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Examiners' report

A LEVEL

PHYSICS A

OCR Level 3 Advanced GCE in Physics A

H556

For first teaching in 2015

H556/01 Summer 2025 series

Version 1

Contents

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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 responses 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 Teach Cambridge.

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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 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 carefully • worked through the multiple-choice questions logically having removed unlikely answers first • remembered definitions of important terms and could reproduce them correctly • performed calculator operations accurately.	• misread the question • did not address all the requirements 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 • showed their thinking in a disorganised way • did not use ideas about how investigative work is performed and reported, including the almost universal need for a relevant graph • made errors with trigonometric functions.

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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 of these physical constants requires the greatest number of **different** base SI units?

A Avogadro constant, N_A

B Boltzmann constant, k

C Gravitational constant, G

D Molar gas constant, R

Your answer ☐

[1]

Candidates got the right answer often by writing relevant formulas with these constants in them and performing 'unit algebra'.

Question 2

2 A metal block of mass m is at temperature T_0. An electrical heater of constant power P heats the block for time t and it reaches a temperature T_1. The overall efficiency of the process is x.

Which expression gives the correct value of c, specific heat capacity of the block?

A $\dfrac{Pt}{m(T_1 - T_0)}$

B $\dfrac{Pt}{mx(T_1 - T_0)}$

C $\dfrac{Ptx}{m(T_1 - T_0)}$

D $\dfrac{Px}{mt(T_1 - T_0)}$

Your answer ☐

[1]

This question was answered successfully by the majority of candidates who rearranged and substituted accurately.

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Question 3

3 Which row of the table describes the conditions which apply to an **inelastic** collision?

	Kinetic energy	**Total energy**	**Momentum**
A	Conserved	Not conserved	Conserved
B	Not conserved	Conserved	Conserved
C	Not conserved	Conserved	Not conserved
D	Not conserved	Not conserved	Not conserved

Your answer

[1]

Total energy and momentum are always conserved in inelastic collisions (unless there is an external force, which would have been mentioned). This leaves B as the only possible answer.

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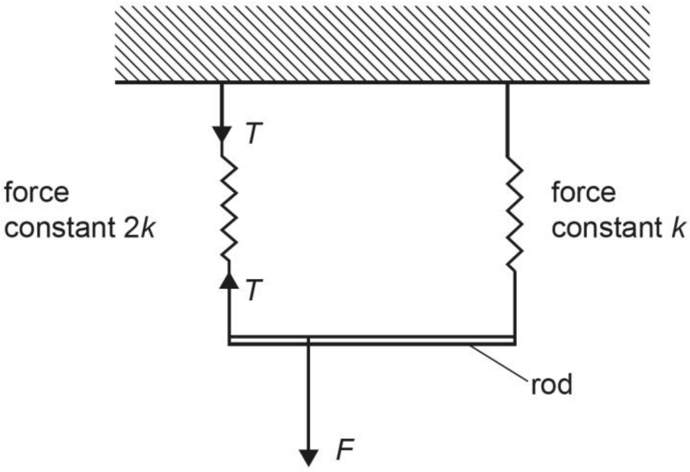
Question 4

4 A light rod is hung from a horizontal ceiling using 2 springs, one attached to each end. The springs have force constants k and $2k$.

A downwards force F is applied closer to one end of the rod such that the rod is horizontal.

What is the tension T in the spring with the force constant $2k$?



A $\frac{F}{3}$

B $\frac{F}{2}$

C $\frac{2F}{3}$

D F

Your answer

[1]

The rod ensures that the extension of both springs is the same. This means that the tension in the left spring must be twice the tension in the right spring.

This in turn means that F must equal three times the tension of the right spring, since the sum of the two tensions must equal F.

Finally, this gives the tension in the right spring as $\frac{F}{3}$ and hence the tension in the left spring must be $2\frac{F}{3}$.

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Question 5

5 A material is heated so that it changes state from solid to liquid and after further heating changes to gas.

Which of the following properties of the particles have increased?

1 Mean kinetic energy

2 Order

3 Spacing

A 1 and 3 only

B 1, 2 and 3

C 2 and 3 only

D 3 only

Your answer

[1]

The heating process decreases the order, whereas the spacing and mean kinetic energy of the particles increases, giving the correct answer as A.

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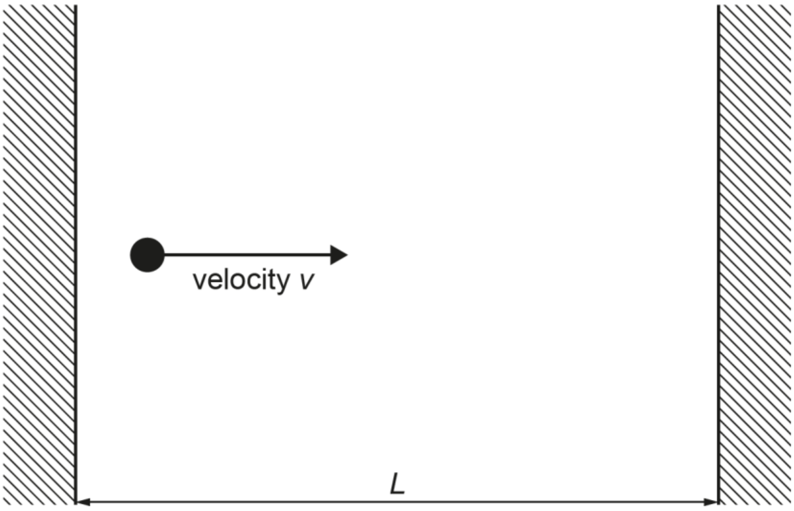
Question 6

6 A small particle of mass m is travelling horizontally between two parallel walls with a velocity v. The weight of the particle is equal to the upthrust caused by the air. The distance between the walls is L. The effect of drag on the particle is negligible.

After colliding with a wall the particle rebounds with a velocity of equal magnitude and travels in the opposite direction, hitting the opposite wall. The motion continues.



Which row in the table is correct?

	Change in momentum during each collision	**Time between collisions with the <u>same</u> wall**	**Average force exerted on the wall**
A	mv	$\frac{2L}{v}$	$\frac{mv^2}{2L}$
B	$2mv$	$\frac{2L}{v}$	$\frac{mv^2}{L}$
C	$2mv$	$\frac{L}{v}$	$\frac{2mv^2}{L}$
D	$2mv$	$\frac{2L}{v}$	$\frac{2m}{L}$

Your answer ☐

[1]

This question is the introduction to the derivation of the ideal gas equation. The particle changes direction after the elastic collision with the wall, so that the momentum change is $2mv$.

If the particle starts having just collided with the left wall, the time taken to return to that wall is the distance divided by the speed i.e. $2\frac{L}{v}$.

Average force exerted on the wall must be the change in momentum ÷ time between collisions so the final column must be calculated accordingly. The only row that satisfies this and the two previous conditions is answer B.

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Question 7

7 The apparent position of a star changes by an angle of 1.0×10^{-4} degrees between observations made 6 months apart from the same place on Earth.

What is the distance of the star from Earth in parsecs?

A 2.8

B 5.6

C 170

D 330

Your answer

[1]

The data in the question gives a parallax angle of 0.5×10^{-4} degrees. This equates to 0.18 arcseconds. Parallax angle and distance in parsecs are inversely proportional, with 1 arcsecond giving a distance of 1 parsec.

0.18 arcseconds gives a distance of (1 ÷ 0.18) = 5.6 parsecs.

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Question 8

8 A washing machine with a circular drum of diameter 0.60 m is rotating at an angular velocity of 15 radians per second.

What is the magnitude of the force exerted by the drum on a 0.30 kg item of clothing which is at the bottom of the spinning drum?

