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A LEVEL

Examiners' report

PHYSICS A

H556
For first teaching in 2015

H556/01 Summer 2018 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 H556/01 series overview

H556/01 is one of the three examination components for the new revised A Level examinations. 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.
- Used imprecise language to describe quantities or didn't refer to a quantity at all, e.g. "The Universe is the same everywhere" instead of "The universe has a constant density throughout".

This examination produced a very wide range of marks, from 2 to 99 out of 100, with most candidates displaying either good or excellent recall of points of physics. The mean score was just under two marks lower 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.

Candidate's scripts are scanned, clipped and then marked by examiners. It is important that answers are written as far as possible within the spaces provided or, failing that, on the additional pages at the back of the answer booklet. Most candidates took this advice from last year, except on Q17ci, where many responses leaked into Q17cii.

Exemplar 1

(i) Explain briefly the overall shape of the graph in Fig. 17.3.

From $r = (1\times10^{10}$ m to 4.4×10^{10} m) the resultant gravitation field strength is weaker as Mars is getting further away from us. Since $g = -\frac{GM}{r^2}$, g is inversely proportional to r^2 so it's a curve with decreasing gradient. At this period earth have a small field strength than Mars so earth is attracted to it, after 4.4×10^{10} m it goes to negative as earth have large field strength than Mars so the resultant is toward earth. **[2]**

(ii) Use the value of r when $g = 0$ from Fig. 17.3 to determine the ratio

$$\frac{\text{mass of Earth}}{\text{mass of Mars}}.$$

When $g = 0$

$r = 4.4\times10^{10}$ m

$$\frac{GM_{earth}}{r^2} = \frac{GM_{mars}}{r^2}$$

This is an example of where a candidate should use the additional space at the back of the booklet, rather than extending their response into the next question. Anything below the dotted answer line runs the risk of not being seen by the examiner.

Section A overview

The multiple choice questions were answered slightly better than last year, which is encouraging. It was interesting to see that some multiple choice questions, particularly questions 5 and 13, were not answered at all by some candidates. It is always a good idea to enter an answer for multiple choice questions!

Question 1

1 Which of the following units is **not** an S.I. base unit?

A ampere

B mole

C volt

D kilogram

Your answer ☐ **[1]**

About three quarters of all candidates recognised that the volt is not an S.I. base unit.

Question 4

4 The acceleration *a* of a simple harmonic oscillator is related to its displacement *x* by the equation

$$a = -25x.$$

What is the frequency of the oscillator?

A 0.80 Hz

B 1.3 Hz

C 4.0 Hz

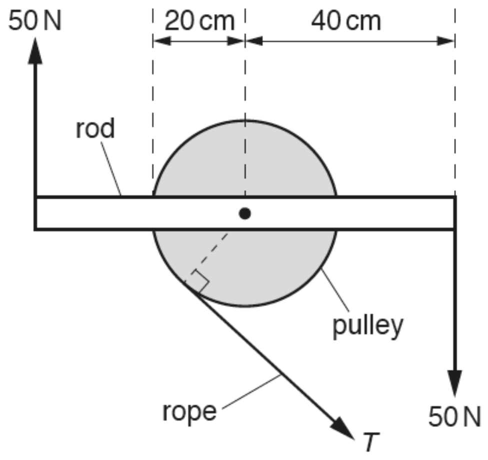
D 5.0 Hz

Your answer ☐ **[1]**

About three quarters of all candidates recognised that since $= -\omega^2 x$, the angular frequency of this motion was 5. Also, since $\omega = 2\pi f$, the frequency must be equal to $5/(2\pi)$.

Question 5

5 A rod is fixed to a pulley. Two 50 N forces are applied to the ends of the rod as shown. The tension in the rope attached to the pulley is *T*. The system is in equilibrium.



Not to scale

What is the moment of the tension *T* about the centre of the pulley?

A 10 N m

B 20 N m

C 30 N m

D 40 N m

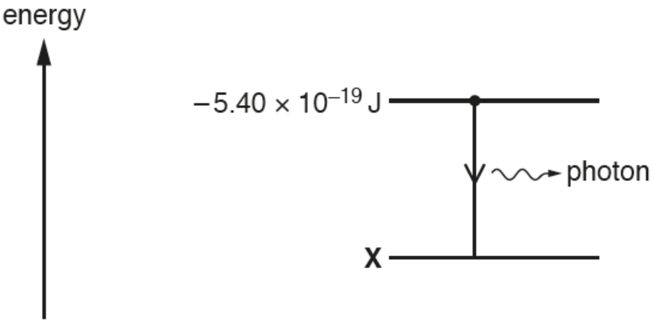
Your answer ☐ **[1]**

Please note an erratum notice was issued for this question. You can view this at the end of the report.

If this system is in equilibrium, then the moment due to tension T must equal the moment of the *couple* formed by the two 50 N forces. Many candidates forgot to include one of the two 50 N forces. Since the force is 50 N and the separation is 0.80 m, then the moment of the couple is 40 Nm.

Question 8

8 An electron makes a transition between the two energy levels shown below.



This transition produces a photon of frequency 4.10×10^{14} Hz.

What is the value of the energy level **X**?

A -2.68×10^{-19} J

B -2.72×10^{-19} J

C -5.40×10^{-19} J

D -8.12×10^{-19} J

Your answer ☐ **[1]**

The key to this question is to find the energy of the photon (from E = hf) which gives 2.72×10^{-19} J. The energy level X is this amount of energy *below* -5.40×10^{-19} J, which can only be answer D.

Question 9

9 A pendulum is oscillating in air and experiences damping.

Which of the following statements is/are correct for the damping force acting on the pendulum?

1 It is always opposite in direction to acceleration.
2 It is always opposite in direction to velocity.
3 It is maximum when the displacement is zero.

A Only 1 and 2

B Only 2 and 3

C Only 3

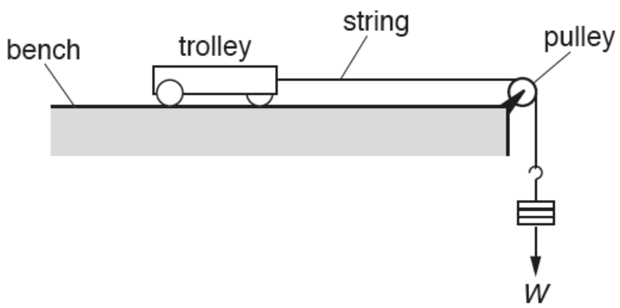
D 1, 2 and 3

Your answer [ ] **[1]**

The damping force is always opposite in direction to velocity. If the displacement is zero, then the speed is greatest and hence the damping force is also greatest in magnitude. The damping force is *not* always opposite in direction to acceleration, although the displacement must be, according to the definition of SHM.

Question 10

10 A trolley of mass M is pulled along a horizontal table by a force W provided by a mass hanging from the end of a string as shown.



Frictional forces are negligible. The acceleration of free fall is g.

What is the correct equation for the acceleration a of the trolley?

A $a = \frac{W}{M}$

B $a = g$

C $a = \frac{W}{2M}$

D $a = \frac{W}{M + \frac{W}{g}}$

Your answer [ ] **[1]**

Most candidates did not realise that both the suspended mass and the trolley are moving with acceleration *a*. The resultant force along for this composite object is *W* and the total mass is (M + W/g), giving D as the acceleration.

