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OCR A LEVEL PHYSICS A (H556): QUESTIONS BY TOPIC

Newton's laws of motion and momentum (3.5)

A Level Physics A (H556) · Module 3: Forces and motion

30 questions · 158 marks · Mark schemes included

OCR A Level Physics A (H556), June 2017 – June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

30 questions · 158 marks · 2 sub-topics



SUB-TOPIC 3.5.1

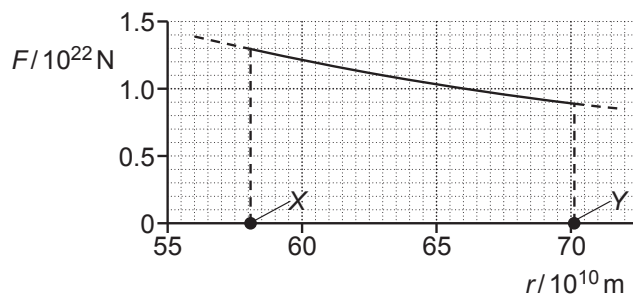
NEWTON'S LAWS OF MOTION

Sub-topic 3.5.1 · 12 questions · 73 marks · lowest tariff first



- 7 The planet Mercury has a highly elliptical orbit around the Sun.

The gravitational force F acting on Mercury due to the Sun varies with its distance r from the centre of the Sun. The graph of F against r for Mercury in its orbit is shown below.



Mercury is closest to the Sun when $r = X$ and furthest when $r = Y$.

What does the **area** under the graph between the distances X and Y represent?

- A The centripetal force acting on Mercury.
- B The change in the gravitational potential energy of Mercury.
- C The impulse of the force acting on Mercury.
- D The kinetic energy of Mercury.

Your answer

[1]

- 1 A student has constructed the table below of possible scalar and vector quantities.

	Scalar	Vector
A	acceleration	momentum
B	displacement	amplitude
C	frequency	wavelength
D	mass	centripetal force

Which row is correct?

Your answer

[1]



- 3 A student has plotted a velocity against time graph for a trolley moving down a ramp.

Which of the following pair of quantities can be determined from the gradient of the graph and the area under the graph?

- A acceleration, displacement
- B acceleration, impulse
- C displacement, kinetic energy
- D force, work done

Your answer

[1]



11 Which pair of quantities do **not** have the same, or equivalent, units?

- A acceleration, gravitational field strength
- B angular frequency, angular velocity
- C gravitational potential, kinetic energy
- D impulse, momentum

Your answer

[1]

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Turn over



1 Which row contains **only** scalar quantities?

A Absolute temperature, displacement, moment

B Acceleration, force, momentum

C Gravitational potential, kinetic energy, mass

D Kinetic energy, mass, momentum

Your answer

[1]



- 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 .

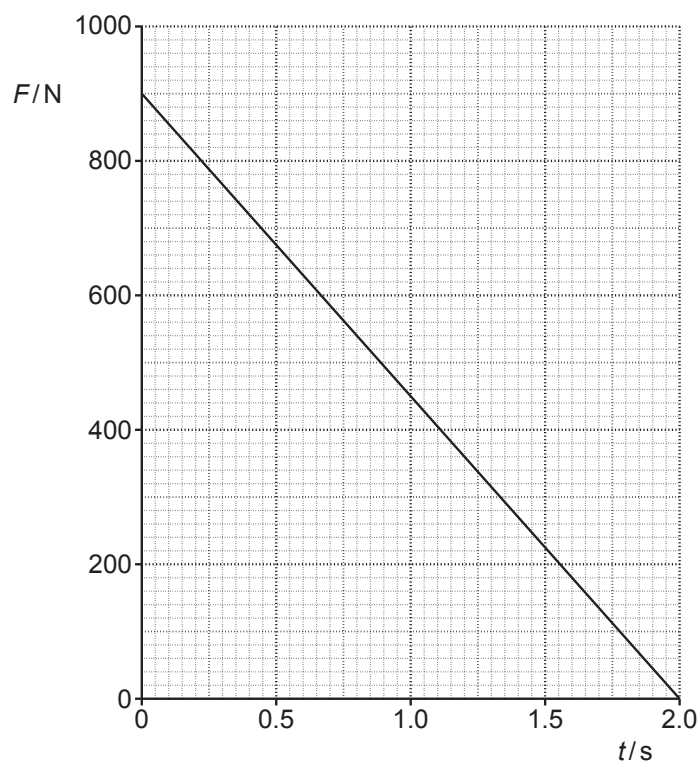


Fig. 20.1

- (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 .

