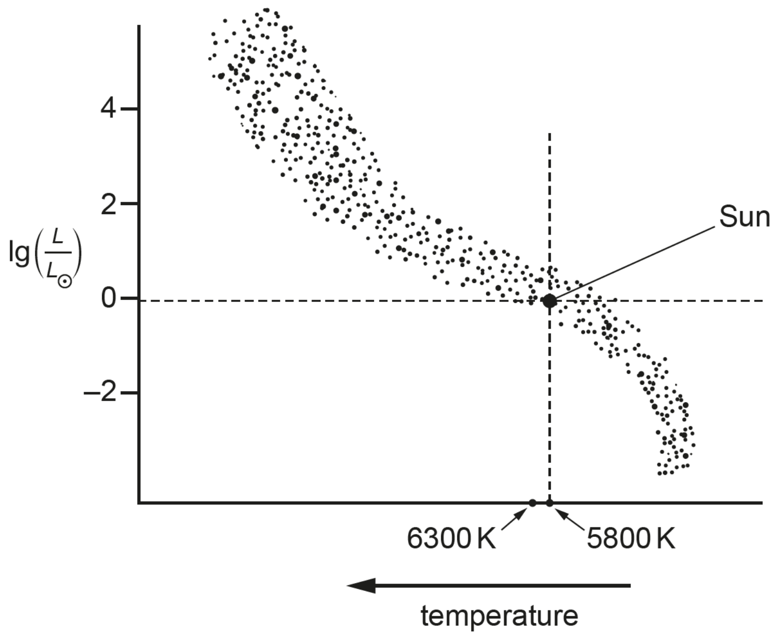
(c) The luminosity of Nu Persei was estimated using the temperature of Nu Persei and the Hertzsprung-Russell (HR) diagram in **Fig. 21.2**. L is the luminosity of a star and $L_{\odot}$ is the luminosity of the Sun.

The temperature data from earlier in this question is repeated in the table below.

Star	**Surface temperature / K**
Sun	5800
Nu Persei	6300

Comment on the uncertainty in your value, calculated in **b(ii)**, of the distance of Nu Persei from Earth. You may write on the diagram as part of your answer.

Fig. 21.2



....

....

....

.... **[3]**

This item also proved very challenging. The key idea here is that there is a range of luminosities (the inherent power of the star) that correspond to a temperature of 6300 K, not least that the star may not be main sequence at all. These ideas are reminiscent of a question in a previous paper.

After those initial ideas, the candidates needed to discuss this more quantitatively by noticing that the range of luminosities was about 10, given that the scale is logarithmic.

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Assessment for learning

There is a lot of Physics relevant to the H-R diagram other than merely the shape of the main sequence and the positions of other classifications of stars. Teachers might consider explaining how the data for the H-R diagram is collected and processed, along with the accompanying uncertainties in those measurements.

Question 22 (a) (i)

22

(a) A satellite in a geostationary orbit around the Earth appears to remain at the same point in the sky when viewed from the ground.

(i) State **one** condition required for an orbit to be geostationary.

....

.... **[1]**

In previous series, candidates needed to explain at least three conditions for a geostationary orbit for complete credit. This item, though, is considerably simpler: most candidates scored a mark here.

There was some confusion about terminology with those candidates that did not score the mark. Often this was muddling up the time of orbit, the time of rotation of the Earth and the time of an orbit of the Earth around the Sun.

Question 22 (a) (ii)

(ii) Calculate the orbital radius of the geostationary satellite. The mass of the Earth is 6.0×10^{24} kg.

orbital radius = ... m **[3]**

Most candidates correctly used the equation representing Kepler's Third Law to find the orbital radius. Common errors included mis-converting or mis-remembering the time for one complete orbit.

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Question 22 (b) (i)

(b) A satellite of mass *m* is in a circular orbit around a planet of mass *M*. The radius of the orbit from the centre of the planet is *r*.

The gravitational potential V_g at a point a distance *r* from the centre of the planet is given by the equation

$V_g = -\frac{GM}{r}$.

