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A LEVEL

Examiners' report

PHYSICS A

H556
For first teaching in 2015

H556/01 Summer 2019 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates. The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. 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 can be downloaded from OCR.

Paper 1 series overview

H556/01 is one of the 3 examination components for the revised A Level examination. The scope of this paper is modules 1, 2, 3 and 5 from the specification.

Candidate performance overview

Candidates who did well on this paper generally did the following:

- Completed numerical and descriptive questions equally well.
- Understood the difference between the command verbs such as 'describe' and 'explain'.
- Used the white space around the multiple choice questions to help figure out the answer.
- Rounded their answers at the last step in a calculation.
- Answered practical skills-based questions confidently, having planned their response out first.
- Had considered practical work consistently and regularly throughout their studies.
- Sketched diagrams that were large enough to be clear and labelled those diagrams clearly.

Candidates who did less well on this paper generally did the following:

- Were not familiar with standard scientific terms from the Practical Skills Handbook.
- Arranged their work poorly, particularly in unstructured calculations.
- Missed out putting a final answer for multiple choice questions.
- Forgot the correct value for the given S.I. prefix i.e. nm, MW.
- Rounded their answers at too early a stage in their calculations.

This examination produced a very wide range of marks, from 0 to 100 out of 100, with most candidates displaying either good or excellent recall of points of physics. The mean score was just under 8 marks higher than last year. The application of knowledge in both familiar and unfamiliar situations was encouragingly good. There was little evidence that the candidates could not complete the paper in the scheduled time.

Note

From this series students have been provided with a fixed number of answer lines and an additional answer space. The additional answer space will be clearly labelled as additional and is only to be used when required. Teachers are encouraged to keep reminding students about the importance of conciseness in their answers. Please follow this link to our SIU https://www.ocr.org.uk/administration/support-and-tools/siu/alevel-science-538595/

Section A overview

Multiple choice questions were answered very well by most candidates. Very few candidates left any gaps.

Question 2

2 A paper cone is held above the ground and dropped. It falls vertically and reaches terminal velocity before it hits the ground.

Which statement correctly describes the **resultant** force on the falling cone before it reaches terminal velocity?

A decreasing and upwards

B decreasing and downwards

C increasing and downwards

D increasing and upwards

Your answer **[1]**

Before the cone reaches terminal velocity, it is still accelerating downwards so there is still a resultant force downwards. Once the cone is at terminal velocity, the resultant force must be zero. This means that the resultant force has decreased, giving the correct answer B.

Question 3

3 A solid cylindrical glass rod has length 20.0 ± 0.1 cm and diameter 5.00 ± 0.01 mm.

What is the percentage uncertainty in the calculated volume of this rod?

A 0.1%

B 0.2%

C 0.7%

D 0.9%

Your answer **[1]**

Most candidates understood that the percentage uncertainties, rather than the absolute uncertainties should be combined here. The percentage uncertainty in the length is 0.5% and the percentage uncertainty in the diameter is 0.2%. The most common incorrect response here was C, because this is what you get when you add the 2 percentage uncertainties. The percentage uncertainty in the diameter must be doubled, because the formula for the volume of the cylinder include diameter^2. This gives the correct answer D.

Question 4

4 A simple harmonic oscillator has maximum speed $24\,\mathrm{m\,s^{-1}}$ and amplitude 5.6 cm.

What is its angular frequency?

A $0.23\,\mathrm{rad\,s^{-1}}$

B $21\,\mathrm{rad\,s^{-1}}$

C $68\,\mathrm{rad\,s^{-1}}$

D $430\,\mathrm{rad\,s^{-1}}$

Your answer [1]

The correct formula here is $v_{max} = A\omega$. This means that to find the angular frequency, ω, you must divide the maximum speed by the amplitude. The amplitude is given in centimetres so that needs to be converted to metres. This gives 24/0.056 = 429 rad s^{-1}, giving the answer D.

Question 6

6 The Earth is surrounded by a gravitational field.

Which of the following statements is/are correct about the gravitational field lines near the **surface** of the Earth.

1 They are parallel.
2 They show the direction of the force on a small mass.
3 They are equally spaced.

A Only 1

B Only 1 and 2

C Only 2 and 3

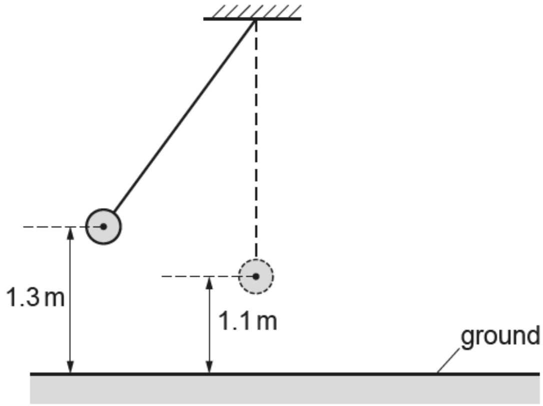
D 1, 2 and 3

Your answer [1]

Near to the surface of the Earth, the gravitational field is approximately uniform. This means that they are parallel and equally spaced. Gravitational field lines in general show the direction of the force on a small mass. This makes all 3 statements are correct, giving the answer D.