$$U = \dots\dots\dots \text{ms}^{-1} \text{ [2]}$$

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

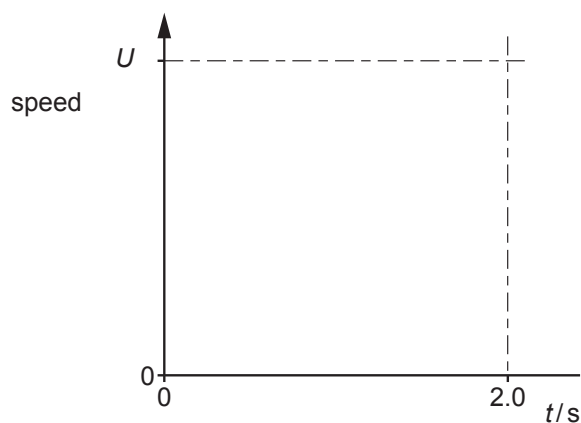


Fig. 20.2

[2]



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

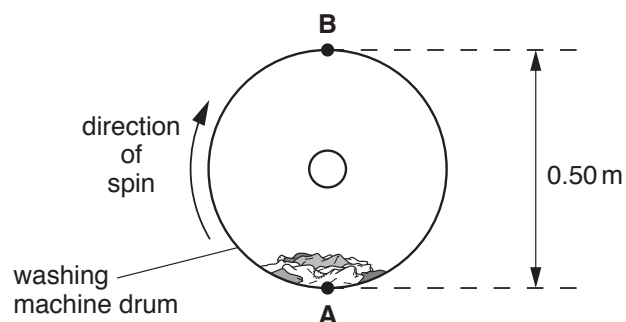


Fig. 21

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]

- (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 = ... $\pm$ ms^{-1} [3]

- (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 .

$v = \dots\dots\dots \text{ms}^{-1}$ [3]



17

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

.....
 [1]

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

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

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

horizontal component of velocity = ... m s^{-1}
 vertical component of velocity = ... m s^{-1}
 [2]

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

.....

 [2]

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

$F =$ N [3]

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- 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.

$$1\text{AU} = 1.5 \times 10^{11}\text{m}$$

(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 1AU has a period of 1 year.

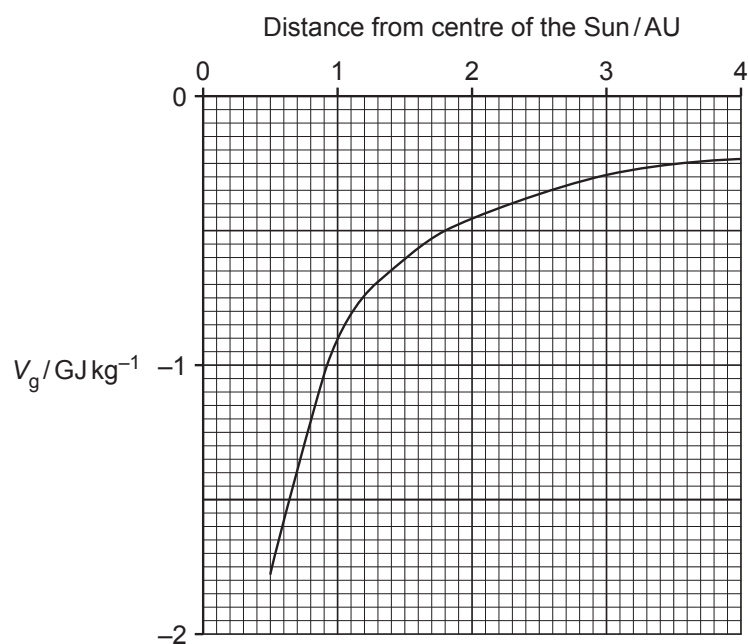
period = ... years **[2]**

- (ii)** Calculate the kinetic energy of the asteroid.