Question 11

11 The table below shows some data on two wires **X** and **Y**.

Wire	Young modulus of material / GPa	Cross-sectional area of wire / mm^2
X	120	1.0
Y	200	2.0

The wires **X** and **Y** have the same original length. The tension in each wire is the same. Both wires obey Hooke's law.

What is the value of the ratio $\dfrac{\text{extension of } \mathbf{X}}{\text{extension of } \mathbf{Y}}$?

A 0.30

B 1.7

C 2.0

D 3.3

Your answer [ ] **[1]**

The tension for both wires is the same, yet wire X has half of the cross-sectional area. This means the stress for X will be twice that of Y. Strain = stress/Young modulus, so with half of the stress and (120/200) of the Young modulus, the strain for X will be 2 x (200/120) or times that of the strain for Y. The original lengths for X and Y are the same, so the extension of X will be 3.3 times that of Y.

Question 13

13 Earth has a mass of 6.0×10^{24} kg and a radius of 6400 km.
A satellite of mass 320 kg is lifted from the Earth's surface to an orbit 1200 km above its surface.

What is the change in the gravitational potential energy of the satellite?

A 9.1×10^2 J

B 9.9×10^6 J

C 3.2×10^9 J

D 3.8×10^9 J

Your answer ☐ **[1]**

This question requires the candidate to calculate the gravitational potential energy when r = 6.4×10^3 m and again when r = 7.6×10^3 m. The difference of those two energies gives answer C. About two thirds of all candidates got this correct.

Question 14

14 The volume of one mole of an ideal gas is *V*. The gas exerts pressure *p* and has thermodynamic temperature *T*.

Which of the following has the units $\text{J mol}^{-1}\text{K}^{-1}$?

A pV

B $\frac{p}{T}$

C $\frac{V}{T}$

D $\frac{pV}{T}$

Your answer ☐ **[1]**

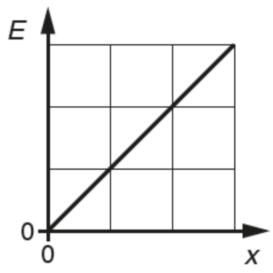
The unit $\text{J mol}^{-1}\text{ K}^{-1}$ is the same unit as the molar gas constant, such that pV = nRT. It follows that the unit of R must be the same as the unit of pV/T as 'n' has no units.

Question 15

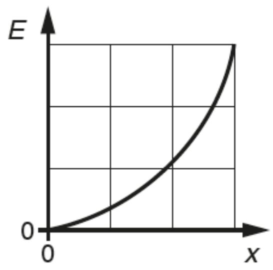
15 An object oscillates with simple harmonic motion.

Which graph **best** shows the variation of its potential energy *E* with distance *x* from the equilibrium position?

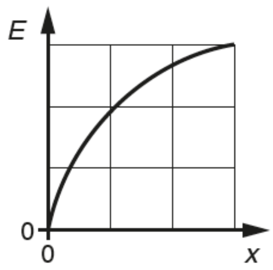
A



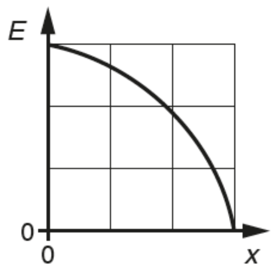
B



C



D



Your answer ☐ **[1]**

In SHM, when x = 0, the object is moving at its fastest and so has maximum KE. This in turn means that the PE must be minimum, eliminating option D. The speed of the object slightly away from the point where x=0 does not increase rapidly nor linearly. This only leaves option B.

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 LoR items and Q17cii, 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) (i)

16 (a) A tennis ball is struck with a racket.
The initial velocity v of the ball leaving the racket is 30.0 m s^{-1} and it makes an angle of 70° to the horizontal as shown in Fig. 16.
Air resistance is negligible

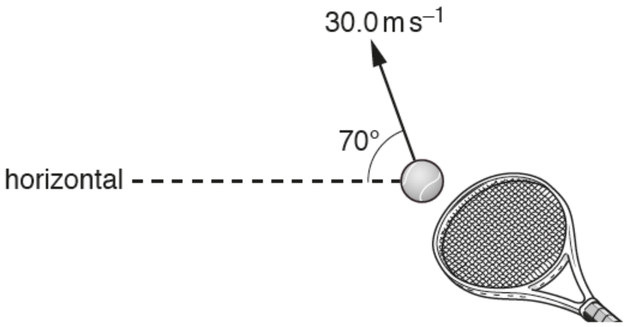


Fig. 16

(i) Calculate the vertical component of the initial velocity of the ball.

vertical component = ... m s^{-1} **[1]**

Question 16 (a) (ii)

(ii) Use your answer in **(i)** to show that the ball reaches a maximum height *h* of about 40 m.

h = ... m **[2]**

Question 16 (a) (iii)

(iii) Explain why the kinetic energy of the ball is not zero at maximum height.

....

.... **[1]**

Question 16 (a) (iv)

(iv) The mass *m* of the ball is 57.0 g.
Calculate the kinetic energy E_k of the ball when it is at its **maximum** height.

E_k = ... J **[2]**

Part (i) was particularly well answered by 95% of all candidates. Nine out of ten candidates scored full marks in part (a)(ii), as they remembered that the question asks to *show* that the maximum height is around 40m. Working for this type of question is essential. In part (a)(iii), three quarters of all candidates correctly talked about the ball still having a horizontal velocity (which wasn't zero) and therefore still possessing some KE. The key to this part (a)(iv), remembered by most candidates, was to use the horizontal component of velocity to find the KE at the maximum height. Some used the initial speed and others used the initial vertical velocity component found in part (a)(i).

Question 16 (b)

(b)* A metal ball is rolled off the edge of a horizontal laboratory bench. The initial horizontal velocity of the ball is *v*. The ball travels a horizontal distance *x* before it hits the level floor.

Use your knowledge of projectile motion to suggest the relationship between *v* and *x*. Describe how an experiment can be safely conducted to test this relationship and how the data can be analysed.

....

....

....

....

....

....

....

.... **[6]**

Many candidates had plenty to say that was sensible. There was plenty of evidence that candidates had seen this experiment or had performed a similar one themselves. A few confused the question, instead describing how to find the time of flight or that the ball was falling vertically. Others described what they thought would happen to the vertical component of velocity when they changed the vertical distance that the ball dropped.

Exemplar 2

Use your knowledge of projectile motion to suggest the <u>relationship</u> between *v* and *x*. Describe how an experiment can be <u>safely</u> conducted to test this relationship and how the data can be <u>analysed.</u>

make sure no one in way

As in a projectile the horizontal component of velocity is constant given air resistance is negligible then a equation of $x = \frac{1}{2}(u+v)t$ could become $x = vt$ where x is distance traveled v is velocity of ball and t is time of flight therefor for a constant time of flight it can be said $x \propto v$.

~~To test this it is very hard to keep time of flight constant as this is due to its time of freefall~~

To test this a ball would be rolled of a table at varying speeds. To calculate this speed a light gate can be used passing through the center of the metal ball. As distance travelled is equal to the diameter of the ball, measured by a ruler, speed can be calculated using distance/time from light gate. For safety the ball should land in sand as not to shatter or land on someones foot. This also makes measuring x much easier as x is equal to the horizontal distance from the edge of the table to the crater in the sand measured using a ruler. If the time taken to fall is kept constant measured by using a stop watch and controlled by raising or lowering the launch point when v is plotted against x on a graph it can be expected to be linear and pass through the origin.