Question 7

7 A pendulum bob is oscillating in a vacuum.
The maximum height of the bob from the ground is 1.3 m and its minimum height is 1.1 m.



What is the maximum speed of the pendulum bob?

A $2.0\,\mathrm{m\,s^{-1}}$

B $3.9\,\mathrm{m\,s^{-1}}$

C $5.1\,\mathrm{m\,s^{-1}}$

D $26\,\mathrm{m\,s^{-1}}$

Your answer **[1]**

The key to this question is to consider the GPE lost and equate it to the KE gained. The GPE lost here = mass × 9.81 × 0.20 = ½ × mass × v^2. The masses cancel (which is why the mass wasn't given). This makes $v^2 = 3.924$. The most common wrong answer was B, as candidates had forgotten to take the square root. The correct speed is 1.98 $\mathrm{m\,s^{-1}}$ giving the correct answer, A.

Question 9

9 A solid molecular substance is supplied with energy and it starts to melt.

Which of the following pairs of quantities remains the same as the substance melts?

A Kinetic energy of molecules and internal energy of molecules.

B Potential energy of molecules and internal energy of molecules.

C Kinetic energy of molecules and temperature of substance.

D Potential energy of molecules and temperature of substance.

Your answer ☐ **[1]**

As a substance melts, the PE of the molecules increases, ruling out answers B and D. The temperature of a melting substance does not change and so the KE of the molecules cannot change, as the temperature and mean KE of molecules are directly proportional. This means that C must be correct. A cannot be correct since the internal energy is the sum of the KE and PE of the molecules. The KE is constant and the PE increases, meaning the internal energy must also increase.

Question 10

10 Which of the following shows the correct base units for pressure?

A $\mathrm{kg\,m^{-2}}$

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

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

D $\mathrm{kg\,m^{2}\,s^{-3}}$

Your answer ☐ **[1]**

Since P = F/A, we need the units of force and area in base units. F = ma, so force has the base units of kg m s^{-2} . Area's unit in base units is m^2. Hence pressure has the base units kg m s^{-1}/m^2 = kg m^{-1} s^{-2}, which is answer C.

Question 11

11 A student has collected some data on the Solar System.
The student plots a graph, but only two data points are shown below.

The distance from the centre of the Sun is *r*.

Which quantity *y* is represented on the vertical axis?

A Speed of a planet.

B Period of a planet.

C Gravitational potential of the Sun.

D Gravitational field strength of the Sun.

Your answer ☐ **[1]**

Answering this question needs knowledge of Kepler's Third Law and the formulae for gravitational potential and gravitational field strength, all of which are given in the data, formulae and relationships booklet.

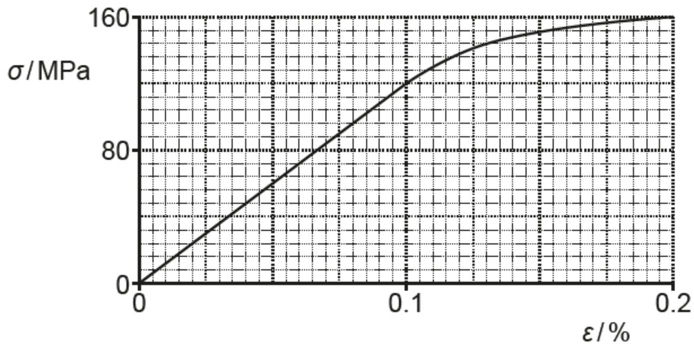
This relationship cannot be gravitational potential or gravitational field strength, as quantity y increases with distance from the Sun.

By equating the gravitational force on a planet with the centripetal force, it can be shown also that (orbital speed)^2 and orbital radius are inversely proportional. This graph does not show an inversely proportional relationship.

The formula sheet says that the square of a planet's period is directly proportional to the cube of the planet's orbital radius. In other words, the relationship shows that as orbital radius increases, so does the period, but not directly proportionally. This is the relationship shown on the graph, giving answer B.

Question 12

12 A graph showing the variation of the stress σ with strain ε for a material is shown below.



What is the Young modulus of the material?

A 6.0×10^4 Pa

B 1.2×10^9 Pa

C 8.0×10^{10} Pa

D 1.2×10^{11} Pa

Your answer **[1]**

The Young modulus is found by calculating the initial gradient of the material's stress-strain graph. The initial portion appears to be a straight line from the origin to the point (0.1, 120). The units on this graph are megapascals and %. This means the co-ordinates of the chosen point are in fact (0.1×10^{-2}, 120×10^6). Many candidates forgot to convert the strain into a decimal and left it as a percentage. Their answer was a factor of a 100 out, ie answer B. The correct answer is 120×10^6 / 0.1×10^2 = 1.2×10^{11} Pa. This is answer D.

Question 14

14 Some stars will evolve into white dwarfs.
The mass of the Sun is 2.0×10^{30} kg.

Which of the following **cannot** be the mass of a white dwarf?

A 1.2×10^{30} kg

B 2.0×10^{30} kg

C 2.7×10^{30} kg

D 3.2×10^{30} kg

Your answer **[1]**

The Chandrasekhar limit for the mass of a white dwarf is 1.4 solar masses. The mass of the Sun is 2.0×10^{30} kg, so the mass limit for a white dwarf is 2.8×10^{30} kg. Only star D exceeds this limit, so it cannot be a white dwarf.