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

- (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]

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

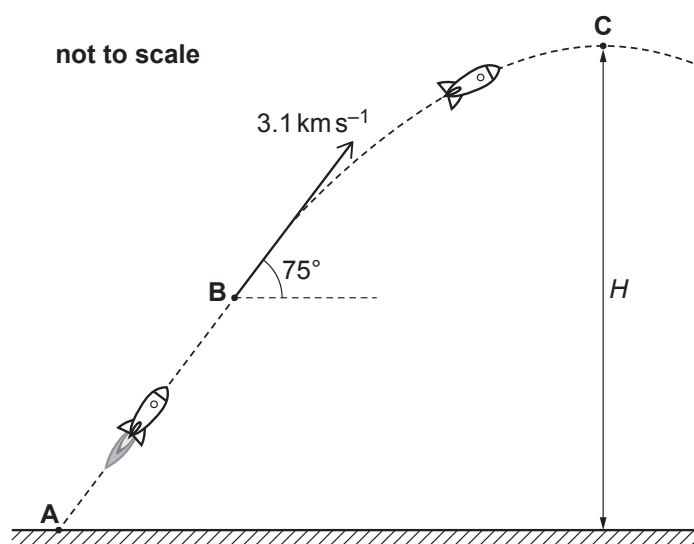
State the other feature of this orbit predicted by Kepler's first law.

.....
 [1]

3 A scientist uses a rocket to study the Earth's atmosphere.

The scientist launches the rocket from rest at the point **A** at $t = 0$ seconds. The force produced by the rocket's engine causes it to accelerate.

At $t = 50$ seconds, the rocket's engine no longer produce an accelerating force as all of the fuel has been used. The rocket has reached point **B**. Its velocity is now 3.1 km s^{-1} at an angle of 75° to the horizontal.



(a) The rocket engine works by expelling hot gas backwards.

Explain, using Newton's laws of motion, how the engine causes the rocket to accelerate between $t = 0$ and $t = 50$ s.

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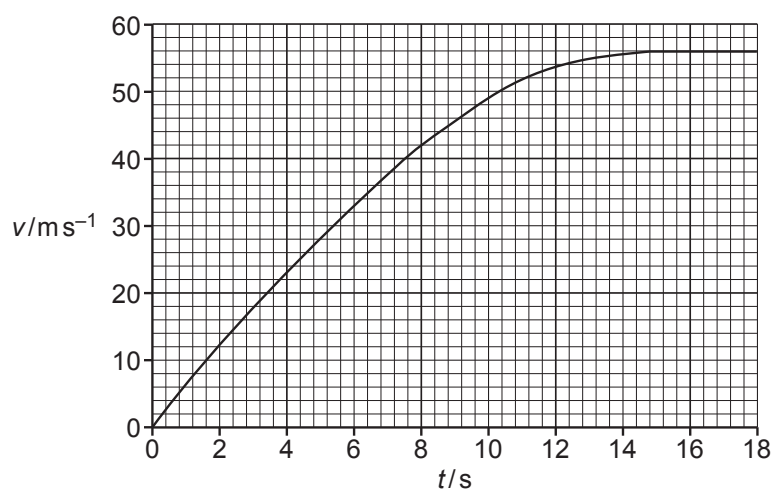
..... [3]

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]

(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 ms^{-2} .

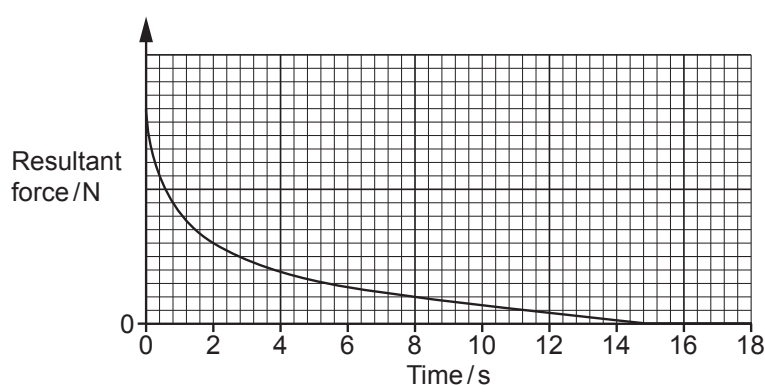
[2]

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

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

(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.

.....