In the first paragraph, the candidate has made clear that the time of flight is constant and goes on to explain why towards the end of the response. This supports the prediction that $v \propto x$. In addition, the candidate takes time to explain how to obtain data for both the horizontal velocity and horizontal distance. It was pleasing to see light gates and motion sensors being employed, with the best answers explaining how to use the data provided by the sensors to calculate the velocity of projection.

The exemplar response also includes the correct analysis. There is a graph of v against x and the resulting best fit straight line through the origin supports the idea that these two variables are directly proportional. Too many candidates did not mention the crucial statement about the line going through the origin, limiting their response to a high L1 or low L2.

Question 17 (a) (i)

17 (a) Phobos is one of the two moons orbiting Mars. Fig. 17.1 shows Phobos and Mars.

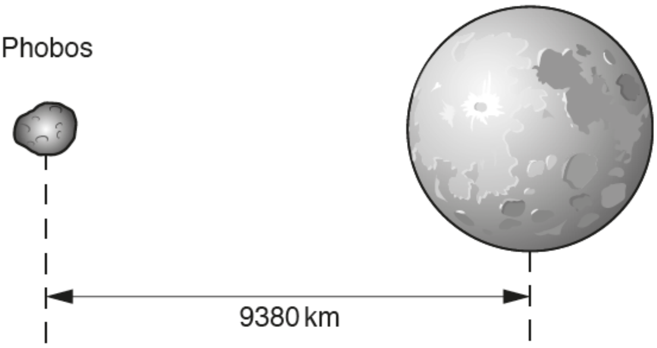


Fig. 17.1

The orbit of Phobos may be assumed to be a circle. The centre of Phobos is at a distance 9380 km from the centre of Mars and it has an orbital speed $2.14 \times 10^3\,\text{m}\,\text{s}^{-1}$.

(i) On Fig. 17.1, draw an arrow to show the direction of the force which keeps Phobos in its orbit. **[1]**

The examiners were quite lenient in this series in terms of the precise direction of the arrow, which should point towards the centre of Mars.

Question 17 (a) (ii)

(ii) Calculate the orbital period *T* of Phobos.

T = ... s **[2]**

Around four fifths of candidates got this right. Those that did not either poorly converted the radius from km or used the area rather than the circumference of the orbit.

Question 17 (a) (iii)

(iii) Calculate the mass *M* of Mars.

M = ... kg **[3]**

Many candidates successfully used the equation for Kepler's Third Law, which is encouraging. A quicker route was to find the Phobos's acceleration (from v^2/r) and equating that to the gravitational field strength at Phobos from Mars (GM_{mars}/r^2) and then rearranging to find the mass of Mars.

Question 17 (b) (i)

(b) The gravitational field strength at a distance *r* from the centre of Mars is *g*.

The table below shows some data on Mars.

g / N kg^{-1}	r / km	lg (g / N kg^{-1})	lg (r / km)
1.19	6000	0.076	3.78
0.87	7000		
0.67	8000	−0.174	3.90
0.53	9000	−0.276	3.95
0.43	10000	−0.367	4.00

(i) Complete the table by calculating the missing values. **[1]**

Although some candidates were confused by the appearance of 'lg', most candidates were not. This notation is on the specification and was used in the previous specification.

Question 17 (b) (ii) (1)

(ii) Fig. 17.2 shows the graph of lg (g/N kg^{-1}) against lg (r/km).

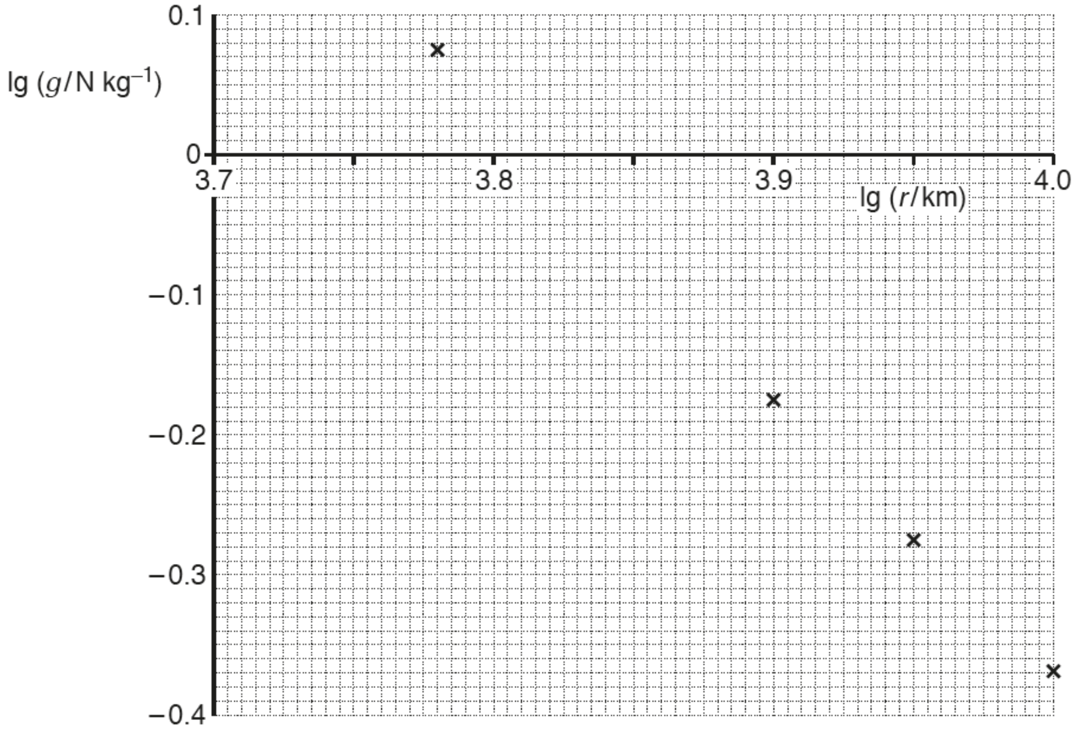


Fig. 17.2

1 Plot the missing data point on the graph and draw the straight line of best fit. **[2]**

Providing the candidate had entered values in the tables, the data point was almost always plotted correctly. The best fit line caused slightly more problems. Candidates should take a ruler into the examination and be careful about the positioning of the ruler for the fairest best fit straight line. The Practical Skills Handbook is helpful on this topic.