(i) By considering the cause of the centripetal force on the satellite, show that the kinetic energy of the satellite is equal to half the magnitude of its gravitational potential energy.

[2]

Many candidates made a good start by equating the formula for gravitational force with the expression for centripetal motion. Others that assumed that *g* of 9.81 $m\,s^{-2}$ did not score any marks.

The simplest way to arrive at the correct expression was to identify GM/r in the gravitational force formula, to rearrange and then multiply both sides by ½. Approximately ½ of all candidates that responded got as far as this gaining both marks.

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Question 22 (b) (ii)

(ii) A tiny satellite of mass 1.0 kg is to be launched from rest from the surface of the Earth into a low Earth orbit. The gravitational potential at any point in this orbit is –56 MJ kg^{-1}.

The value of the gravitational potential at the Earth's surface is –63 MJ kg^{-1}.

Show that the satellite must gain more than 30 MJ of **total** energy to achieve and remain in orbit.

[2]

Many candidates correctly determined how much GPE the satellite needed to gain i.e. 7 MJ in order to reach orbit from -63 MJ to -56 MJ.

To find the KE when in orbit, candidates needed to use the result from the previous part of the question. This explains why the in orbit, the KE required is ½ of 56 MJ i.e. 28 MJ. A small fraction of candidates successfully accomplished this step.

This means the total energy gain is the sum of 28 MJ and 7 MJ i.e. 35 MJ.

Question 22 (c)*

(c)* Large satellites are often launched by rockets from sites near the equator. The rotation of the Earth increases the initial kinetic energy of the rocket and satellite.

A new strategy is to launch using a smaller rocket from a high flying aircraft.

Using the information in **(b)(ii)** and the data below, evaluate the advantages and limitations of this strategy. Use calculations to support your evaluation.

Rotational speed at the equator	460 m s^{-1}

Typical aircraft operating altitude	10,000 m
Aircraft cruise velocity (relative to the ground)	230 m s^{-1}

[6]

Many candidates found this difficult to access. A solely qualitative evaluation was limited to level 1 (2 marks).

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Exemplar 2

The initial kinetic energy - GPE will give the total energy gained by the satellite.
On earth → $\frac{1}{2} \times 1 \times 460^2 = 0.1058$ MJ of kinetic energy
On the aircraft, $\frac{1}{2} \times 1 \times 230^2 = 0.02645$ MJ
However, on the aircraft, the GPE will be higher, and ∴ satellite will need to gain less GPE

$$\frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 1}{r_{earth} + 10000} = \text{GPE advantage.}$$

In conclusion, although the aircraft would slightly reduce energy required for GPE increase, it would reduce initial kinetic energy by a factor of 4, and there would also be energy required to power the aircraft,

In Exemplar 2, the candidate has completed a small number of calculations comparing the KE the two methods would raise. There is also a statement that these differ by a factor of 4 along with an attempt at calculating the GPE advantage by launching from the aircraft rather than from the ground.

Crucially, there is very little mention of limitation and no supporting calculations.

Holistically speaking, therefore, there was not enough evidence to award this candidate Level 3, yet sufficient for a Level 2.

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Exemplar 3

Rotational speed at the equator	$460\,m\,s^{-1}$

Strategy (A)

Typical aircraft operating altitude	10,000 m
Aircraft cruise velocity (relative to the ground)	$230\,m\,s^{-1}$

Strategy (B)

[6]

We need 35 MJ of energy per kg. In strategy A, we start with 460 ms⁻¹, resulting in $\frac{1}{2}(460)^2$ = 105800 J = 0.11 MJ of energy per kg in kinetic energy.

In strategy B, we have ~~kg = ... 6.67×10⁻¹¹ (6×10²⁴) ... and ...~~ an approximate ~~increase~~ increase in GPE of mgh = 9.81 (10 000) = 98100 J ≈ 0.098 MJ per kg ~~assuming the~~ approximating the Earth's gravitational field as uniform. We also have a ~~KE of~~ velocity of 230 ms⁻¹. If we cruise over the equator in direction of rotation ~~as~~ we get a speed of (460 + 230) ms⁻¹

KE = $\frac{1}{2}(460+230)^2$ = 238050 J ≈ 0.24 MJ kg⁻¹ giving us a total energy of about 0.25 MJ per kg, much better than Strategy (A).