A 21 N

B 23 N

C 41 N

D 43 N

Your answer

[1]

The data in the first sentence gives the centripetal force required to make the clothing perform circular motion i.e. $m\omega 2r = 20.25$ N, which caused candidates to pick answer A. Those that used a radius of 0.60 m would get answer C at this point.

Although, at the bottom of the drum, the centripetal force is given by the contact force from the drum – the weight of the clothing. To find the contact force, we must add the weight of the clothing (2.94 N) to the centripetal force, giving 23.2 N, i.e. answer B is correct. Those that used a radius of 0.60 m would get answer D.

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Question 9

9 Two spheres each of radius 10 m and mass 1600 kg exert a gravitational force of 1.7×10^{-8} N on each other.

What is the shortest distance between the surfaces of the spheres?

A 80 m

B 100 m

C 120 m

D 9900 m

Your answer

[1]

The key here is to use the formula for gravitational force ($F = \frac{GMm}{r^2}$) to find the distance between the centres of the spheres. This gives 100.2 m. The question asks for the distance between the surfaces of the two spheres, which is 20 m less than the distance between their centres. Hence A is the correct answer.

Question 10

10 Which of the following determines whether a super red giant evolves to a black hole?

A Dark matter

B Electron degeneracy

C Mass of the core

D The Chandrasekhar limit

Your answer

[1]

Many students remembered that the mass of the core is the crucial factor in determining whether a super red giant evolves into a black hole.

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Question 11

11 Monochromatic light of wavelength 600 nm is passed through a diffraction grating.

Maxima are formed on a screen 3.0 m from the grating. The distance between the two first order maxima, on either side of the zero maximum, is 1.42 m.

What is the spacing, in m, between lines on the diffraction grating?

A 1.3×10^{-6}

B 1.4×10^{-6}

C 2.5×10^{-6}

D 2.6×10^{-6}

Your answer ☐

[1]

Candidates often confused which formula to use. Some used the two-slit formula and others, correctly, used the diffraction grating formula.

Here using $dsinq = nl$ is the correct approach. The question gives the distance between the two first-order maxima. This means that the distance from the centre to the first-order maximum is *half* of that i.e. 0.71 m. Consequently, the angle q is $\tan^{-1}(0.71 \div 3.0) = 13.3....$ degrees. Substituting in the wavelength (600×10^{-9} m) and n=1 gives d as 2.61×10^{-6} m. Therefore the answer is D.

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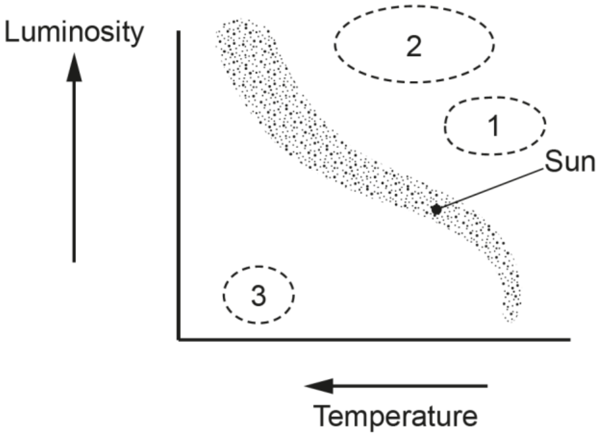
Question 12

12 Which option correctly gives the likely evolution of the Sun?



A $1 \rightarrow 2 \rightarrow 3$

B $1 \rightarrow 3$

C $2 \rightarrow 1 \rightarrow 3$

D $2 \rightarrow 3$

Your answer ☐

[1]

Most candidates remembered that the correct sequence for the Sun is main sequence, red giant, white dwarf (i.e. answer B). Any answer that includes red super giant cannot be correct.

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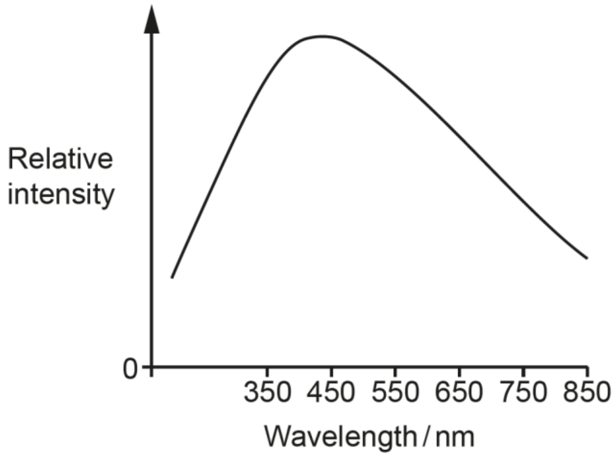
Question 13

13 The surface temperature of the Sun is 5800 K and the peak wavelength is 500 nm.

What is the surface temperature, in K, of the star represented by the graph below?



A 3400

B 5200

C 6400

D 9900

Your answer

[1]

This question tests knowledge of Wien's Law, $l_{max}T = \text{constant}$. Using the given data for the Sun, the constant here is 2.9 × 10^6 nm K. The wavelength of maximum intensity on the graph is roughly 450 nm so the temperature = 2.9 × 10^6 ÷ 450 = 6444 K, giving the correct answer as C.

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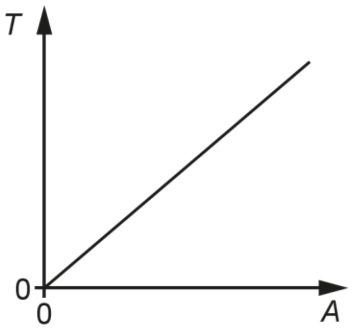
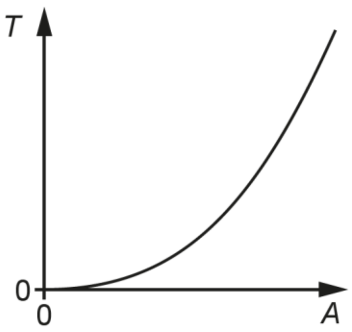
Question 14

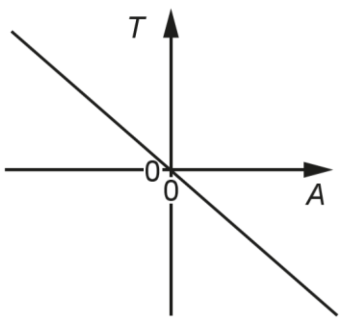
14 A body moves with simple harmonic motion. Which graph shows the correct relationship between its period, *T*, and its amplitude, *A*?



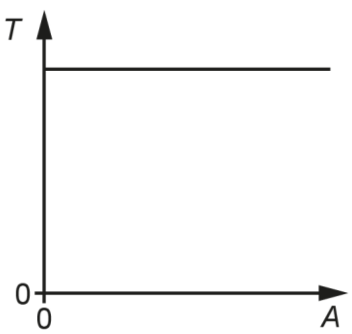
A



B



C



D

Your answer ☐

[1]

Any object performing simple harmonic motion is isochronous, which means that the period is independent of the amplitude of motion. The only graph that shows this is graph D.

Question 15

15 Which of these statements about the Universe is implied by the Cosmological principle?

A Dark energy is found in every galaxy

B Kepler's laws can be applied to any solar system

C Matter and anti-matter were formed in the very early Universe

D Microwave background radiation corresponds to a temperature of 2.7 K

Your answer ☐

[1]

The Cosmological principle is that on a large scale, the universe is homogeneous (the same everywhere) and isotropic (the same in all directions). Answers A, C and D are not implied by this, although they may be true statements. Answer B is correct here.

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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.