Exemplar 3

$\frac{dy}{dx} =$ (4, −0.37) (3.78, 0.076).

$$\frac{0.076 - -0.37}{3.78 - 4} = -2.02$$

[1]

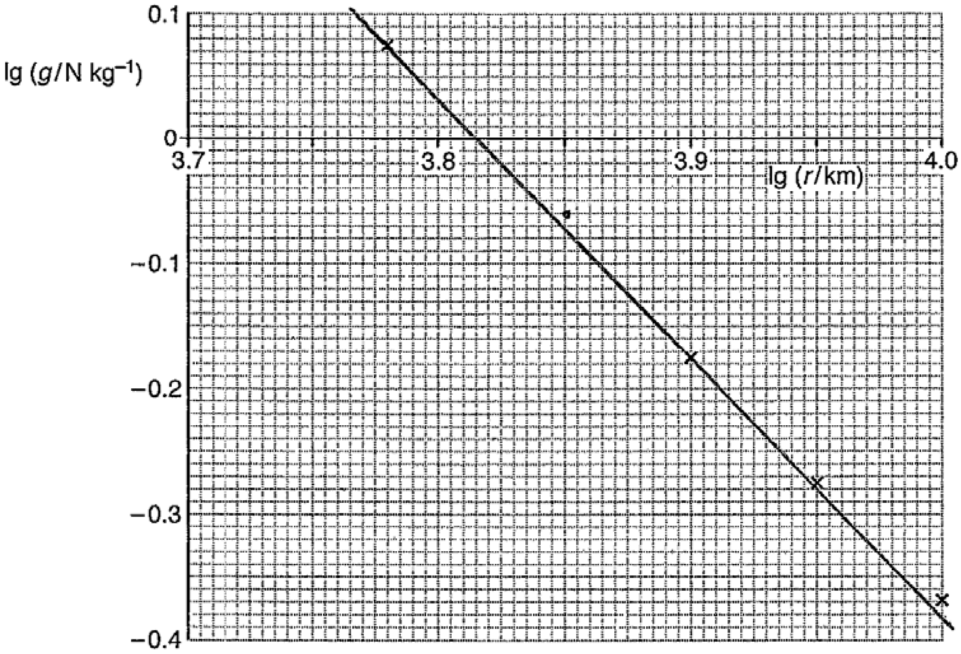


Fig. 17.2

In this example, the candidate's line has missed the final data point. The line of best fit for this item should just graze each of the given points.

Question 17 (b) (ii) (2)

2 Use Fig. 17.2 to show that the gradient of the straight line of best fit is −2.

[1]

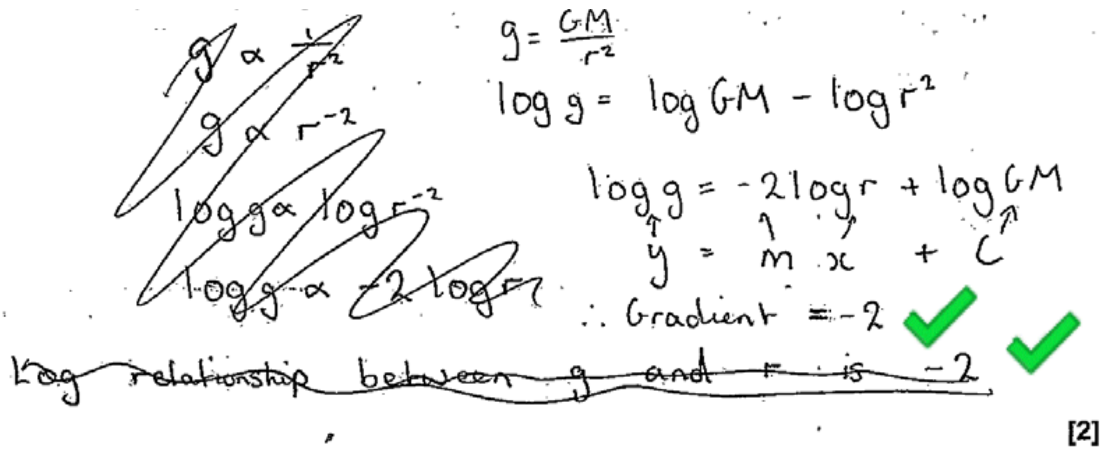
Most candidates correctly found the gradient of their best fit straight line.

Question 17 (b) (ii) (3)

3 Explain why the gradient of the straight line of best fit is −2.

[2]

Exemplar 4



The exemplar shows both an unsuccessful and a successful approach. The crossed-out working was typical across many candidates, with incorrect maths and no handling of the 'GM' term. The successful approach was very clear mathematically, as well as making a clear comparison with the general equation for a straight line.

Some candidates decided to find the gradient of their best fit line again, showing that they did not see the distinction between these two questions, despite the change in command verb.

Question 17 (c) (i)

(c) In July 2018, the closest distance between the centre of Mars and the centre of Earth will be 5.8×10^{10} m.
Fig. 17.3 shows the variation of the **resultant** gravitational field strength g between the two planets with distance r from the centre of the **Earth**.

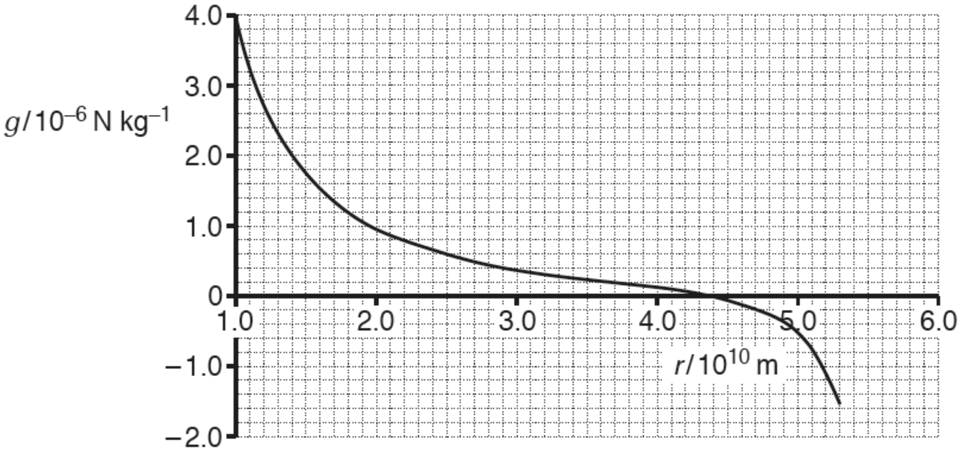


Fig. 17.3

(i) Explain briefly the overall shape of the graph in Fig. 17.3.

....

....

....

....

.... **[2]**

Most candidates mis-read the question and tried to describe the shape of the curve, rather than explain why the curve has that shape. Many candidates also mis-used the term 'exponential' to describe a curve that is related to $1/r^2$. Others thought that the graph showed the effect of Mars and the Earth on each other, rather than on a small mass between them. They went on to describe what happened when Mars and Earth were separated by an increasingly large distance.

It is good practice to be specific about which section of the graph you are talking about. 'When *r* is below 2.0×10^{10} m' is much clearer than 'At the start'.

Potential, potential difference, potential energy, field strength and force

These terms are all very similar yet subtly different and with differing formula. Be careful you know which is which.

Question 17 (c) (ii)

(ii) Use the value of *r* when *g* = 0 from Fig. 17.3 to determine the ratio

$$\frac{\text{mass of Earth}}{\text{mass of Mars}}.$$

$$\frac{\text{mass of Earth}}{\text{mass of Mars}} = \text{..} \quad \textbf{[2]}$$

To correctly answer this question, the candidate should equate the gravitational field strength from Earth (GM_{Earth}/x^2 where x is the distance to the point where g=0 from the centre of Earth) and the gravitational field strength from Mars (GM_{Mars}/y^2 where y is the distance to the point where g=0 from the centre of Mars).

Many candidates did not get this far, yet some that did substituted and re-arranged correctly get a value in the correct range.