However this energy is still ~~is~~ far less than the 30 MJ kg⁻¹ of energy we need to get the ~~satellite~~ satellite in orbit. However the energy gain may be better as the Earth's atmosphere is thinner ~~as there~~ at 10,000 m ~~altitu~~ altitude, so there will have less effect. But still it may not be worth it to get the satellite at 10000 m.

Additional space if required

Firstly the aircraft required will be expensive and specialist and require fuel to get to 10000 m, however it does mean that we don't have to build a rocket ~~here~~ launch facility at the equator (more unstable countries) as we can just fly over the equator and take off there. Overall there the ~~limitation of energy~~

gain by ~~stability it~~ ~~relaxing~~ flying the satellite at the equator are just not significant enough to justify the expensive equipment and design costs; ~~and the extra fuel~~ it's much easier to just add more fuel to the satellite and drop the fuel containers in stages in a grand launch.

Only about 0.83% of total energy required.

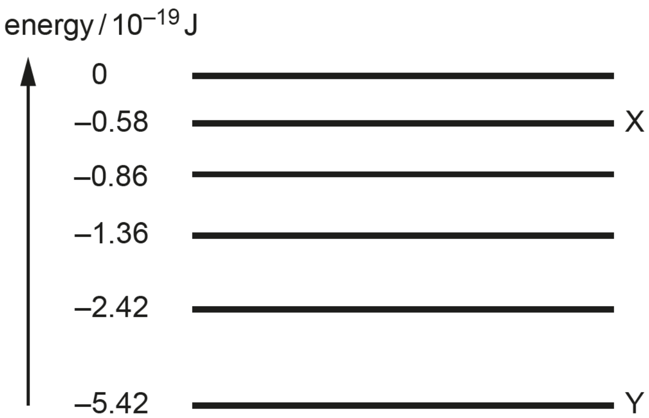
In Exemplar 3, this candidate makes an excellent attempt at every portion of the question. They have taken great effort to make themselves clear with technical language. They have also performed numerous calculations to compare the GPE and KE in the two different scenarios.

A further figure appears right at the bottom of the response. The candidate has correctly calculated the percentage of the overall energy required that is supplied by either method.

In conclusion, the candidate has used their many correct calculations to weigh up evidence effectively in terms of the advantages and limitations.

Question 23 (a)

23 The diagram shows some of the energy levels of the electron in a hydrogen atom.



(a) An electron moves from energy level X to energy level Y.

Show that the wavelength of the photon produced is about 410 nm.

[2]

As with other 'show that' questions, many candidates understood what to do to find their value of the wavelength, without necessarily showing sufficient evidence of formula re-arrangement.

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Question 23 (b) (i)

(b) The light from the stars in a distant galaxy is analysed on the Earth using a diffraction grating.

Dark lines are observed in the spectrum.

An astronomer concludes that the dark line at a wavelength 432 nm corresponds to the electron transition between X and Y.

(i) Explain the origin of the dark lines.

....

....

....

.... **[2]**

Apart from a small number of candidates that confused emission spectra with absorption spectra, it was clear that most candidates recognised that what they needed to do. Technical language skills prevented some otherwise sensible answers from scoring 2 marks.

Question 23 (b) (ii)

(ii) Calculate the recession velocity *v* of the galaxy.

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

Most candidates selected the correct formula in this part. If a candidate responded at all, they were likely to score both marks. A small percentage of candidates used the wrong wavelength for the denominator of the relevant expression. This was marked as 'wrong Physics' (XP) on scripts.

Question 23 (b) (iii)

(iii) State the name of the theory that is supported by evidence from the measurement of the recession velocities of galaxies in the universe.

.... **[1]**

An overwhelming majority of candidates made some reference to either the Big Bang Theory, cosmological expansion or simply 'Hubble's Law'. Some other answers were also given credit as shown in the Mark Scheme although these were very much rarer.

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