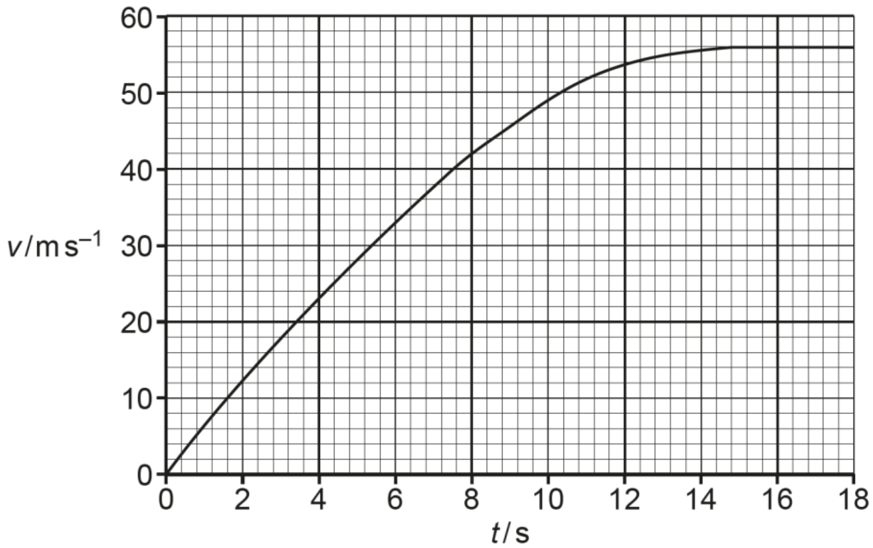
Question 16 (a) (i)

16 An electric car of mass 1700 kg is tested to measure its maximum speed.

Fig. 16.1 shows a graph of velocity *v* against time *t* for the first 18 seconds of the test.

During this time the force produced by the motor is constant.

Fig. 16.1



(a)
(i) Describe using **Fig. 16.1**, the method you would use to estimate the distance travelled in 18 s.

....

....

.... **[2]**

Most candidates stated that they would find the area under the curve. Any valid method was acceptable, ranging from counting squares and multiplying by the area of one square up to using mathematical methods such as the trapezium rule. Integration was *not* accepted (there's no function to integrate here) however, successful candidates went on to describe one of the numerical methods already described.

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Question 16 (a) (ii)

(ii) Use the graph in **Fig. 16.1** to show that the acceleration of the car at time t = 12 s is about 1.5 m s^{-2}.

[2]

Most candidates successfully drew a tangent to the curve, although a small number drew a line that was too steep, too shallow or not touching the curve at the 12 second point. This limited those candidates to maximum of 1 mark.

Question 16 (a) (iii)

(iii) Use **Fig. 16.1** to calculate the change of momentum of the car in 18 s.

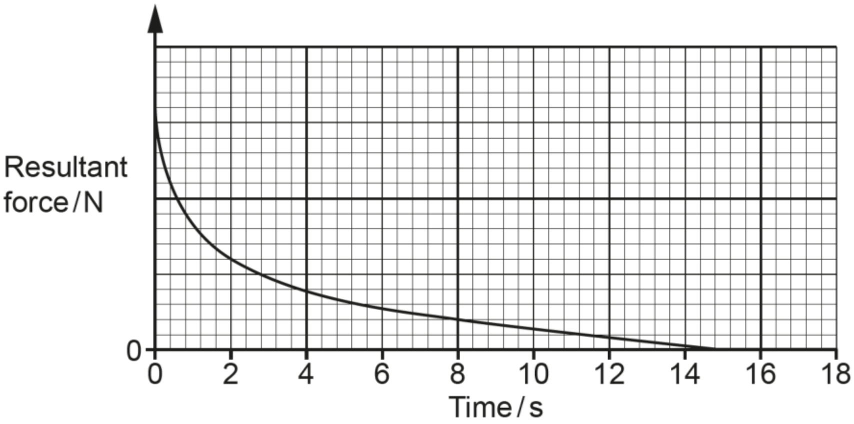
= .... kg m s^{-1} **[2]**

Almost all candidates read the velocity at 18 s correctly and then multiplied by the mass of the car. A small number misread the question and calculated the average rate of change of momentum by dividing the correct answer by 18 seconds.

Question 16 (b) (i)

(b) **Fig. 16.2** shows a graph of **resultant** force against time during the test.

Fig. 16.2



(i) Explain, in terms of the forces acting on the car, the shape of the graph in **Fig. 16.2**.

....

....

....

.... **[2]**

Describing the shape of the curve was not required here and so comments that did that without explanation, such as 'the curve starts steep, decreases at a decreasing rate and then the resultant becomes zero' scored no marks. The question required explanations in terms of forces. Successful responses mentioned drag, how that changes with speed and the condition that the drag must equal the thrust.

OCR support

The Assessment story resource for A Level Physics A makes clear the distinction between different command words as well as providing useful guidance more generally to candidates.

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Question 16 (b) (ii)

(ii) Explain why the value you have calculated in **(a)(iii)** is the area under the graph in **Fig. 16.2**.

....

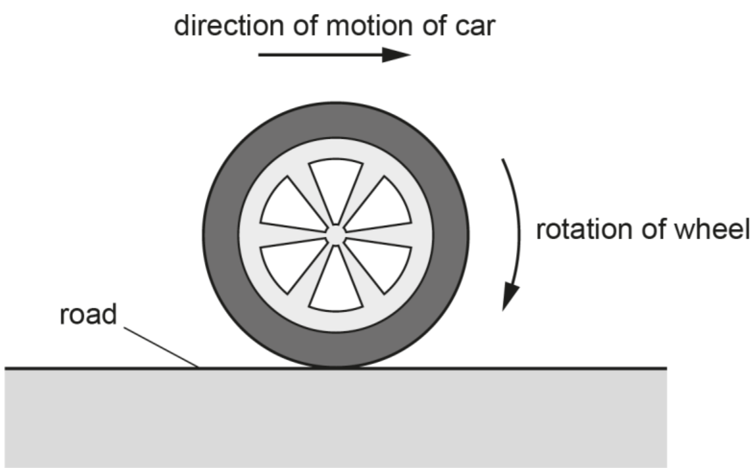
....

.... **[1]**

Many candidates used the correct term of 'impulse' here, often by referring to the product of average force and time taken as representative of the area of a small square.

Question 16 (c) (i)

(c) The diagram below shows one of the wheels of the car that is driven by the electric motor.



(i) Use Newton's third law to explain how frictional forces cause the car to accelerate.

....

....

....

.... **[2]**

Candidates often described Newton's Third Law in generic terms. The question requires application to this specific context such as 'There's a force on the road to the left from the wheel' or 'There's a force on the wheel from the road to the right'.

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Question 16 (c) (ii)

(ii) Calculate the resultant force acting on the car at t = 12 s, using your answer to **(a)(ii)**.

resultant force = ... N **[1]**

Less successful candidates did not use their answer from part (a) (ii), often by dividing their answer to part (a) (iii) and dividing by either 12 or 18 seconds. This found the average force over that time and so was incorrect. The correct method is simply to multiply the acceleration at t = 12 s by the mass of the car.

Question 16 (c) (iii)

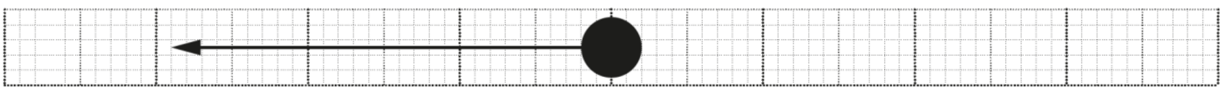
(iii) The black dot in the diagram below represents the car at time t = 12 s. The total resistive forces acting on the car, D, are shown.