Errors occurred when candidates were unsure of which distances to use in the equation. The commonest error was to use 0.9×10^{10} m for the distance of the zero-point since the graph stops at 5.3×10^{10} m, rather than using the data provided that the distance between the centres of the two planets was 5.8×10^{10} m and so the correct value for *r* was 1.4×10^{10} m.

Question 18 (a)

18 Wind turbines convert the kinetic energy of the wind into electrical energy.
Fig. 18 shows a wind turbine.

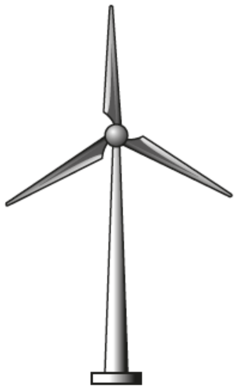


Fig. 18

(a) When the wind speed is $8.0\,m\,s^{-1}$, the kinetic energy of the air incident at the turbine per second is $1.2\,MJ\,s^{-1}$.
Calculate the mass of the air incident at the turbine per second.

mass per second = ... $kg\,s^{-1}$ **[2]**

A large majority of candidates got this right. Those that did not usually forgot to square the velocity.

Question 18 (b) (i)

(b) A group of engineers are investigating the design of wind turbines.
The maximum **input** power *P* from the wind is given by the equation

$$P = \frac{1}{2}\rho A v^3$$

where *A* is the area swept out by the rotating blades, ρ is the density of air and *v* is the speed of the wind.

(i) Show that the equation is homogeneous with both sides of the equation having the same base units.

[3]

Exemplar 5

$[\frac{1}{2}\rho A v^3] = (kg\,m^{-3})(m^2)(m s^{-1})^3$
$= kg\,m^{-3}\,m^2\,m^3 s^{-3}$ ✓
$= kg\,m^2 s^{-3}$ ✓

$[P] = J s^{-1}$
$= N\,m s^{-1}$
$= kg\,m s^{-2}\,m s^{-1}$
$= kg\,m^2 s^{-3}$ ✓

$\therefore [\frac{1}{2}\rho A v^3] = [P]$

$\therefore$ The equation is homogenous

Candidates generally made an excellent attempt at this question, although for many the working was difficult to follow.

In the exemplar, the candidate has made it very clear that they are considering the two sides of the equation separately and have reduced each unit to its S.I. base units as required by the question. The use of square brackets to distinguish between a quantity rather than a base unit was helpful.

Question 18 (b) (ii)

(ii) The input power to the wind turbine is 1.2 MW when the wind speed is 8.0 m s^{-1}.
The density of air is 1.3 kg m^{-3}.

Calculate the length *L* of the turbine blades.

L = ... m **[2]**

About two thirds of candidates got full marks on this item. By substituting the values into the formula, the area required is approximately 3600 m^2. Some candidates did not read the question and instead of thinking about area swept out being a circle, they took it to be square, giving the length of the blade to be $\sqrt{3600} = 60$ m.

Question 18 (b) (iii)

(iii) A wind farm is required to produce an output power of 50 MW when the average wind speed is 8.0 m s^{-1}. The efficiency of each wind turbine is 42%.

Calculate the minimum number *N* of wind turbines required to meet this demand.

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

Rather more candidates got this item right. Some candidates mis-converted the unit and got values that could not be right i.e. 1 or 10^6 yet the majority arrived at 99.2 and correctly stated that the minimum number of required turbines must be 100 and not 99.

Question 19 (a)

19 Fig. 19 is an incomplete Hertzsprung-Russell (HR) diagram of stars in our galaxy.

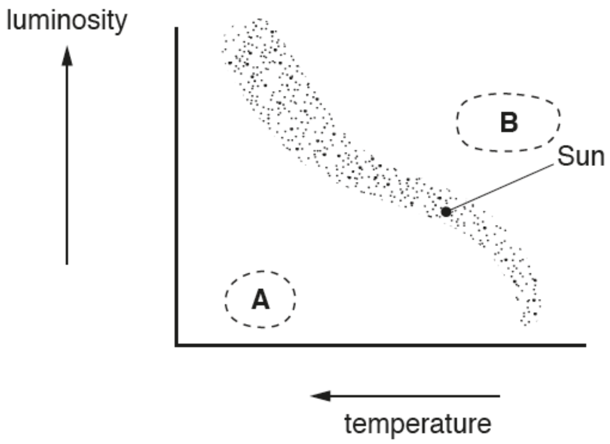


Fig. 19

The position of the Sun on the HR diagram is shown in Fig. 19.

(a) State the type of stars found in regions **A** and **B**.

A .... **B** .... **[1]**

Question 19 (b) (i)

(b) The Sun is a main sequence star. Its surface temperature is 5800 K. The wavelength of the emitted light at maximum intensity is 550 nm.

Beta Pictoris is also a main sequence star. The wavelength of the emitted light at maximum intensity from this star is 370 nm.

(i) Calculate the surface temperature of Beta Pictoris.

temperature = ... K **[2]**

Question 19 (b) (ii)

(ii) On Fig. 19, mark the likely position of Beta Pictoris with a letter **P**. **[1]**

This whole question was well answered in general. Very few could not identify white dwarf and red giant stars. The calculation of the surface temperature was straightforward with a minority suggesting that $\lambda_{max} \propto T$. In either case, most candidates plotted the position of Beta Pictoris on the HR plot successfully.

Question 20 (a)

20 (a) Use the equations for momentum and kinetic energy to derive an expression for the kinetic energy E_k of a particle in terms of its momentum p and mass m.

[2]

Question 20 (b) (i)

(b) Fig. 20.1 shows an electric motor used to lift and lower a load.

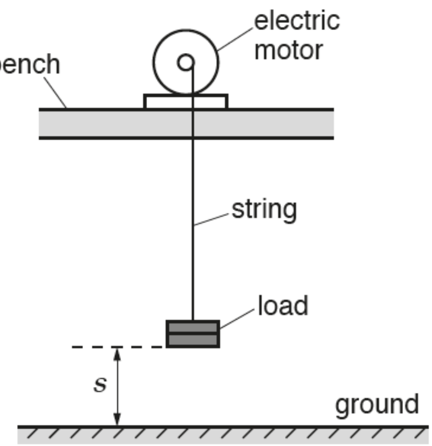


Fig. 20.1

At time t = 0 the load is on the ground with displacement s = 0.
Fig. 20.2 shows the variation of the displacement s of the load with time t.