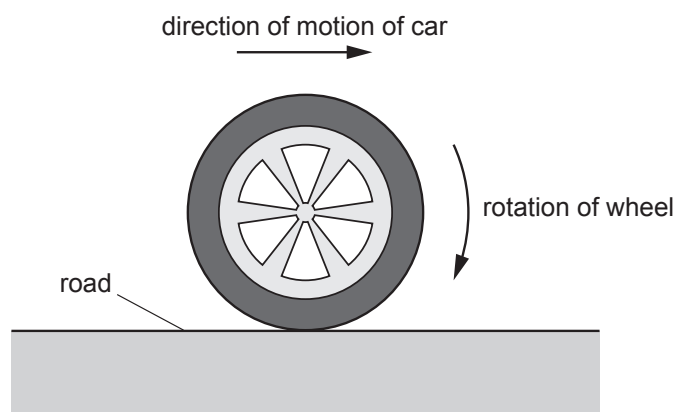
 [2]

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

.....

 [1]

- (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]

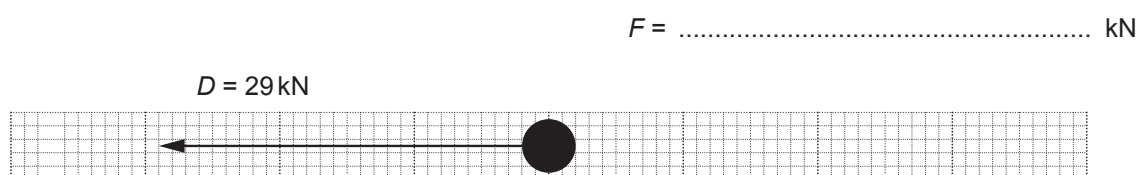
- (ii) Calculate the resultant force acting on the car at $t = 12\text{ s}$, using your answer to (a)(ii).

resultant force = ... N [1]

- (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.

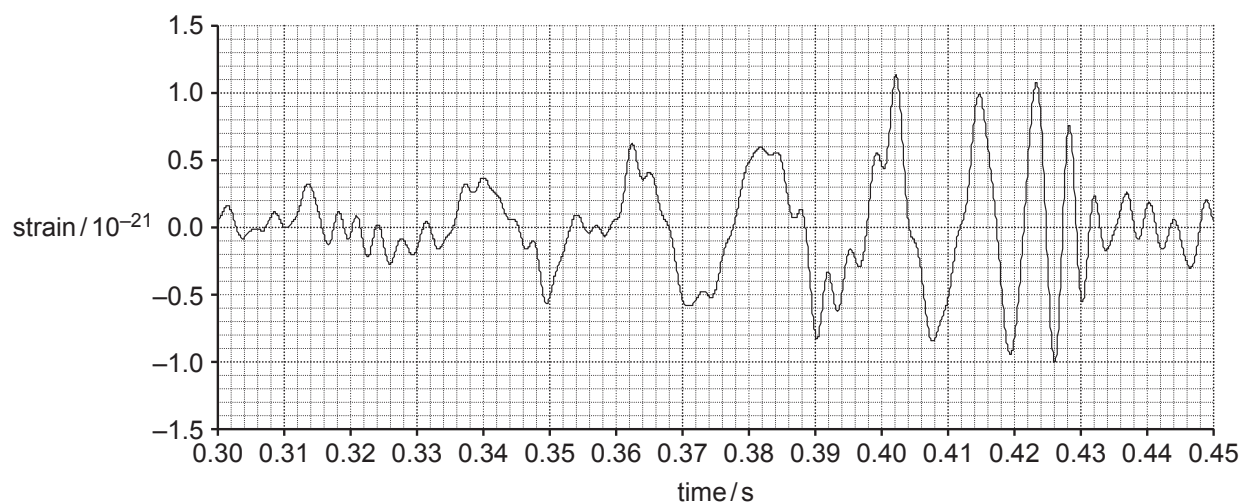
Use your answer to draw an arrow on the diagram below to show the direction and magnitude of F .



[2]

- 6 Gravitational waves are disturbances in space-time that are produced by violent astrophysical events.
- (a) They are detected by measuring the change in length of a detector as the wave passes through. The change in length is reported as a strain.

The graph shows the variation in time of the strain due to the gravitational waves emitted by the collision of two black holes.



- (i) Define **strain**.

.....
 [1]

- (ii) The maximum strain shown on the graph is approximately 10^{-21} .

Calculate the force that would produce the same strain in a copper wire of diameter 2 mm.

Young modulus of copper = 130 GPa

force = ... N [3]

- (iii) By considering the answer to (ii), suggest why it is very difficult to detect the strain caused by gravitational waves.

.....