Calculate the constant **total** frictional force F from the powered wheels of the car which provides the thrust on the car.

Use your answer to draw an arrow on the diagram below to show the direction and magnitude of F.

F = ... kN

D = 29 kN



[2]

The correct approach here is to make sure that the thrust – drag = resultant force calculated in the previous part of the question. Many candidates still gained full marks even though their previous answer was incorrect as 'error carried forward' was applied, as long as the arrow matched the numerical answer.

The answer line includes the unit kN – candidates should be careful to give their answer in the required unit.

Question 17 (a) (i)

17 An aircraft is flying horizontally at an altitude of 10 000 m and a constant speed of 220 m s^{-1}.

While maintaining this speed, the controls are adjusted so that the aircraft is in **projectile** motion until the altitude is 7500 m.

Throughout the projectile motion the passengers experience apparent weightlessness.

(a)
(i) A condition for projectile motion is constant vertical acceleration. State the other condition.

....

.... **[1]**

There were many ways to express the idea that the horizontal velocity should stay constant.

Question 17 (a) (ii)

(ii) Show that *t*, the time taken to reach the new altitude of 7500 m, is about 23 s.

[2]

This question tests the idea of independence of horizontal and vertical motion. There are lots of letters involved in the algebra that are applicable to both motions, e.g. *u*, *v*, *a*, and *s*. Successful candidates made the distinction between horizontal and vertical motion as clear as possible, either by using a two-column table with the headings 'vertical' and 'horizontal' or by using V and H subscripts on the relevant letters. Once candidates got to the starting point of a displacement of 2500 m with zero initial vertical velocity and an acceleration of 'g', they often arrived at the correct answer.

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Question 17 (a) (iii)

(iii) Determine the magnitude and direction of the velocity of the aircraft at time *t*.

velocity = ... $m\,s^{-1}$

angle to the vertical .... ° **[4]**

A diagram of the two components of the velocity here was not mandatory; however, it makes it clear in the mind of the candidate what they are doing. The most successful candidates drew a triangle with the two components of velocity with an angle indicated between the vertical and the resultant velocity. They were then clear about how to work out the resultant velocity (Pythagoras) and the required angle.

Both acute and obtuse angles to the vertical were acceptable. Acute angles over 45 degrees indicated an error in the trigonometry and so the last mark was unavailable.

Few candidates were able to correctly interpret the question's description of 'maintaining this speed' to suggest that the velocity of the plane was 220 $m\,s^{-1}$ throughout.

Question 17 (a) (iv)

(iv) Explain why the engines of the aircraft must provide thrust during the projectile motion.

....

....

....

.... **[2]**

There were lots of ways the candidates used to express the right ideas. As in previous series, phrases such as 'balanced forces' were not specific enough. 'Thrust is required for horizontal net force' is one example of using more specific language to gain credit here.

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Question 17 (b) (i)

(b)
(i) The average radius of the Earth is 6400 km.

Show that the ratio below is greater than 0.99.

$$\frac{\text{gravitational field strength at 10 000 m altitude}}{\text{gravitational field strength at the surface of the Earth}}$$

[2]

The mark scheme indicates two alternative approaches to this item, which covered most attempts by candidates. Common errors, however, included missing the 'squared' sign off the distance from the centre of the Earth either on paper or on the calculator, or getting the fraction upside-down.

Question 17 (b) (ii)

(ii) Explain why the passengers are described as 'weightless' during the projectile motion of the aircraft.

....

....

....

.... **[2]**

There were two separate ideas here. Firstly that the objects are travelling at the same acceleration (i.e. 'g') and the effect this has on the normal contact force between the plane and the passenger (i.e. there is none).

Misconception

Candidates often think that because they've seen things floating on video coverage of astronauts in space that there is no resultant force acting on them. This is a misconception. There is no *relative* motion but both the ISS and the astronauts inside them are travelling very quickly in Low Earth Orbit. They can only do this because of the centripetal force provided by gravitation with the Earth.

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Question 18 (a) (i)

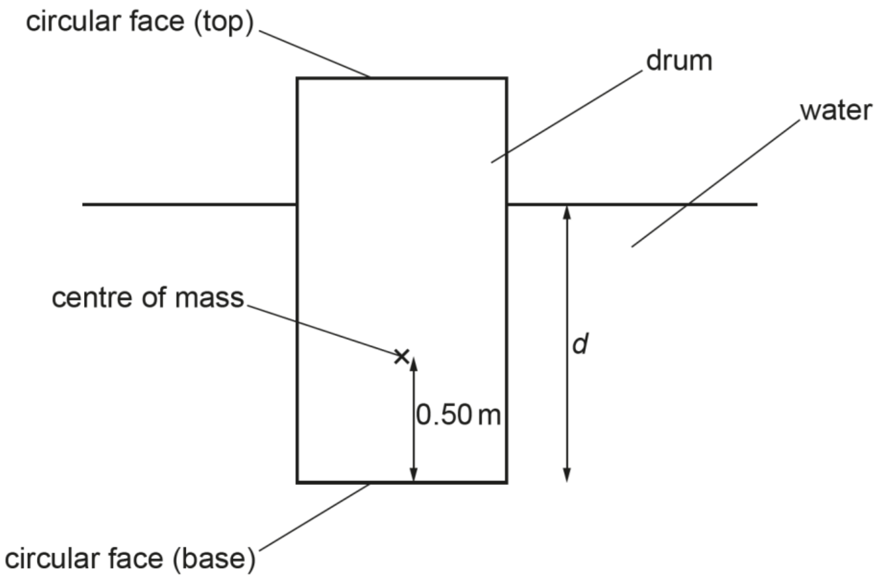
18 Part of a machine to generate electrical energy using waves is a cylindrical drum whose cross-section is shown below. The height of the drum is 2.0 m and its cross-sectional area is $0.79\,m^2$.

The mass of the drum is 1200 kg.

The centre of mass of the drum is 0.50 m from one of the circular faces, on a line joining the centres of the circular faces.

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

The drum floats in flat water with its long axis vertical. The base of the drum is a distance *d* below the surface, where *d* is measured in m.



(a)
(i) Explain why the weight of water displaced must be equal to the weight of the drum.

....

....

.... **[1]**

The key term here is 'upthrust'. Candidates scored no mark for describing that the weight of the water displaced must be equal to the weight of the drum as stated in the question.

Assessment for learning

Candidates should be careful not to inadvertently repeat the text of the question.

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Question 18 (a) (ii)

(ii) Calculate *d*.

d = ... m **[3]**

The most straightforward way to answer this question successfully is to equate the weight of the water displaced (density of water × volume of the drum from the bottom to depth *d*) to the weight of the drum (1200 x *g*). A neat approach was to find the density of the drum and using the ratio of the densities of the drum and water to work out the fraction of the drum (and hence the depth of the drum) that must be underwater.

Question 18 (a) (iii)

(iii) Upthrust forces act at the centre of mass of the fluid displaced.

Explain why the drum cannot float in **equilibrium** on its side with the long axis horizontal.

....

....

.... **[2]**

The language of the question here is quite subtle. The upthrust acts at the centre of mass of the fluid displaced. This is not the centre of mass of the drum. Successful candidates drew a labelled diagram to represent this and from there could make a valid assertion about why the drum could not be in equilibrium.

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Question 18 (b) (i)

(b)
(i) When the vertical drum is displaced a distance x deeper into the water from the equilibrium position, the magnitude of the resultant force on the drum, F, is given by

$F = -kx$

where k is a constant and d is measured in m.

By considering the magnitude of the additional upthrust on the drum, show that k is about $8000\,\mathrm{N\,m^{-1}}$.