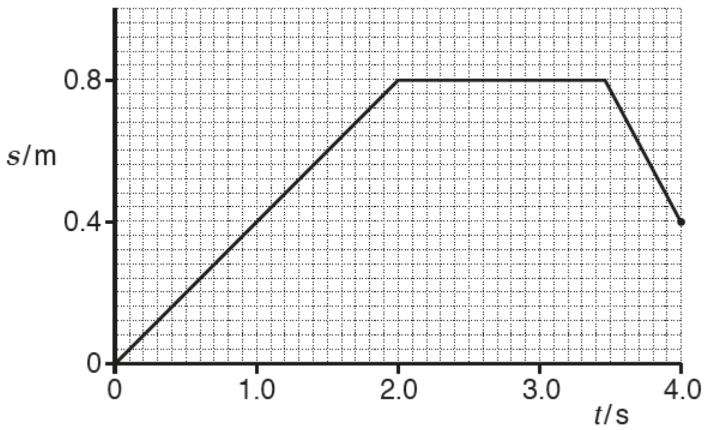


Fig. 20.2

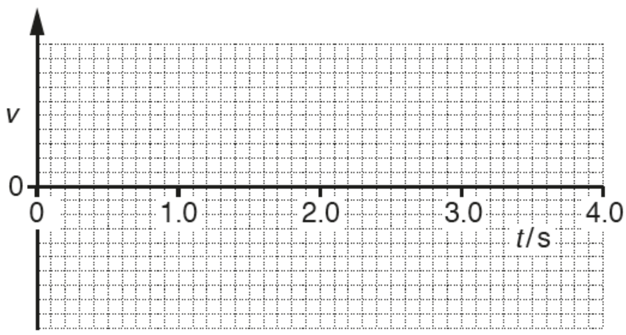


Fig. 20.3

(i) On Fig. 20.3, sketch a graph to show the variation of the velocity v of the load with time t. You do not need to insert a scale on the v axis. **[3]**

Question 20 (b) (ii)

(ii) Describe how the kinetic energy and the gravitational potential energy of the load varies from $t = 0$ to $t = 2.0\,\text{s}$.

....

....

....

.... **[2]**

Nearly four fifths of candidates completed 20a well, especially if they clearly stated the equations for momentum and kinetic energy. Those that did not generally forgot that the question required an expression with 'p' and 'm' in it. ½ pv was a common wrong answer.

20bi was answered well, with some candidates either slightly misreading the graph when the velocity became negative or not spotting that the line was steeper for the last section of the movement than it was in the first.

Most candidates spotted that the KE was constant because the velocity was constant. Rather fewer candidates explained that the GPE increased *at a constant rate*.

Question 20 (b) (iii) (1)

(iii) During the **downward** journey of the load, the string breaks at $t = 4.0\,\text{s}$. It then falls vertically towards the ground. The mass of the load is 120 g.
Air resistance is negligible.

1 Calculate the velocity V of the load just before it hits the ground.

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

Many candidates selected the correct equation, although did not realise that the load was not at rest when it was released. The initial velocity was found from the graph on page 22 of the paper and was 0.80 ms^{-1}.

Question 20 (b) (iii) (2)

2 The load hits the ground and comes to **rest** in a time interval of 25 ms.

Calculate the average force *F* exerted by the ground on the load.

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

Nearly three quarters of the candidates used the correct method for finding the average force acting on the load by considering the rate of change of momentum.

Question 21 (a)

21 Fig. 21 shows the drum of a washing machine.

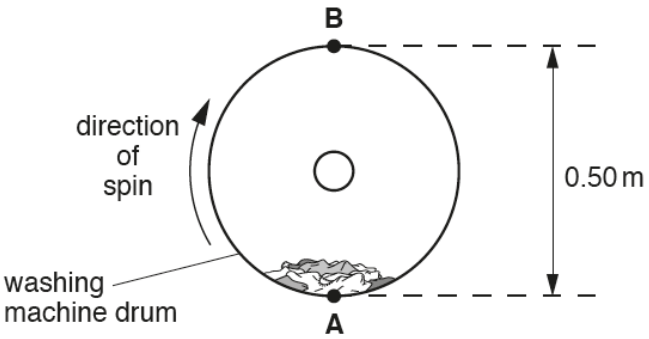


Fig. 21

The clothes inside the drum are spun in a **vertical** circular motion in a clockwise direction.

(a) When the drum is at rest, the weight of the clothes is equal to the normal contact force on the clothes at point **A**.

Explain why these two forces are not an example of Newton's Third Law of motion.

....

....

....

....

.... **[2]**

Many candidates incorrectly quoted Newtons' Third Law (N3L) or did not realise that a pair of N3L forces must be of the same type. The two forces in the question are acting on the same object, whereas N3L forces must act on different objects.

Some candidates thought that the clothes were in motion, while the question states that the clothes are at rest.

Normal Contact Force

Normal contact force is essentially an electrostatic force between the two objects in contact.

Question 21 (b)

(b) The drum has diameter 0.50 m. The manufacturer of the washing machine claims that the drum spins at 1600 ± 100 revolutions per minute.

Calculate the speed of rotation of the drum and the absolute uncertainty in this value.

speed = ... ± .... $m s^{-1}$ **[3]**

About half of the candidates got this item right or provided clear working to show where they were going. There was much confusion about which quantity was which. 1600 revolutions per minute refers to the frequency of the rotation, not the angular speed, angular frequency or the speed itself.

The percentage error of the frequency was 6.25%, prior to rounding. Some candidates multiplied this by their value for the speed to get the correct absolute uncertainty, although good practice is to round uncertainties to 1 SF.

Question 21 (c)

(c) The washing machine is switched off and the speed of the drum slowly decreases. The clothes at the top of the drum at point **B** start to drop off at a certain speed *v*.

At this speed *v*, the normal contact force on the clothes is zero.

Calculate the speed *v*.

v = ... $m\,s^{-1}$ **[3]**

This question was answered well by those above the mean result. When the machine is switched off, the clothes are still in circular motion and at point B, the resultant force is still the weight of the clothes plus the normal contact force.

This means at the critical speed when the clothes fall off at point B, the centripetal force will equal the weight of the clothes, since the question states that the normal contact force is zero.

Question 22 (a) (i)

22 (a) A helium atom **X** travelling at $610\,m\,s^{-1}$ makes an elastic collision with a stationary helium atom **Y**. The magnitude of the velocity of **X** after the collision is $258\,m\,s^{-1}$. The directions of the velocities of **X** and **Y** are as shown in Fig. 22.

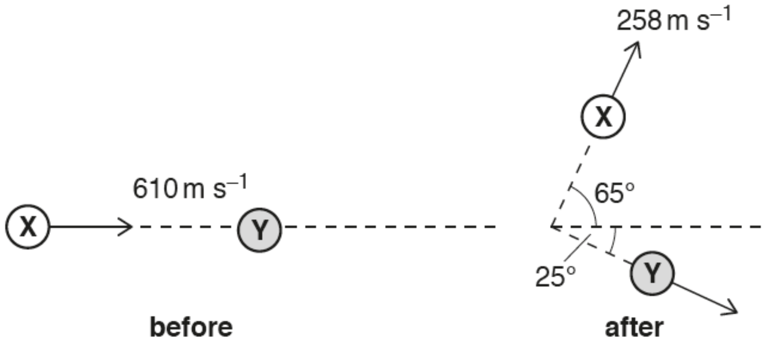


Fig. 22

(i) Explain what is meant by an *elastic collision*.

....

.... **[1]**

Question 22 (a) (ii)

(ii) The mass of a helium atom is 6.64×10^{-27} kg.
Calculate the magnitude of the momentum *p* of **Y** after the collision.

p = ... $kg\,m\,s^{-1}$ **[3]**

Most candidates correctly remembered that an elastic collision is one in which KE is conserved. In this series, it was acceptable to refer to 'no loss of KE'.

Using the idea that the KE was conserved would have made calculating the velocity of particle Y straightforward. Most candidates preferred a conservation of momentum approach, which of course still works. Many candidates remembered that momentum is conserved in both the x- and y-directions independently and consideration of either was enough. Some candidates forgot that trigonometry was necessary to complete this step, or made errors with which of sine or cosine was required.