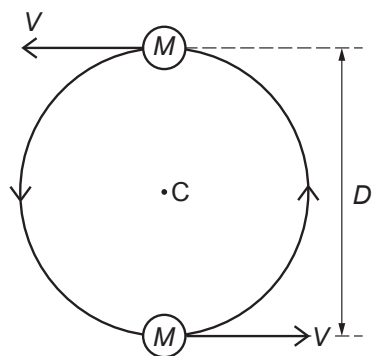
.....

..... [2]

- (b) In this part of the question you will use Newtonian physics to estimate the power output of the black hole collision.

The diagram shows two identical black holes, each of mass M , orbiting each other with period T .

Prior to colliding, the black holes move at speed V in identical circular orbits of diameter D about the central point C .



- (i) Write down an expression for the gravitational force, F , acting between the black holes in terms of M , D and the universal gravitational constant, G .

$F =$ [1]

- (ii) The total orbital energy, E , of the black holes is the sum of their kinetic energy and gravitational potential energy. Show that E is given by the expression:

$$E = k (\pi^2 G^2 M^5)^{1/3} (1/T^{2/3})$$

where k is a numerical constant.

.....

.....

.....

.....

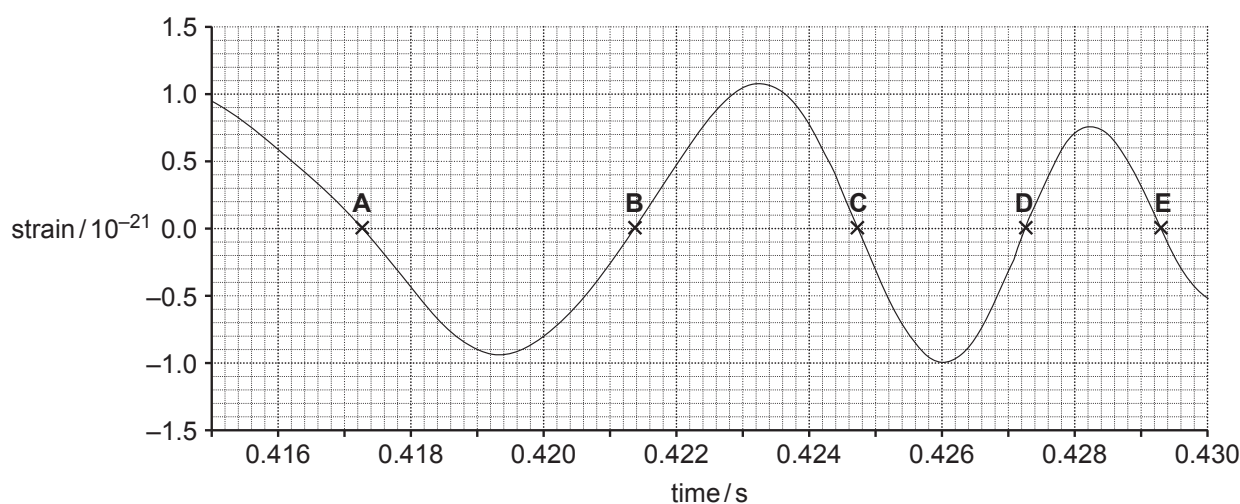
.....

..... [3]

- (iii) The graph below shows detail from the graph in (a).

The black holes spiral towards one another before colliding. As they do so their orbit period decreases.

The orbit period is equal to the period of the gravitational waves.



By considering the time periods **AC** and **CE**, estimate the orbital energy lost by the black holes between these two orbits.

Use $k (\pi^2 G^2 M^5)^{1/3} = -2.04 \times 10^{46}$

energy lost = ... J [3]

- (iv) By considering times **B** and **D**, use your answer to (iii) to estimate the power radiated as gravitational waves in this time interval.

power = ... W [2]



SUB-TOPIC 3.5.2

MOMENTUM, IMPULSE AND COLLISIONS

Sub-topic 3.5.2 · 18 questions · 85 marks · lowest tariff first



- 13 A puck of mass 0.16 kg is sliding on ice with a constant velocity of 11.0 m s^{-1} . A hockey stick exerts a force on the puck, for a short period of time, in the **opposite** direction to the velocity of the puck. The momentum of the puck changes by 2.0 kg m s^{-1} .

Ignore friction.

What is the speed of the puck when it leaves the hockey stick?

- A 1.5 m s^{-1}
- B 3.8 m s^{-1}
- C 12.5 m s^{-1}
- D 23.5 m s^{-1}

Your answer

[1]

- 11 An electron moves in a circle of radius 2.0 cm in a uniform magnetic field of flux density 170 mT.