[2]

Erratum Notice

Turn to **page 20** of the **question paper** and look at **question 18(b)(i)**.

In line 4, cross out the '*d*' and replace with '*x*'.

The line: where k is a constant and d is measured in m

should now read: where k is a constant and x is measured in m

The erratum did not appear to have any effect on the ability of candidates to answer the question.

The best way to answer this is to find an expression for the additional upthrust provided by displacing the drum by the distance, x, as this is equal to the resultant force. The candidate then needed to be clear about how they had cancelled 'x' from both sides of the equation, giving a value consistent with 8000 $\mathrm{Nm^{-1}}$.

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Question 18 (b) (ii)

(ii) When the drum is released, it oscillates vertically. Explain why the oscillations are simple harmonic motion.

....

....

.... **[2]**

Successful candidates related the conditions for simple harmonic motion i.e. that the force or acceleration is directly proportional to the displacement and that the force or acceleration is acting towards a fixed point.

The idea that the acceleration is opposite to the direction of motion is incorrect. Any reference to 'negative displacement' was insufficient – there needed to be an interpretation of what that minus sign meant.

Question 18 (b) (iii)

(iii) Calculate the natural frequency *f* of the oscillations.

f = ... Hz **[2]**

Most candidates completed this calculation correctly. Those who did not did not gain marks for not dividing the value of *k* by the drum's mass.

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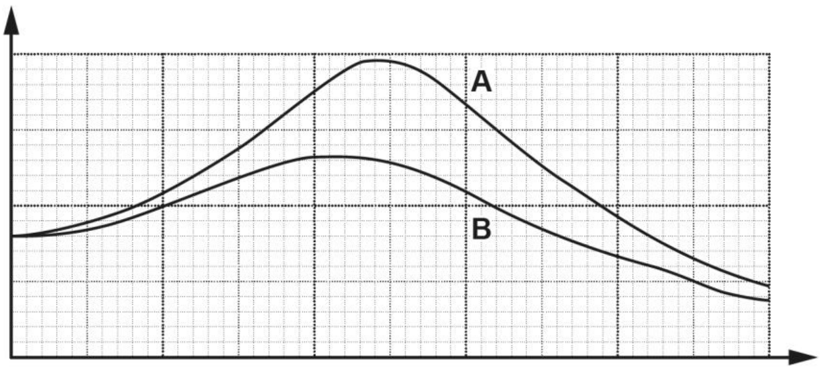
Question 18 (c)*

(c)* Two designs, **A** and **B**, of the machine are tested in a large ripple tank.

The ripple tank can produce waves whose amplitude and frequency can be varied over wide ranges.

The natural frequencies of the two machines are identical. The graphs show the results of the tests but are incomplete.

- Describe how the amplitude of the machine could be measured at each frequency tested. You do not need to describe how to vary the amplitude or frequency of the waves.
- Complete the graphs with suitable labels and annotations.
- Discuss which of the designs is the most effective at generating electrical energy. **[6]**



Many candidates gave themselves the best chance of scoring well on this question by ensuring that they attempted responses to each of the three bullet points outlining what to cover. Most candidates kept answers suitably simple by suggesting a vertically mounted ruler and some way of capturing the largest displacement of the wave from the undisturbed water. Finding the speed of the wave horizontally and relating that to the wave's angular frequency to arrive at the amplitude was incorrect. Those candidates confused the horizontal speed of the wave and maximum vertical speed of particles that made up the wave.

Most candidates correctly annotated the graph up to a point – perfection was not required (e.g. there is a distinction between 'natural' and 'resonant' frequency) yet in some cases labels were contradictory or simply unphysical.

The real challenge here was the analysis and interpretation of the graphs. As the mark scheme indicates, there are valid arguments for either design A or design B. Provided that the conclusion was consistent with the candidate's discussion, either answer was acceptable.

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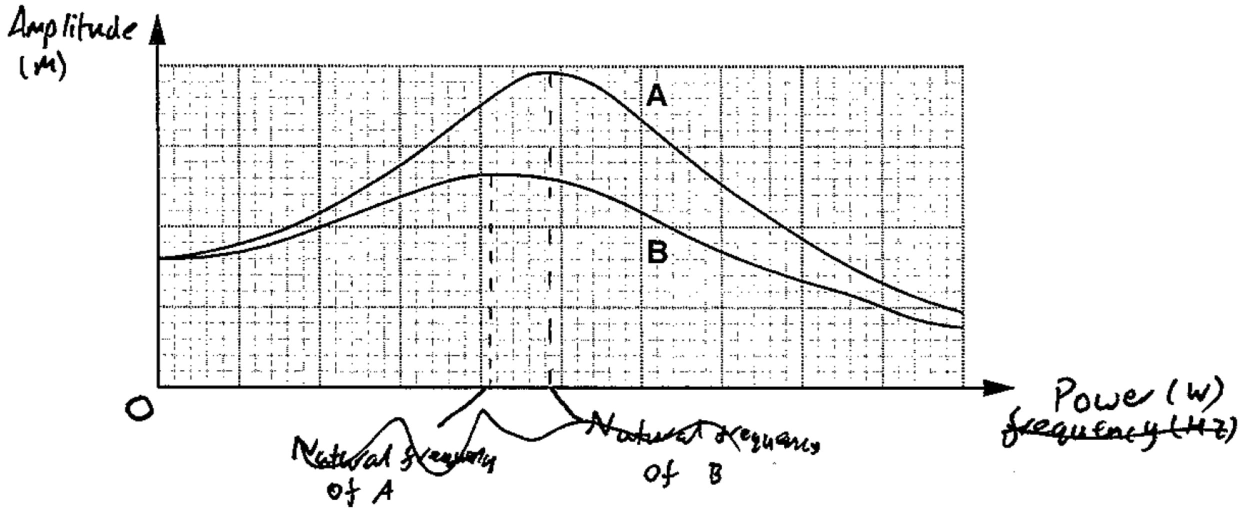
Exemplar 1



• At each frequency, ~~measure~~ mark the ~~dista~~ point at which the peak of the wave occurs, and the point at which the trough occurs. Then, measure this distance with a ruler and divide it by two to obtain the amplitude

• ~~B~~A seems to be most efficient at generating electrical energy as, whilst B peaks earlie on the graph, the peak amplitude of A is much higher, meaning much more of the power drawn by A is used to create the wave, so A must be more effective.

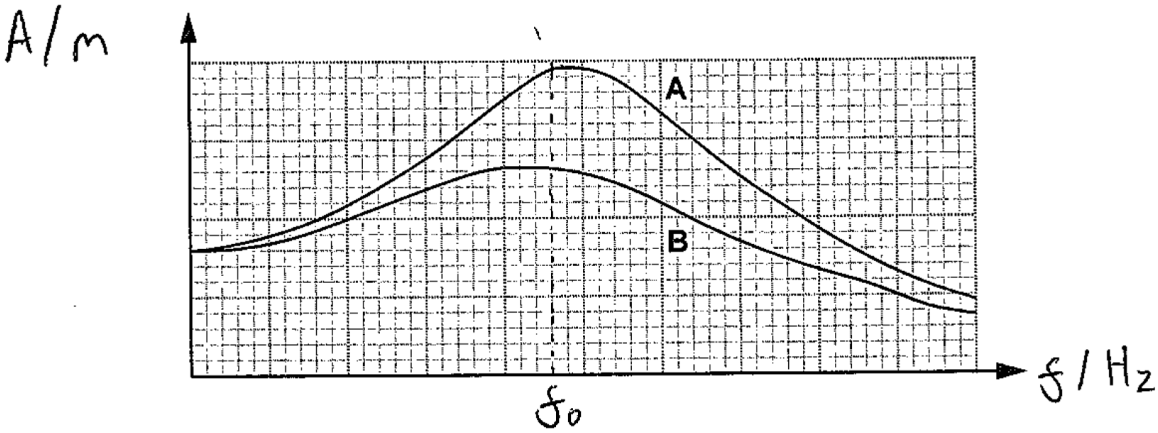
This candidate has fulfilled the rubric of the question by completing all three tasks, namely annotating the graph, describing how to find the amplitude and then discussed which of the designs would be most effective.