Question 15

15 An astronomer analyses the light from a distant galaxy.
One of the spectral lines in the spectrum observed from the galaxy has wavelength 610 nm.
The same spectral line has a wavelength of 590 nm when measured in the laboratory.

What is the speed of this galaxy?

A $9.8 \times 10^{6}\,\mathrm{m\,s^{-1}}$

B $1.0 \times 10^{7}\,\mathrm{m\,s^{-1}}$

C $2.9 \times 10^{8}\,\mathrm{m\,s^{-1}}$

D $3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$

Your answer [ ] **[1]**

Option D is the speed of light, so the galaxy cannot be travelling this fast.

The change in wavelength for the galaxy is 20 nm. The laboratory wavelength for this light is 590 nm. The relationship we need is that the fractional change in wavelength for light from a galaxy approximately equals the fraction of the speed of light for that galaxy.

The fractional change in wavelength is 20/590 = 3.39 %

3.39% of the speed of light = $1.02 \times 10^{7}\,\mathrm{m\,s^{-1}}$, i.e. option B.

Option A was the most common incorrect response, which is the speed when the change is wavelength is divided by the wavelength of light from the galaxy.

Section B overview

Lots of candidates confidently answered questions with mathematical content. This was true of those questions which relied on GCSE maths topics. Candidates have clearly rehearsed this type of question carefully.

Questions which required longer responses, such as the level of response items and Question 18(b), need to be answered well by any candidate wishing to gain a grade above grade C. It is these questions that candidates need to practise more effectively. Key to this would be to look carefully at the command word, such as 'show', 'describe' and 'explain', which require the candidate to direct their response accordingly. Guidance for this is available on the OCR website, along with excellent exemplar material.

Question 16 (a)

16 (a) Explain what is meant by the **ultimate tensile strength** of a material.

....

.... **[1]**

Ultimate tensile strength is the maximum stress a material can withstand without breaking or failing. The most common incorrect answer included descriptions of force rather than stress.

Question 16 (d)

(d) Explain why the work done on the cable when its extension changes from 3.0 mm to 4.0 mm is greater than when its extension changes from 1.0 mm to 2.0 mm.

....

....

.... **[2]**

This question is best answered by referring to the graph in the question. Exemplars 1 and 2 indicate the difference between a low level and a high level response.

Exemplar 1

Work is the force aplied over a distance.

If initial distance is larger then

the work will be larger. **[2]**

This exemplar shows a response that contains broadly true statements yet is only loosely linked to the context and so scored zero marks.

Exemplar 2

work done is equal to the area under the force extension graph and this area is larger for the area between 3 + 4 mm than 1 + 2 mm. **[2]**

This response is clearly and specifically about this context and uses the graph as supporting evidence. The link to the graph is that the area gives the work done and that a larger area for one region means a larger amount of work done for that region.

Question 17 (c)

(c) Use your answer in **(b)** to calculate the drag on the ball at time t = 0.25 s.

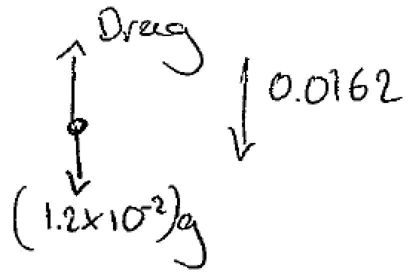
drag = ... N **[3]**

Most candidates correctly calculated the ball's weight. They had calculated the resultant force on the ball, using F = ma. The resultant force from the previous question was checked, as error carried forward rules applied. Exemplar 3 shows an excellent way of planning out how to answer this sort of question.

Exemplar 3

≈ 0.016 (2sf) F = 0.016 N **[1]**

(c) Use your answer in **(b)** to calculate the drag on the ball at time t = 0.25 s.



$0.0162 = (1.2\times10^{-2})g - D$

$D = 0.10152$

≈ 0.10 (2sf) drag = 0.10 N **[3]**

This candidate has drawn a free-body force diagram to make their intention clear. From it, they know that the resultant force must equal the weight minus the drag. From there they have found the drag force.

Question 17 (d) (i)

(d) The student now adds a small amount of sand inside the hollow ball.
As before, the ball is dropped from rest and it also reaches terminal velocity before it reaches the ground.

(i) Describe how the forces acting on the sand-filled ball at $v = 0.50\,\text{m}\,\text{s}^{-1}$ compare with the forces acting on the hollow ball at this speed.

....

....

....

.... **[2]**

Lots of candidates described the familiar ideas involving drag increasing with speed until the drag equals the weight's magnitude. The question was constructed to be simpler than this and asks to compare the forces on the 2 balls at a given speed. The weight of the sand-filled ball is larger. The 2 balls are identical in shape so at the same speed will have the same drag force.

Know what is coming!

Reading through to the end of the whole question is sensible. The answer candidates gave for Question 17(d)(i) would have formed part of the answer for Question 17(d)(ii), so valuable time can be saved by planning your answers for each part.

Question 17 (d) (ii)

(ii) Explain why the terminal velocity of the sand-filled ball will be greater than the terminal velocity of the hollow ball.

....

....

....