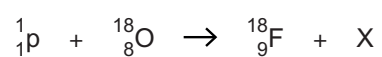
What is the momentum of this electron?

- A $3.4 \times 10^{-3} \text{ kg ms}^{-1}$
B $5.4 \times 10^{-17} \text{ kg ms}^{-1}$
C $1.4 \times 10^{-18} \text{ kg ms}^{-1}$
D $5.4 \times 10^{-22} \text{ kg ms}^{-1}$

Your answer

[1]

- 12 A proton collides with a stationary oxygen-18 nucleus. The collision produces a fluorine-18 nucleus and particle X.



What is particle X?

- A neutron
- B proton
- C electron
- D positron

Your answer

[1]



- 3 An electron has a de Broglie wavelength equal to the wavelength of X-rays.

What is the **best** estimate of the momentum of this electron?

A $10^{-30} \text{ kg ms}^{-1}$

B $10^{-27} \text{ kg ms}^{-1}$

C $10^{-23} \text{ kg ms}^{-1}$

D $10^{-18} \text{ kg ms}^{-1}$

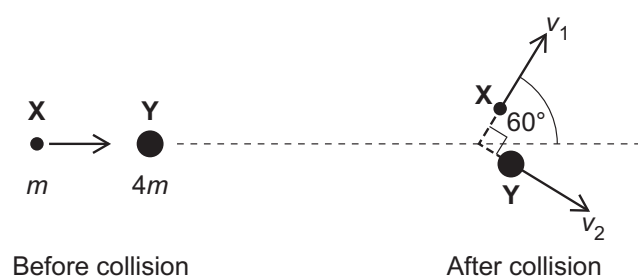
Your answer

[1]



- 6 A particle **X** of mass m collides with a stationary particle **Y** of mass $4m$.

Immediately after the collision the particle **X** is moving at velocity v_1 at an angle of 60° to its original direction and the particle **Y** is moving with velocity v_2 at 90° to the velocity of particle **X**.



What is the value of the ratio $\frac{v_1}{v_2}$?

- A 2.3
- B 3.9
- C 4.0
- D 6.9

Your answer

[1]

- 7 A particle is moving at right angles to a uniform magnetic field of flux density B . The particle has mass m , charge q and moves in a circular arc of radius r in the region of the magnetic field.

What quantities are required to determine the momentum of this particle?