The annotations are clearly imperfect – the x-axis is labelled as power, rather than the crossed-out 'frequency'. The crossed-out 'natural frequency' labels for curves A and B would have been acceptable if they had been 'resonant' frequency.

The method for the amplitude would work, despite its simplicity. There is an attempt to link the higher amplitude of curve A for all frequencies to a larger power draw although the link isn't explained in any depth.

Overall, this was awarded at the lower end of Level 2.

Exemplar 2



To measure amplitude at different frequencies, set up a floating bob in the ripple tank with a fiducial marker on the side of the tank as well as a ruler. Use a camera to video the bob for 10 oscillations at the given frequency. Use the video to measure the amplitude of each oscillation and find an average. Measure from the same point of the bob each time (top/bottom). Repeat with multiple different frequencies* ~~in each tank~~ and draw a graph of amplitude (m) against frequency (Hz). Design A will be more effective at generating electrical energy because the amplitude at every frequency is higher which means that ~~more charge~~ a larger change in magnetic flux linkage is possible for each oscillation so more emf is able to be generated.

* for each design

This candidate has made a more complete and accurate attempt at annotating the graph and curves.

The method for finding the amplitude of the motion is more sophisticated that in exemplar 1 and would probably yield better quality results.

The analysis and discussion uses much more technical language in an organised and logical fashion. The candidate has connected the idea to larger amplitude of motion to a larger induced e.m.f.

Overall, this was awarded Level 3, 6 marks.

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Question 19 (a)

19 A lorry used to transport liquid oxygen has a tank with a maximum volume of $10\,m^3$.

The tank is filled until it contains $9.8\,m^3$ of liquid oxygen.

The pressure of the gas above the liquid is 100 kPa and the temperature of the gas and the liquid is –183 °C, the boiling point of oxygen.

The temperature of the oxygen remains constant.

The walls of the tank allow thermal energy to pass through at a constant rate of 1.3 kW.

The latent heat of vaporisation of oxygen is $214\,kJ\,kg^{-1}$.

The density of **liquid** oxygen is $1140\,kg\,m^{-3}$.

(a) State why thermal energy passes into the tank.

....

....

.... **[1]**

This was a straightforward question that most candidates got correct.

Misconception

It is temperature difference that drives thermal energy transfer such as conduction, not energy difference as stated by some candidates.

Question 19 (b)

(b) Explain, in terms of particle energies, why the temperature of the oxygen remains constant despite the transfer of thermal energy into the tank.

....

....

.... **[2]**

As in previous series, there is a requirement to be explicit about the change in potential energy of the particles (it increases) and about the kinetic energy remaining unchanged. Statements such as 'KE doesn't increase' are consistently insufficient throughout.

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Question 19 (c)

(c) Show that in one hour the volume of liquid oxygen that evaporates is about 0.02 m^3.

[3]

Successful candidates either rearranged all of the variables into a viable expression and then substituted into that expression or they performed each calculation separately. The common thread to all of the best answers was that the working was clear, with words often accompanying the calculations.

Question 19 (d)

(d) After one hour the number of moles of gas above the remaining liquid oxygen is 710.

Calculate the pressure of the gas.

pressure = ... kPa **[3]**

Candidates used a wide variety of volumes in the ideal gas equation to arrive at pressure values that were all broadly sensible. The correct volume was the original volume of the gas (0.2 m^3) added to the volume of liquid oxygen that had evaporated after 1 hour (0.02 m^3) giving a volume of 0.22 m^3. There was still some credit available for volumes that were incorrect as shown in the mark scheme.

Almost all candidates remembered to convert the temperature of the gas into kelvin and then rearrange the ideal gas equation correctly.

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Question 20 (a)

20 The specific heat capacities and molar masses of some common gases are given in the table.

Gas	**Specific heat capacity / $J kg^{-1} K^{-1}$**	**Molar mass / $kg mol^{-1}$**	**Number of particles per unit mass / 10^{24}**
Neon	1030	0.020	30
Argon	520	0.040	15
Krypton	250	0.084	
Xenon	160	0.130	4.6
Radon	90	0.220	2.7

(a) Complete the missing value in the table. **[1]**

Most candidates recorded a correct value in the table.

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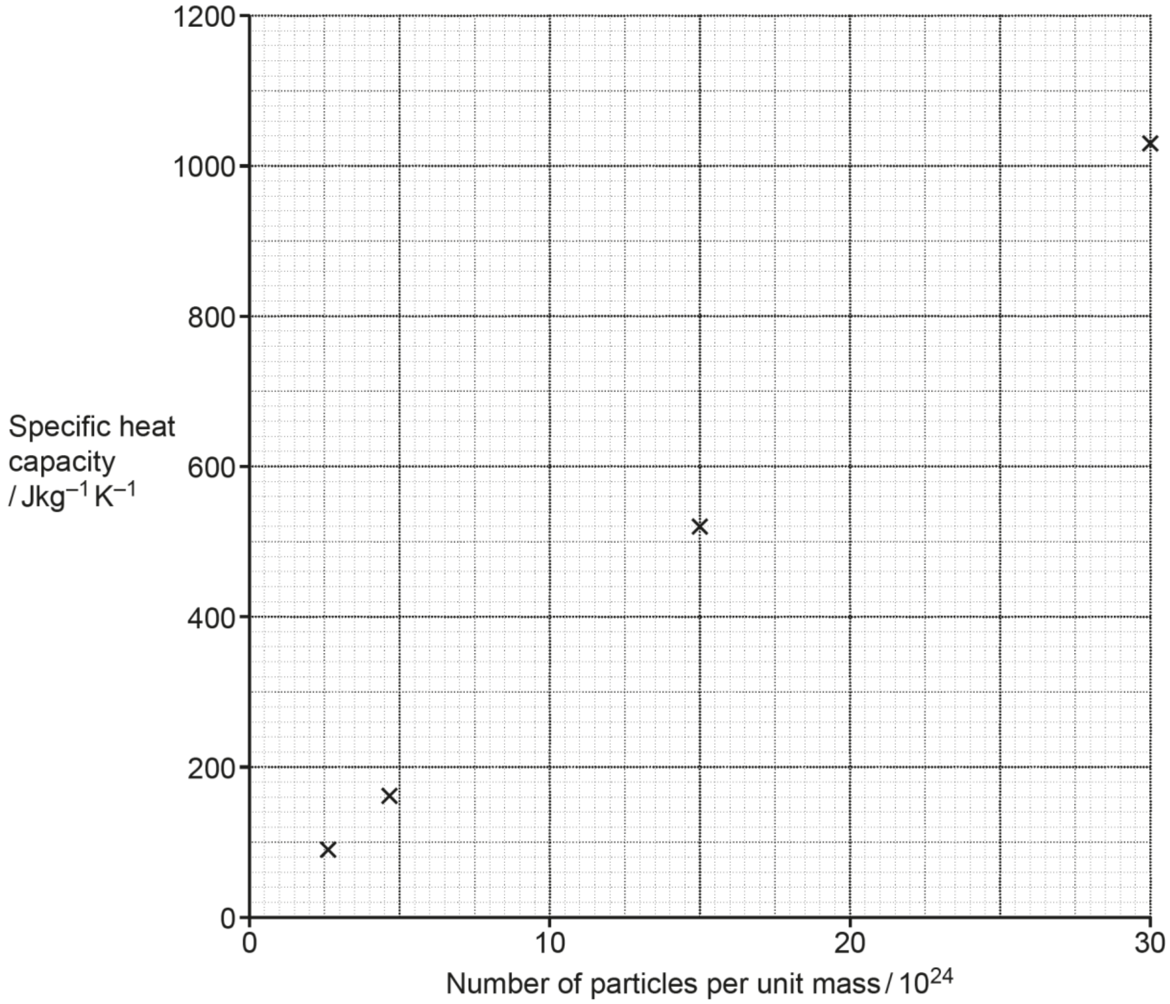
Question (20) (b)



(b) Plot the missing data point on the graph above and draw a line of best fit. **[2]**

Most candidates plotted their data point correctly and drew a line of best fit that was consistent with the data. Some lines were incorrect as they did not have sufficient points either side of the line.