.... **[2]**

The first mark here was for the knowing that the condition for terminal velocity was required, linked to the idea of the sand-filled ball having a larger weight. The second mark was more difficult to achieve, since a clear link between increased speed and increase drag was required.

Question 18 (a) (ii)

(ii) Calculate the amplitude *A* of the oscillations.

A = ... m **[2]**

As the mass is pulled down before release, the mass is away from the equilibrium position. This means that the sine relationship between displacement and time cannot be correct. Many candidates got this idea correct.

The relationship $x = A\cos(\omega t)$ requires that the value of ωt is expressed in radians. This meant that to calculate the amplitude correctly, the calculator has to be in radians mode, rather than degrees mode.

Question 18 (b)

(b) The mass-spring system shown in Fig. 18.1 is now made to oscillate in **air**.

Different types of energy are involved in the oscillations of this mass-spring system.

Describe the energy changes that will take place as the mass moves from the lowest point in its motion through the equilibrium position to the highest point in its motion.

.... **[4]**

The best way to answer this question is to plan out what happens to each of the relevant energy types. Exemplar 4 starts off well yet is insufficient. Exemplar 5 is far clearer.

In this case the relevant energy types are elastic potential, gravitational potential and kinetic energy. Candidates often carefully recalled the details of energy changes for a horizontal mass-spring system, which was incorrect.

Earlier in the question, the candidates were told that the spring is always under tension. This means that the elastic potential energy cannot be zero or indeed negative.

At the bottom and the top of the motion, the kinetic energy of the system is zero, as the objects have zero velocity. At the equilibrium position, the kinetic energy of the system is maximum.

Responses that included merely 'potential energy' were too vague, unless it was clear that the potential energy of this system is the sum of both the gravitational and elastic potential energies.

Exemplar 4

Describe the energy changes that will take place as the mass moves from the lowest point in its motion through the equilibrium position to the highest point in its motion.

At lowest point there is maximum elastic potential energy
At highest point it has maximum gravitational potential energy
During inbetween lowest and highest point GPE → kinetic energy
which changes into elastic potential.

The first 2 statements in this response are true yet not enough. The third statement is untrue, as it implies that GPE is decreasing (and so contradicts the second statement) and also states that the elastic potential energy is increasing. Zero marks.

Exemplar 5

Describe the energy changes that will take place as the mass moves from the lowest point in its motion through the equilibrium position to the highest point in its motion.

~~KE~~ Kinetic energy – Increase from 0 to max from lowest to equilibrium, decrease back to 0 from equilibrium to highest.
Gravitational P.E – Increase from lowest to highest point.
Elastic P.E – Decrease from lowest to highest point

This response is separated out into the 3 main energy types. The changes for each of the types is correct. The only thing they haven't mentioned is that the total energy of the system will decrease because of the damping effect of the air. 3 marks.

Question 18 (c) (i) and (c) (ii)

(c) Fig. 18.2 shows the mass and spring now attached to a mechanical vibrator, which can oscillate with variable frequency.

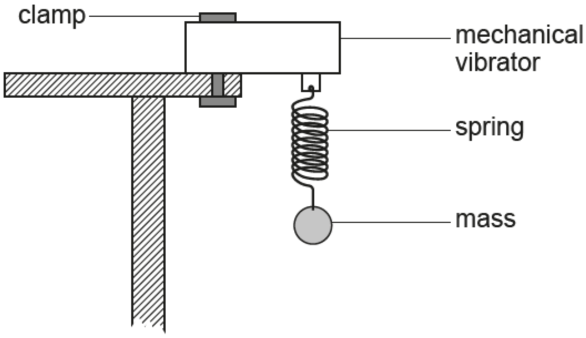


Fig. 18.2

The mass oscillates in air.

(i) The vibrator frequency is varied from 0 Hz to 2.5 Hz.
On Fig. 18.3, sketch a graph to show the variation with vibrator frequency of the amplitude of the mass. Label your graph **K**.

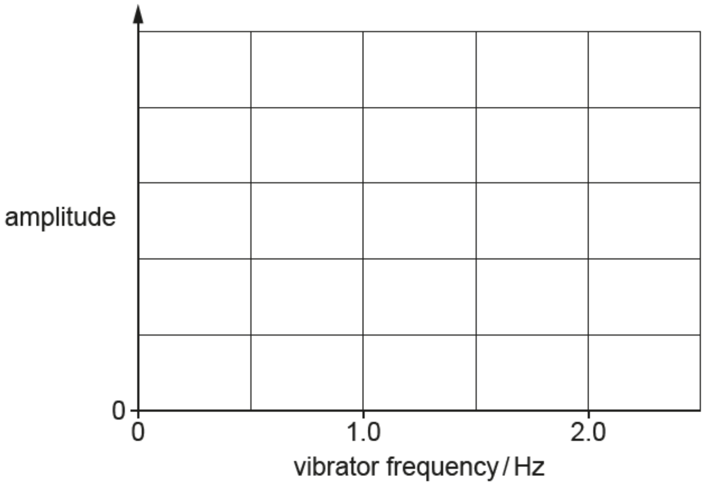


Fig. 18.3

[2]

(ii) A light disc is now attached to the mass to increase the damping.
The vibrator frequency is again varied from 0 Hz to 2.5 Hz.
Sketch a second graph on Fig. 18.3 to show the new variation of the amplitude.
Label this graph **D**. **[1]**

The correct shape for Question 18(c)(i) is a standard resonance curve. The natural frequency of this system is 1.4 Hz, as stated in Question 18(a). This means that the peak of the curve should come at 1.4 Hz.