- A B , q and r
- B B , q and m
- C B , q , r and m
- D q , r and m

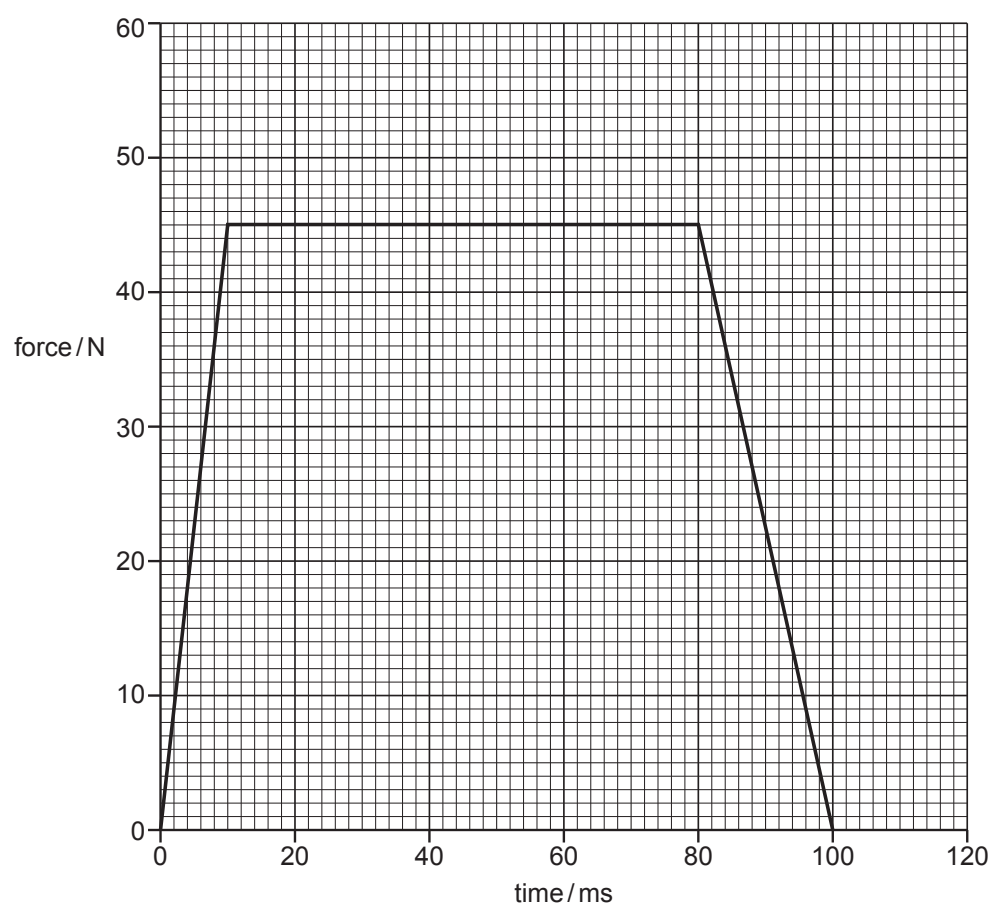
Your answer

[1]

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



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

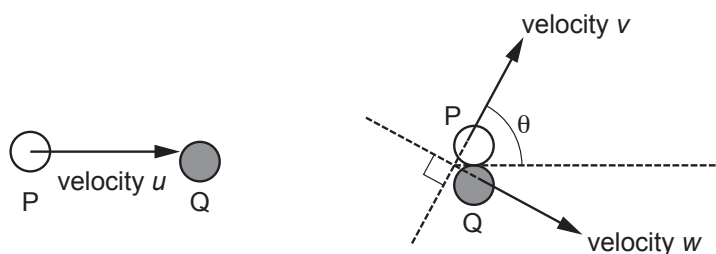
- A 2.3 kg ms^{-1}
- B 3.8 kg ms^{-1}
- C 2300 kg ms^{-1}
- D 3800 kg ms^{-1}

Your answer

[1]

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

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



Before collision

After collision

Which of the following equations is/are correct?

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

- A** 1 only
- B** 1 and 2
- C** 2 and 3
- D** 1, 2 and 3

Your answer

[1]

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

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

The two objects stick together.

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

A 7.1

B 10

C 14

D 20

Your answer

[1]

- 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

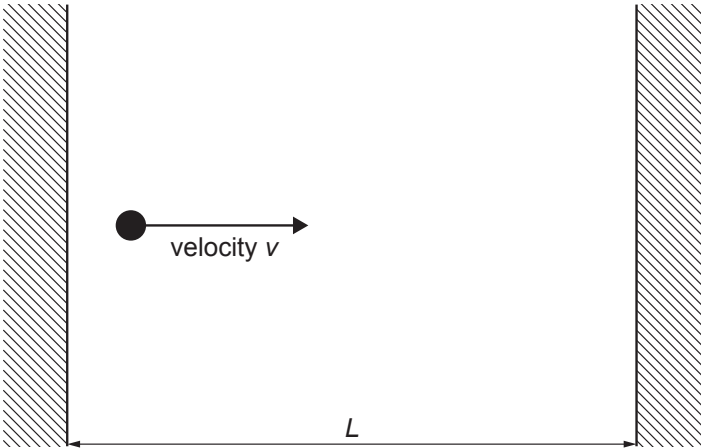
Your answer

[1]



- 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?

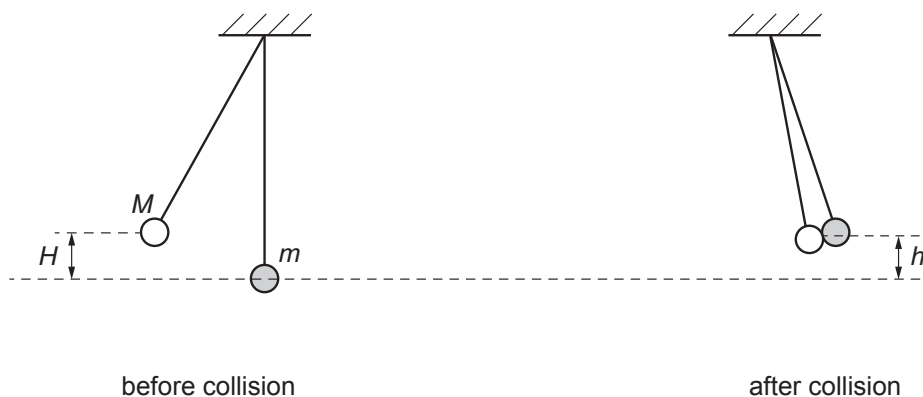
	Change in momentum during each collision	Time between collisions with the <u>same</u> wall	Average force exerted on the wall
A	mv	$\frac{2L}{v}$	$\frac{mv^2}{2L}$
B	$2mv$	$\frac{2L}{v}$	$\frac{mv^2}{L}$
C	$2mv$	$\frac{L}{v}$	$\frac{2mv^2}{L}$
D	$2mv$	$\frac{2L}{v}$	$\frac{2m}{L}$