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Question 20 (c)

(c) Describe the relationship suggested by the graph and suggest an explanation.

....

....

....

....

....

.... **[4]**

Candidates produced excellent answers here. Most scored two marks straight away by stating the directly proportional nature of the relationship and justifying that with a statement about a straight line of best fit passing through the origin.

Although a small number of candidates incorrectly asserted that the mass of each of the particles would change depending on the number density, many correctly suggested that there was a link to the average kinetic energy of the particles.

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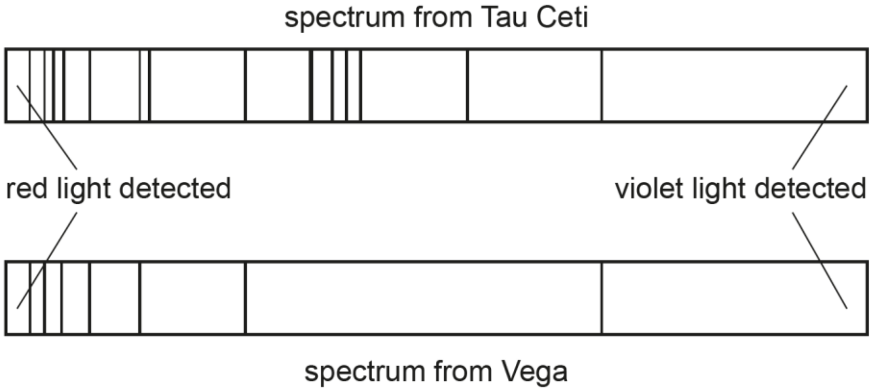
Question 21*

21* Analysis of stellar light can identify the elements that are present in the outer layers of a star.

Absorption spectra of visible light collected from two main sequence stars, Vega and Tau Ceti, are shown below. The spectra were collected by a telescope orbiting the Earth. The dark lines on the diagram show wavelengths where the intensity was zero or close to zero.

- Explain the cause of the dark lines.
- Describe and explain at least one difference between the spectra.
- Analyse the spectra to determine which star is older.



[6]

Many candidates spotted that the spectral lines from Vega exactly matched up to the corresponding lines in the spectrum from Tau Ceti. This rules out the idea that one star's spectrum has been red shifted by more than the other, as suggested by many candidates. The principal difference is that Tau Ceti has more lines because its atmosphere has more elements in it than that of Vega. A small number of candidates also spotted that one of the lines in Tau Ceti's spectrum is darker than the rest.

Many candidates produced exceptionally detailed explanations of how absorption spectra occur. Very few attributed the spectra to such phenomena as destructive interference or something to do with the Earth's atmosphere.

The key to accessing Level 3 for this question lay in explaining why the two spectra were different. Many candidates suggested that there were more elements in the atmosphere of Tau Ceti because it had been fusing hydrogen for so long that some of those products were also fusing together to produce even heavier elements. A few candidates linked the darker line in Tau Ceti's spectrum to a large abundance of an element that wasn't hydrogen.

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Exemplar 3

An absorption spectrum is a series of dark lines on a continuous spectrum due to light being passed through a cold low density gas such as the photosphere of a star, causing the electrons in the atoms to absorb the photons and be excited. The position of the dark lines correspond to the frequency of the photons absorbed. Each element has a unique spectrum due to the unique energy levels in their atoms, as to excite ~~a photon~~ an electron, the energy of the photon must be equal to the difference between energy levels.

The spectrum of Tau Ceti has more lines than Vega, and all of the lines in Vega's spectrum align with Tau Ceti. This means that Tau Ceti's photosphere contains elements that are not present in Vega's. Additionally Vega's spectrum seems to be redshifted as the lines ~~are~~ are more to the left and more spaced out. This could be because, according to Hubble's law, Vega is futher away and is receding with a greater speed, $v = H_0 D$.

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Tau Ceti is older because the spectra shows that there are many more elements in the star, indicating that Tau Ceti is no longer just fusing hydrogen into helium, but is fusing ~~a~~ heavier elements. Tau Ceti may be a red giant and Vega may be a main sequence star.

The first paragraph of this response is a detailed description of how continuous light from a star can be selectively absorbed by the atmosphere of that star. The candidate doesn't add in the details about de-excitation or of re-emission of the light in random directions; however, they have included everything up to that point.

The candidate has also spotted that there are more lines for Tau Ceti than for Vega and attributes this to elements that are present in the photosphere of Tau Ceti that are not present in that of Vega. The argument about red shift is incorrect. Having said that, the candidate has gone on to mention about the fusion products other than helium and attributes this to Tau Ceti being the older star. At the end, the mention of Tau Ceti *maybe* being a red giant and no longer main sequence is incorrect (the question says that both stars are main sequence).

On balance, this response was awarded Level 3.

Question 22 (a) (i)

22 An asteroid of mass 10 kg is in a circular orbit around the Sun at a distance of 3.5AU from the centre of the Sun.

1 AU = 1.5×10^{11} m

(a)
(i) Use Kepler's third law to calculate the period of the orbit of the asteroid in years.

An object orbiting the Sun at a distance of 1 AU has a period of 1 year.

period = ... years **[2]**

While some candidates missed off the correct power for either time or orbital radius, many knew which relationship to use. The challenge here was to get the right units for both time and orbital radius. By using the units of AU and years, it was possible simply to write that $T^2 = R^3$ and to work from there. The full relationship involving the mass of the Sun and working in SI units was less straightforward; however, many candidates managed to complete this correctly. Errors were made with the mass (using 10 kg instead of the mass of the Sun) or the radius (which needed to be in metres) for the time to be calculated in seconds (requiring a further conversion to be able to give the period in the required unit of years.)

Question 22 (a) (ii)

(ii) Calculate the kinetic energy of the asteroid.

kinetic energy = ... J **[3]**

The 'error carried forward' rule was applied here in the case of the wrong value for the orbital period and again if the orbital velocity was incorrectly calculated. Otherwise this question was successfully completed.