The curve for Question 18(c) needed to be of lower amplitude throughout the frequency range (not including at 0 Hz). Some candidates put the peak of curve D at the same frequency as curve K and others put the peak of curve D slightly to the left. Both were given the mark.

Question 18 (c) (iii)

(iii) Explain why the phenomenon demonstrated in this experiment can cause problems for engineers when designing suspended footbridges.

....

....

....

.... **[2]**

Many candidates linked the possibility of a driving force, such as footsteps or the wind, giving a driver frequency at or near the natural frequency of a bridge and that this phenomenon is known as resonance. The second mark was for a link of the resonance idea of maximum amplitude to a consequence, such as a bridge shaking itself apart or being too unstable for use.

Question 19 (a)

19 (a) A car is travelling along a straight road at $18\,\mathrm{m\,s^{-1}}$.
The driver sees an obstacle and after 0.50 s applies the brakes.
The **stopping** distance of the car is 38 m.

Calculate the magnitude of the deceleration of the car when the brakes are applied.

deceleration = ... $\mathrm{m\,s^{-2}}$ **[3]**

Many candidates use the stopping distance for the braking distance of the car, giving a deceleration that was too low and scoring 1 mark only. More successful candidates remembered to calculate the thinking distance involved (9 m) and subtract this from the stopping distance to give a braking distance of 29 m. Algebraic rearrangement, substitution and evaluation from then on was excellent.

Question 19 (b)

(b)* A student rolls a marble at different speeds on a carpet to model the braking of a car.

The student wishes to investigate how the total distance *x* travelled before the marble stops (braking distance) depends on its initial speed *v*.

The speed *v* and distance *x* are related by the equation $\frac{1}{2}mv^2 = Fx$ where *m* is the mass of the marble and *F* is the constant frictional force acting on the marble.

- Describe how an experiment can be conducted in the laboratory to investigate the relationship between *v* and *x*.
- Explain how the data can be analysed to determine *F*. **[6]**

Most candidates made excellent attempts at describing this investigation. The analysis section was particularly well completed compared with previous sessions. Many of these investigations would have been successful had they been given as instructions to year 12 students as shown by Exemplar 6. The higher ability candidates distinguished themselves by being clear about how they were going to measure or calculate the speed of the marble and do that in a predictable way. This is shown best by exemplar 7.

Exemplar 6

- Describe how an experiment can be conducted in the laboratory to investigate the relationship between v and x.
- Explain how the data can be analysed to determine F. **[6]**

Using a light gate on a rough surface, measure initial speed of each different speeds (6 different). Measure 'x' distance before stopping with a metre ruler or tape measure and measure from point it leaves light gate ~~to~~ the point where it stops. Record all 6 reading in a table and plot a graph of v^2 against x drawing a line of best fit with a ruler which may go through the origin if relationship v^2 against x is true.

$\frac{1}{2}mv^2 = Fx$ gradient $= \frac{2F}{m}$

$mv^2 = 2Fx$

$v^2 = \frac{2F}{m}x$

$y = mx$

to find gradient of of line of best fit draw a large triangle

To find the mass of the marble use a scale

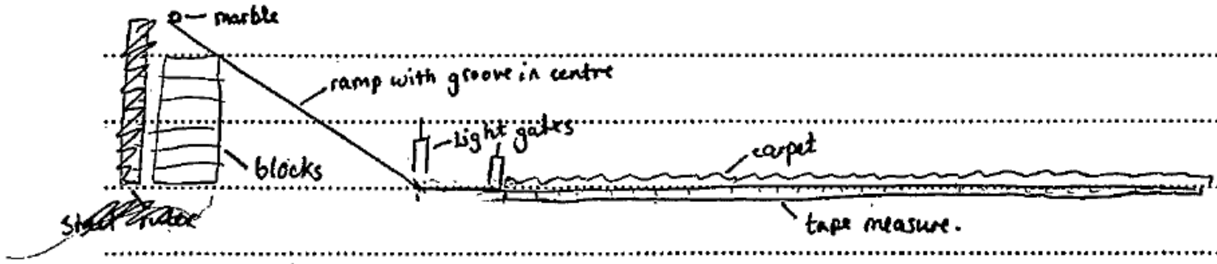
then the ~~Frictional force = gradient of line of best fit x mass~~

Frictional force $= \frac{\text{gradient of line of best fit} \times \text{mass of marble}}{2}$

This response is a very good attempt. They have employed a light gate to measure the speed, without much explanation of how that device would calculate the speed itself. The analysis is sound, with a clear indication of what they would do with the data and how the relationship in the question matched up to a straight line of best fit. The candidate has made sure that they have explained how to calculate *F* from the gradient, rather than leaving it to the reader to work it out for themselves. This response scored Level 2.

Exemplar 7

- Describe how an experiment can be conducted in the laboratory to investigate the relationship between v and x.
- Explain how the data can be analysed to determine F. **[6]**



~~+ measure height of ramp which should have a smooth surface~~

• ① Put blocks under a ramp with a groove in centre - this makes sure marble rolls in straight line. Start with maximum number of blocks.