Question 22 (b)

(b)* There is a lot of helium in the Universe. This was also true of the Earth when it was formed billions of years ago. However, only small traces of helium are now found in the atmosphere of the Earth.

Use the kinetic theory of gases to explain why only small amounts of helium are found in the Earth's atmosphere. Use the information below to do suitable calculations to support your answer.

- typical atmospheric temperature = 10 °C
- mass of helium atom = 6.64×10^{-27} kg
- escape velocity from the Earth = $11\,km\,s^{-1}$

....

....

....

.... **[6]**

Exemplar 6

$\frac{1}{2}m\bar{c}^2 = \frac{3}{2}kT$

$\bar{c}^2 = \frac{3kT}{m} =$ ~~3×1.38×10⁻²³×283~~

$\frac{3 \times 1.38 \times 10^{-23} \times 283}{6.64 \times 10^{-27}} =$

$\bar{c}^2 = 1764487.95$

$\bar{c} = 1328.34$

$\approx 1330\ ms^{-1}$

Particles move around randomly with random speeds. Collisions are elastic so KE is not lost. Most particles are moving at speeds around 1330 ms⁻¹ or a little less but given the random motion of particles, which follow a Boltzmann's distribution, a very little amount of these have speeds ≥ 11 kms⁻¹. Eventually all helium molecules should escape Earth's atmosphere but since helium nuceii are just alpha particles which are generated in radioactive reactions, these are constantly being produced. Hence, we can still find small amounts of helium today on Earth

L3

In correctly calculating the root means square speed and by being clear about how that has been calculated, this candidate has gained L2 already. There is a correct comparison of this speed with the escape velocity. There is also reference to the Boltzmann distribution of speeds, suggesting that even though a small fraction will have a sufficient velocity, over time those particles will escape.

Most candidates made good progress with the calculation or provided an alternative by calculating the mean KE of a particle and comparing that with the KE a particle with escape velocity would have. A significant fraction made a poor comparison of their value with escape velocity (e.g. that 1300 ms^{-1} was greater than 11 km s^{-1}) or compared the mean squared speed with the escape velocity.

Question 23 (a)

23 **(a)** According to the Cosmological principle, the Universe is isotropic, homogeneous and the laws of physics are universal.

State what is meant by the term *homogeneous*.

....

.... **[1]**

Just under half of the candidates got this term correct. The majority that did not confused this term with isotropic or used insufficiently clear language, such as 'the universe is the same everywhere'.

Question 23 (b) (i)

(b) Astronomers often use absorption spectral lines to determine the relative velocity of distant galaxies. The wavelength of a specific absorption spectral line observed in the laboratory is 280 nm.

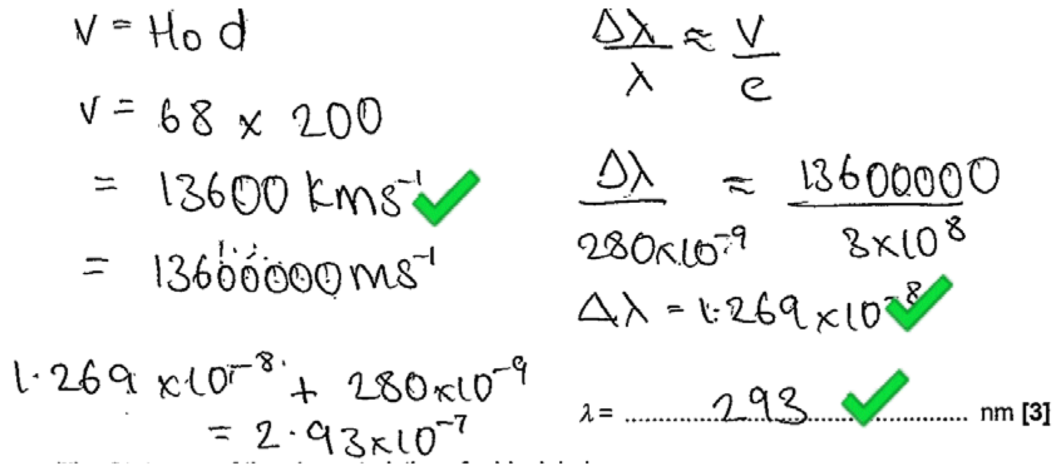
The galaxy RXJ1242-11 is 200 Mpc away from the Earth and it has a massive black hole at its centre.

(i) Calculate in nm the wavelength λ of the same spectral line from RXJ1242-11 when **observed** from the Earth. Assume the Hubble constant is 68 $km\,s^{-1}\,Mpc^{-1}$.

λ = ... nm **[3]**

This is a more challenging question with several steps. In multiplying the distance in Mpc by the H_0 as quoted, the velocity of the galaxy was 13600 km s^{-1}. Some candidates handled the units well in this question, reaching a change in wavelength of 13 nm. If the candidate got as far as that, then approximately half then went on to add the change in wavelength correctly. The change is added as the galaxy is going away from us.

Exemplar 7


$v = H_0 d$

$v = 68 \times 200$

$= 13600\ \text{km s}^{-1}$

$= 13600000\ \text{m s}^{-1}$

$\frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$

$\frac{\Delta\lambda}{280\times10^{-9}} \approx \frac{13600000}{3\times10^{8}}$

$\Delta\lambda = 1.269\times10^{-8}$

$1.269\times10^{-8} + 280\times10^{-9} = 2.93\times10^{-7}$

λ = ...293...... nm [3]

This candidate has laid out the calculation very carefully. It is obvious that they have handled the idea that the speed of light is given in m s^{-1} and that the galaxy's velocity is in km s^{-1}. This gives the correct change in wavelength and eventually the correct wavelength.

Question 23 (b) (ii)

(ii) State one of the characteristics of a black hole.

....

.... **[1]**

Lots of candidates had some good ideas here, and had clearly read widely about black holes. The better answers were those that were specific to black holes rather than merely 'high mass', for example. Good ideas included:

- 'has an escape velocity greater (or equal to) the speed of light'
- 'infinitely dense'
- 'emits Hawking radiation'
- 'event horizon greater than physical radius'

Question 23 (c)

(c) The Universe evolved from the Big Bang.

Describe the evolution of the Universe up to the formation of the first nuclei.

....

....

....

....

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....

....

....

....

....

....

.... **[4]**

Many candidates did well on this question as they had learnt the stages and the order of those stages well. The most common reason for loss of marks was not including details about leptons or getting the stages in the wrong order.

Question 24 (a)

24 A group of students are conducting an experiment to determine the wavelength of monochromatic light from a laser.
Fig. 24.1 shows the laser beam incident normally at a diffraction grating.

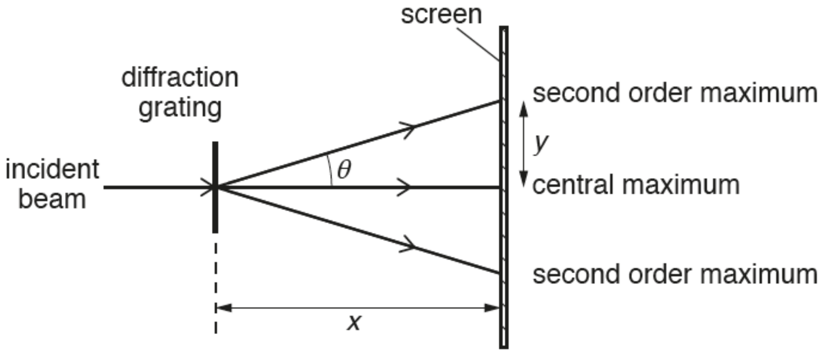


Fig. 24.1

The students use a diffraction grating with 600 lines mm^{-1}. They vary the distance x between the grating and the screen from 1.000 m to 2.000 m. They measure the distance y from the **central** maximum to the **second order** maximum.