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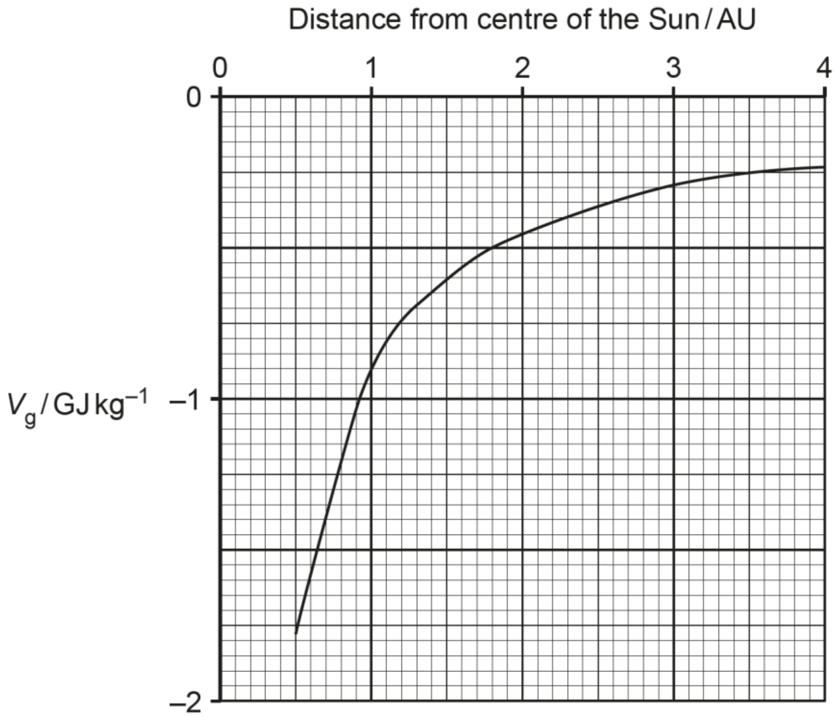
Question 22 (b) (i)

(b) After a collision the asteroid falls towards the Sun.

The graph below shows the variation of gravitational potential, V_g, due to the Sun with the distance from the centre of the Sun.



(i) Use the graph to calculate the change in gravitational potential energy of the satellite from the moment of collision until it crosses the Earth's orbit.

change in gravitational potential energy = ... GJ **[2]**

Candidates found this challenging. The graph gives the gravitational potential. The correct approach is to find the difference in the gravitational potential at 1 AU and at 3.5 AU and then multiply this difference by the mass of the satellite.

Assessment for learning

Candidates should learn the difference between gravitational potential, potential energy, force and field strength. They are all similar ideas with only minor differences in their formulae. A similar approach could be taken with the electric field equivalent elsewhere in the specification.

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Question 22 (b) (ii)

(ii) Eventually, the asteroid falls into a new orbit around the Sun. This orbit is elliptical.

State the other feature of this orbit predicted by Kepler's first law.

....

.... **[1]**

A large proportion of candidates successfully identified that the other feature was that the Sun lay at one of the foci of an orbit.

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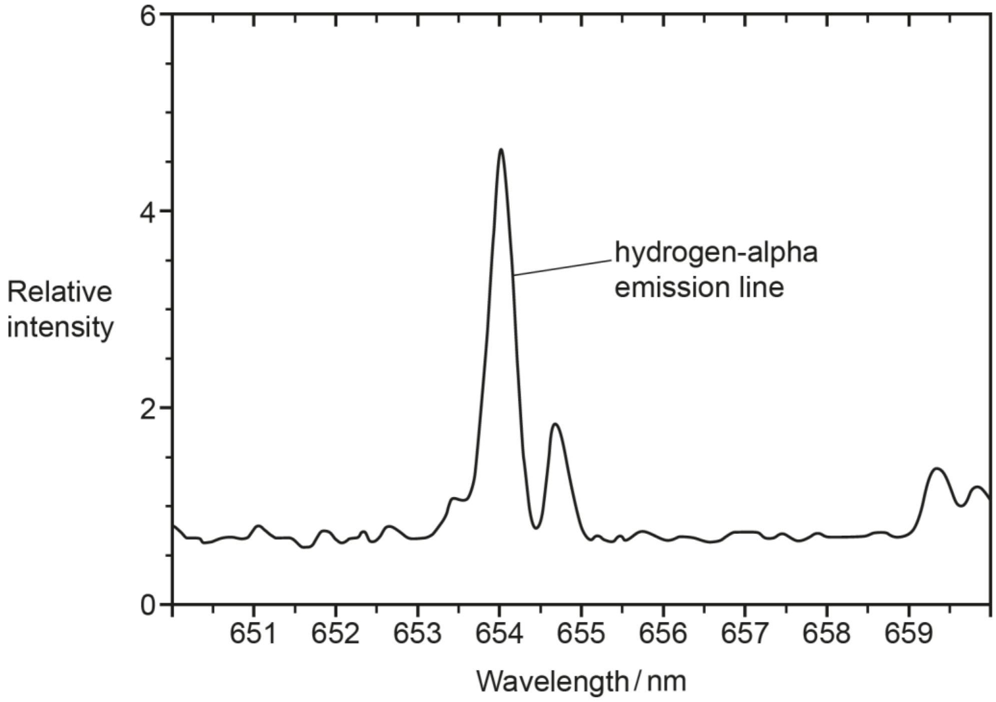
Question 23 (a)

23 The diagram below shows the part of the spectrum of light from the galaxy M87 with a strong hydrogen-alpha emission line.

The spectrum of a sample of hydrogen gas analysed in a laboratory on Earth showed this emission line to be at 656.3 nm.



(a) Calculate the magnitude of the recession velocity of M87.

velocity = ... $km\,s^{-1}$ **[3]**

The approach here is to find the wavelength corresponding to the peak of the hydrogen-alpha emission line and find the difference between that and the laboratory wavelength of the same line.

The shift in wavelength as a fraction of the original wavelength is equal to the velocity of M87 as a fraction of the speed of light. Answers that used the wavelength 654 nm as the denominator were judged as 'XP' i.e. wrong physics, just as in previous series, even though this gave a very similar answer to the correct value for the velocity.

Finally the unit on the answer line is $km\,s^{-1}$, so there was a conversion to complete. Most candidates completed all of these steps.

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Question 23 (b)

(b) Estimate the distance in light years to M87 using Hubble's law.

Hubbles constant $H_o = 2.5 \times 10^{-19}\,s^{-1}$

distance = ... ly **[2]**

Erratum Notice

Turn to **page 32** of the **question paper** and look at **question 23(b)**.

In line 2, cross out the 's' in 'Hubbles'. Then cross out '10^{-19}' and replace with '10^{-18}'.

The line: Hubbles constant $H_o = 2.5 \times 10^{-19}\ s^{-1}$

should now read: Hubble constant $H_o = 2.5 \times 10^{-18}\ s^{-1}$

By using the candidate's value from part (a), quoted in ms^{-1} for this part, most candidates used an appropriate value for Hubble's constant to arrive at a distance in metres to M87. Once more there is a conversion to complete to get the value in the required unit.

The mark scheme allows full credit for the correct use of the original value of H_0 if the erratum was not used, as well as use of any handwritten replacement value for H_0 used correctly.

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Question 23 (c)

(c) Estimate the percentage uncertainty in the distance calculated in part **(b)** using the width of the emission line in the diagram.

percentage uncertainty = +/– .... % **[2]**

This was a challenging item. Many candidates correctly found the width of the emission line according to the scale on the diagram. Others completed this incorrectly by using mm or cm. The percentage uncertainty in the distance is the same as the percentage uncertainty in the change in wavelength. Hence the correct expression to evaluate is the ratio of the width of the line (roughly 0.8 nm but there is a significant allowable range here) to the shift in the line (2.3 nm). Many candidates did not use the shift in the line but incorrectly used either the observed or the original wavelength instead.

Question 23 (d)

(d) Other methods have shown M87 is actually 50 million light years from Earth.

Suggest why M87 might contradict Hubble's law.

....

....

.... **[2]**

The mark scheme shows a wide variety of acceptable ideas that were creditworthy for this item. Many candidates provided one acceptable idea with some providing at least two.

Question 23 (e)

(e) Suggest **one** reason why the Big Bang theory is still the accepted model of the origin of the Universe.

....

.... **[1]**

There were also a wide variety of acceptable candidate responses to this question.

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