② release marble without pushing from top of the ramp. Measure its start velocity as it begins to roll along the carpet using 2 light gates a small distance apart (which should be measured with a ruler) along a smooth surface where edge of carpet is at the start of the 2nd light gate. find velocity by recording time for ball to travel between gates with a data logger, and using $v = \frac{d}{t}$. The ball then rolls along the carpet for a distance, ~~d~~ and stops. Record this value next to v in a table. Repeat this twice more for ~~a value~~ ~~of~~ the same number of blocks as initial speed, v, should be the same. ~~Calculate average~~ Find average distance travelled for a value of v. Take one block out from under the ramp to change its height, and therefore v. Repeat step 2 for the new ramp height. Do this until there is only one block under the ramp.

③ Plot a graph of v^2 against x. Draw a straight line of best fit through the origin, since $v^2 \propto x$. The gradient will be $\frac{2F}{m}$. You can determine m by measuring mass of the ball with a ballance. You can find F by calculating gradient $\times \frac{m}{2}$

Additional answer space if required.

This response is similar in many ways to the previous exemplar. The difference is that the candidate has explained carefully how they will achieve different speeds and equally, how 2 light gates connected to a datalogger will measure the time of transit between the gates. The calculation of the speed v is easy to spot as the distance between the light gates divided by the time between them. Furthermore, there is reference to repeat readings for given v and an average distance for x. The analysis to find F is not quite as explicit as that in the previous exemplar, yet it is easily sufficient for a Level 3 response.

Question 20 (a) and (b)

20 A bicycle manufacturer carries out tests on the braking system of their new model.
A cyclist on this new bicycle travels at a constant initial speed U.
The cyclist applies the brakes at time $t = 0$ and the bicycle comes to a stop at time $t = 2.0$ s.

Fig. 20.1 shows the variation of the braking force F on the bicycle with time t.

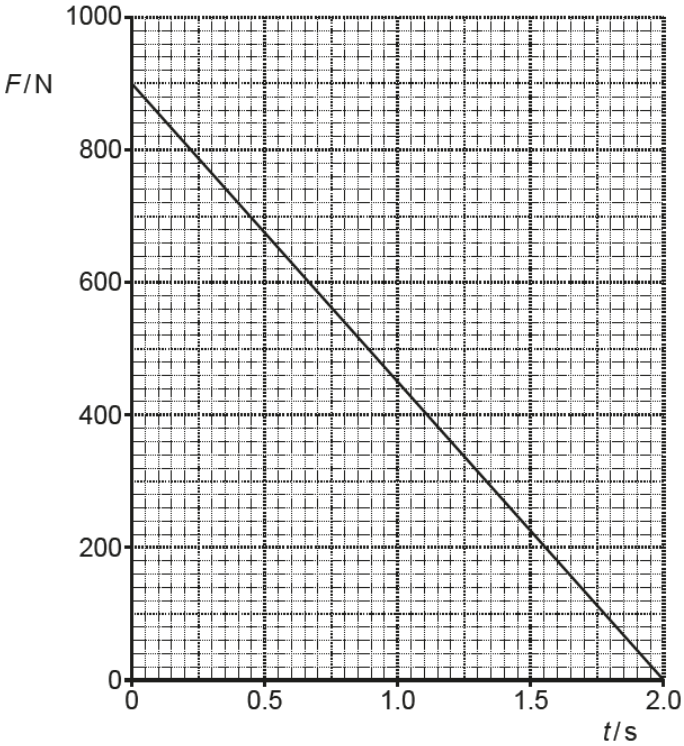


Fig. 20.1

(a) Use Newton's second law of motion to explain the physical quantity represented by the area under the graph shown in Fig. 20.1.

....

....

.... **[2]**

(b) The total mass of cyclist and bicycle is 71 kg.

Use Fig. 20.1 to calculate the initial speed U.

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

It was good to see that most candidates understood that Newton's second law of motion is more than the statement that *F=ma*. Many had successful attempts with some candidates missing that it is the rate of change of momentum, rather than the change of momentum that is required. About two-thirds of candidates also correctly indicated that the area under the graph represents the impulse or the change in momentum.

In Question 20(b), some candidates assumed, incorrectly, that the maximum force multiplied by the time taken would give the change in momentum and so scored zero marks. Rather more simply divided the maximum force by the mass, which gave the right answer yet with incorrect physics. This approach also scored zero. In fact, more successful responses made it clear that the area of the triangle on the graph was the impulse and that that area gave a change in momentum of 900 Ns.

Question 20 (c)

(c) Complete Fig. 20.2 to show the variation of the speed of the bicycle from $t = 0$ to $t = 2.0$ s.