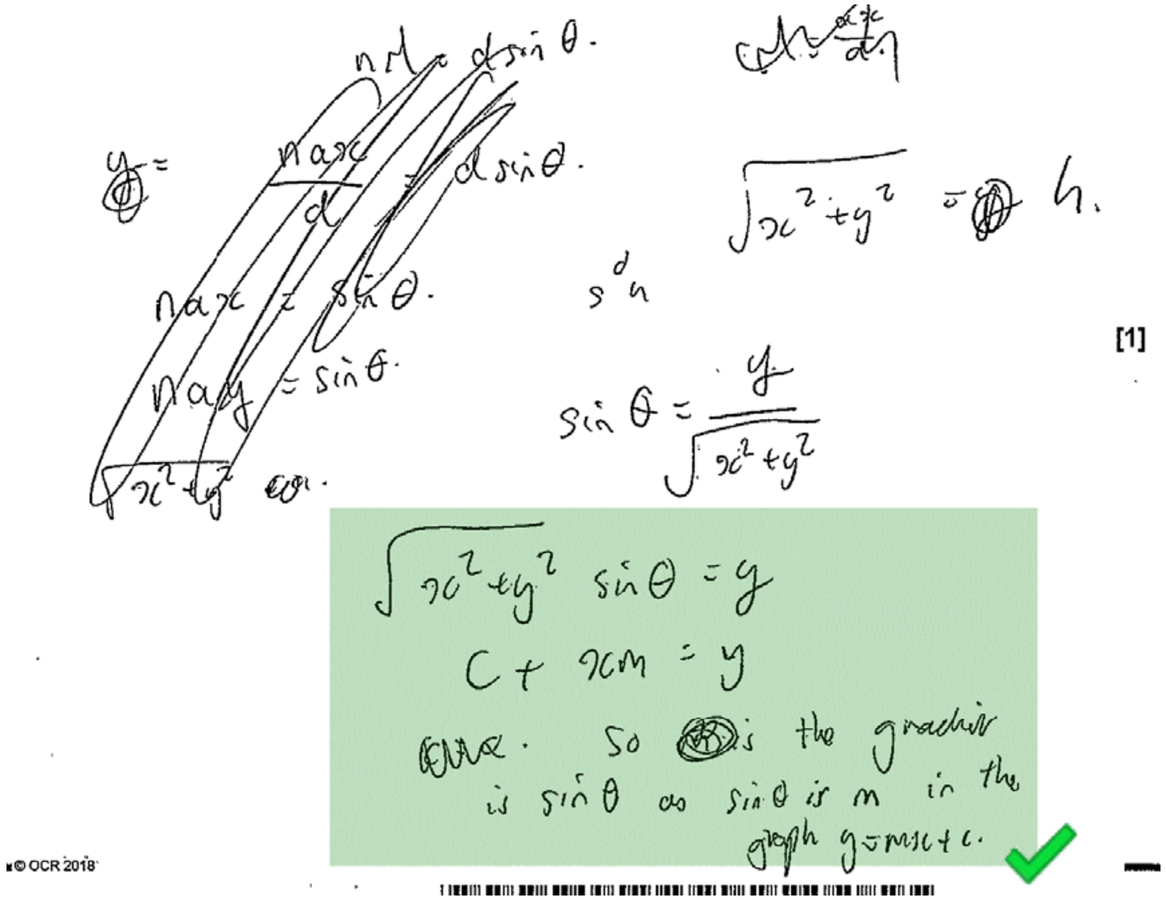
(a) The students decide to plot a graph of y against $\sqrt{x^2 + y^2}$.

Show that the gradient of the graph is equal to sin θ, where θ is the angle between the central maximum and the **second** order maximum.

[1]

Candidates found this item tricky even if they realised that $\sin(\theta) = y/\sqrt{x^2 + y^2}$ and then re-arranged the equation into a form comparable with the general equation of a straight line, "*y*=*mx* +*c*". Unless that comparison was clear, then the mark could not be credited.

Exemplar 8



The exemplar shows a clear way of demonstrating how to show that the gradient of the line of the graph should be $\sin(\theta)$.

Question 24 (b) (i)

(b) Fig. 24.2 shows the graph plotted by the students.

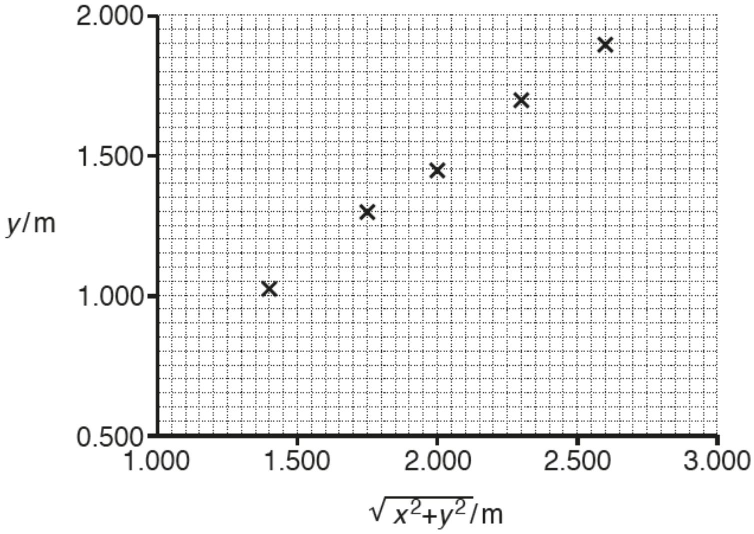


Fig. 24.2

(i) Use Fig. 24.2 to determine an accurate value of the wavelength λ of the light from the laser.

λ = ... m **[3]**

Many candidates could plot the best fit straight line and attempted to calculate the gradient. Not many candidates after that point realised that the gradient had given them $\sin(\theta)$ and could make no further meaningful progress. Common errors included not calculating *d* correctly from the quoted number of lines mm^{-1} or, less frequently, was using a value different from 2 for *n*.

Question 24 (b) (ii)

(ii) Suggest why there are no error bars shown in Fig. 24.2.

....

.... **[1]**

20 per cent of candidates did not attempt this item. Some candidates were on the right lines but very few mentioned about absolute uncertainty and that for these instruments and this graph, the absolute uncertainty was too small to view on this scale.

Question 24 (b) (iii)

(iii) Suggest how the precision of this experiment may be affected by using a protractor to measure the angle θ.

....

.... **[1]**

About two fifths of candidates appreciated that the precision would not be as good with a protractor, as repeated measurements would be less likely to cluster in close proximity.

Precision

The term 'precision' is defined of page 40 the Practical Skills Handbook, along with other useful terms that attempt to describe the quality of data

Erratum notice

Turn to **page 3, question 5** of the question paper and look at **the first sentence**.

Cross out the first word 'A' and replace it with 'The centre of a'.

The first sentence should now read:

'The centre of a rod is fixed to a pulley.

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