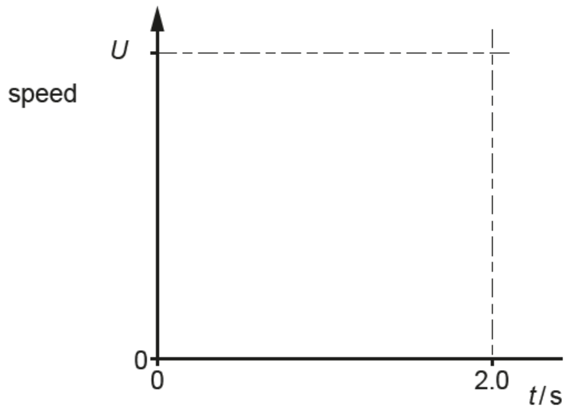


Fig. 20.2

[2]

Successful candidates spotted that the resultant force, the acceleration and hence the gradient of this speed- time graph decreased in magnitude with time. A constant gradient, ie a straight line between (0,U) and (2.0,0), can only be achieved by a constant decelerating resultant force.

This gives a curve that starts off (0,U) with a steep negative gradient and finishes with a small negative gradient at (2.0,0).

Question 21 (b)

21 A substance can exist as a crystalline solid, a liquid or a gas.
A solid sample of the substance is placed in a sealed container and heated at a constant rate until it changes into a gas.

Fig. 21 shows the variation with time t of the temperature θ for the substance.

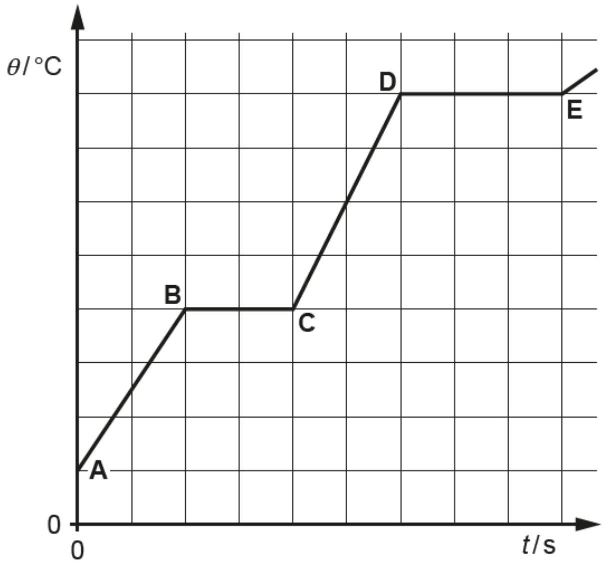


Fig. 21

(b) Use Fig. 21 to explain how the specific heat capacity of the liquid compares with the specific heat capacity of the solid.

....

....

....

.... **[2]**

Many candidates realised that the gradients of the lines AB and CD were related to the specific heat capacities of the solid and liquid states. Higher level responses included the formula relating energy change, mass, specific heat capacity and the temperature change, and how that formula related to the gradient of the line on a temperature-time graph. Once that link was established, the lower gradient indicates a larger specific heat capacity.

Question 21 (c)

(c) State what is meant by the **internal energy** of the substance.

....

....

.... **[1]**

This is a simple definition that many candidates recalled well. Lower level responses missed out that this is to do with the kinetic energy and potential energy of **particles**.

Question 21 (d) (i)

(d) Beyond the point **E** in Fig. 21, the substance behaves as an ideal gas.

(i) The mass of a gas molecule is 4.8×10^{-26} kg.
Calculate the root mean square speed of the gas molecules at a temperature of 250 °C.

root mean square speed = ... m s^{-1} **[3]**

The key to this question is equating 2 formulae. The first is the familiar ½ m v^2 for kinetic energy. In this case, the squared speed will be the mean squared speed of the particles. The second is the connection between average kinetic energy of a particle at absolute temperature, T, $E_k = 3/2\ k\ T$.

If candidates did that, then they not only scored the first mark but also could go on to complete the question. A common error was to forget to find the square root, as the question asks for the root mean square speed.

Question 21 (d) (ii)

(ii) Calculate the internal energy of 1.3 moles of the gas at 250 °C.

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

There were 2 ways to answer this question. The first was to find the kinetic of one particle using the mean square speed and the second was to find the kinetic energy of one particle using the absolute temperature. Lower level responses stopped at that point, or there was misunderstanding how to scale that value up to the whole gas.

For either route, the value for one particle needed to be multiplied by the number of particles in the gas. This can be found by multiplying the number of moles by the Avagadro constant given in the data, formulae and relationship booklet.

Question 23 (a)

23 (a)* In 2017, an ultra-cool star TRAPPIST-1 was discovered with at least five of its own orbiting planets. Astronomers are interested about the possibility of finding life on some of the planets orbiting TRAPPIST-1.

The table below shows some data.

	TRAPPIST-1	**Sun**
Luminosity L/W	2.0×10^{23}	3.8×10^{26}
Surface temperature T/K	2500	5800
Radius of star/m	R	7.0×10^{8}
Distance between Earth and Sun/m		1.5×10^{11}
Distance between planets and TRAPPIST-1/m	1.6×10^{9} to 9.0×10^{9}	

The temperature T in kelvin of a planet, its distance d from the star and the luminosity L of the star are related by the expression

$$\frac{T^4 d^2}{L} = \text{constant.}$$

- The average temperature of the Earth is about 290 K. Explain how life may be possible on some of the planets orbiting TRAPPIST-1.
- Use your knowledge of luminosity to show that the radius R of TRAPPIST-1 is smaller than the Sun.
- Support your answers by calculations. **[6]**

This level of response question was very well answered, largely due to the highly mathematical content. Higher level responses showed clarity of method as well as one of a range of ways of supporting the idea that life may be possible on the planets of TRAPPIST-1.

Many candidates opted to show that that the temperature of the nearest planet was approximately 430 K while that at the furthest planet was approximately 180 K. The argument went that there must be a distance at which the temperature was approximately 290 K. Other methods found the distance from TRAPPIST-1 that would give a surface temperature of 290 K and showed that lay within the range of distances given in the table.

Question 23 (b) (ii)

(b) Kepler's third law can be applied to a satellite in a geostationary orbit around the Earth.

(ii) The mass of Earth is 6.0×10^{24} kg.
Calculate the radius of the circular path of a satellite in a geostationary orbit around the Earth.

radius = ... m **[2]**

The radius of the orbit of a geostationary satellite was found with ease by the majority of candidates by using the formula in the data book or by looking at their response for part 23(b)(i). There were a few ways of generating an arithmetical error, such as using the square root instead of the cube root for the final step, getting the wrong power for the time or by using a time equal to one year instead of one day.

Question 24 (a) (i)

24 (a) Proxima Centauri is the closest star to Earth.
Fig. 24.1 shows the apparent positions of this star against the background of very distant stars as seen from the Earth over a period of exactly 6 months.

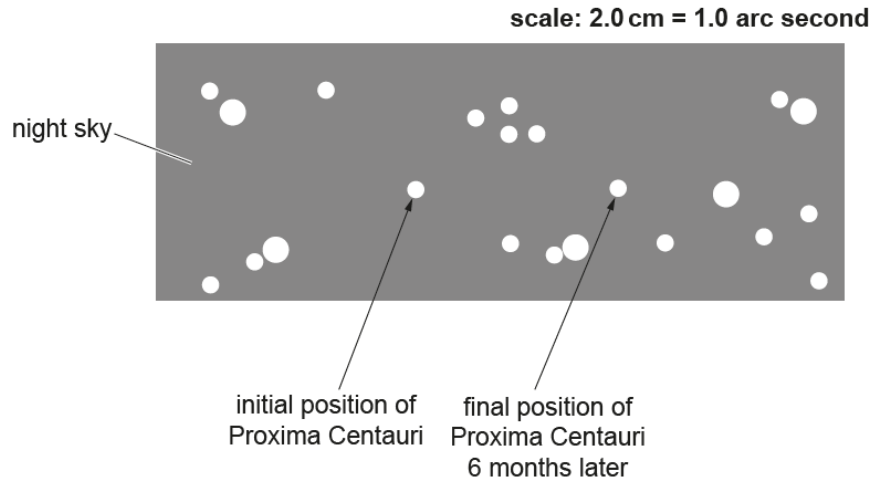


Fig. 24.1

The parallax angle for Proxima Centauri can be determined from Fig. 24.1 using the scale provided.

(i) Show that the parallax angle *p* for Proxima Centauri is about 0.8 arc second.

[2]

Almost all candidates scored a mark for measuring the distance between promixa centauri's positions 6 months apart. The scale was well understood, giving an angle of approximately 1.5 arc seconds. The parallax angle is defined to be half of this value, giving a parallax angle in this case of 0.75 arc seconds. This final step was what prevented candidates receiving the second mark.

Question 24 (a) (ii)

(ii) Use your answer in **(i)** to calculate the distance *d* of Proxima Centauri from the Earth in light-years (ly).

1 pc = 3.26 ly

d = ... ly **[2]**

Most candidates used the data in the previous part of the question ie that the parallax angle was 0.8 arc seconds or trusted their own value which was close to 0.8 arc seconds. Nearly everyone that presented a distance in parsecs could then calculate the distance in light years.

Question 24 (b) (i)

(b) The galaxies in the Universe may be assumed to be distributed uniformly through space.

In this model, the separation between two neighbouring galaxies is 1.4×10^{23} m and each galaxy occupies a cube of space of volume 2.7×10^{69} m^3 as shown in Fig. 24.2.

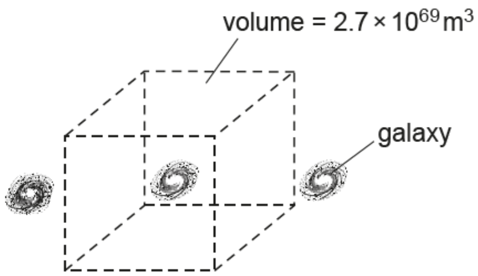


Fig. 24.2

There are on average 10^{11} stars in each galaxy and the mass of an average star is about 2.0×10^{30} kg.

(i) Estimate the gravitational force between two neighbouring galaxies.

force = ... N **[2]**

While some lower level responses included an attempt to find the gravitational field strength rather than the force most selected the correct formula. After selecting the correct relationship, most candidates could then correctly find the force, provided that they remembered to multiply the masses and square the distance of separation.

Question 24 (b) (iii)

(iii) Suggest why the actual mean density of the Universe is different from the value calculated in **(ii)**.

....

.... **[1]**

This was a question about challenging the model of the universe. The model takes into account an average mass and average distance of separation, so answers that referred to a variation in masses or distances between galaxies did not score. Higher level responses included that the universe was expanding, so that the distances involved were always changing, or that dark matter was not included in the calculations. There was no indication that candidates were constrained by time in this paper.

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