Your answer

[1]

- 19*** A student makes a pendulum using a length of string with a ball of adhesive putty which acts as a bob. The mass of this bob is M .
A similar second pendulum is constructed with the same length of string but with a bob of a smaller mass. The mass of this bob is m .

The arrangement of the pendulums is shown below.



The bob of mass M is pulled back to a vertical height of H from its rest position. It is released and collides with the bob of mass m . The two bobs then stick together and reach a maximum vertical height h from the rest position.

The height h is given by the equation $h = \left(\frac{M}{M+m}\right)^2 H$.

Describe how to perform an experiment to test the validity of this equation and how the data can be analysed. [6]

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Additional answer space if required

[illegible]

- 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.

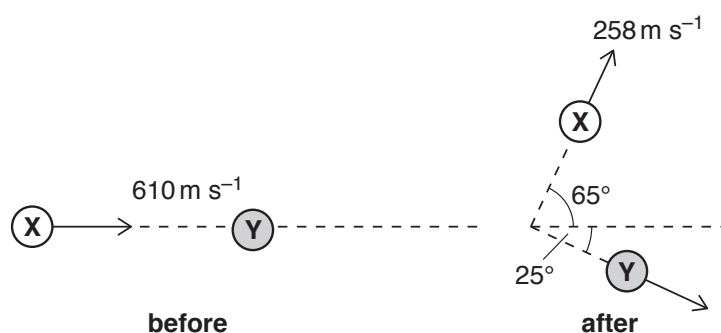


Fig. 22

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

.....
 [1]

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

$p = \dots\dots\dots \text{ kg m s}^{-1}$ [3]

- (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 = $6.64 \times 10^{-27} \text{ kg}$
- escape velocity from the Earth = 11 km s^{-1}

[6]

Turn over



3 This question is about the Sun and its radiation.

- (a) (i) Use the data below to show that the luminosity of the Sun is about $4 \times 10^{26} \text{ W}$.
- radius of Sun = $7.0 \times 10^8 \text{ m}$
 - surface temperature of Sun = 5800 K

[1]

- (ii) Sirius, the brightest star in the night sky, has a luminosity 25 times greater than that of the Sun. It has diameter 1.7 times greater than that of the Sun.

Calculate the surface temperature T of Sirius.

$T = \dots\dots\dots \text{ K}$ [3]

***(b)** A student attends a lecture about the Sun and makes the following notes.

1. The Sun loses more than 4×10^9 kg of its mass every second to maintain its luminosity.
2. Treating hydrogen nuclei (protons) as an ideal gas, a temperature of 10^{10} K provides a kinetic energy of about 1 MeV, which is necessary for fusion.
3. However, the Sun's core temperature is only 10^7 K, so the chance of protons fusing on collision is very small. This explains why the Sun has such a long lifetime.

Explain the principles of physics which are involved in each of the three points.
You should include relevant formulae, but no numbers or calculations are required.

[6]

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Additional answer space if required.

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- 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]

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

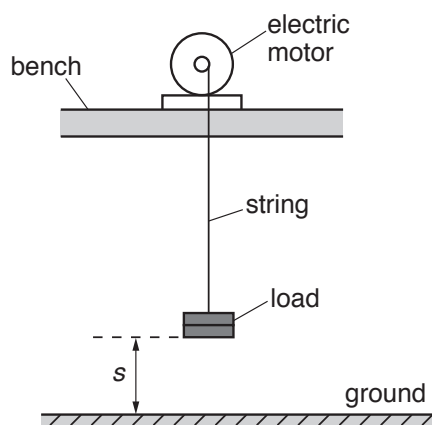


Fig. 20.1

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 .

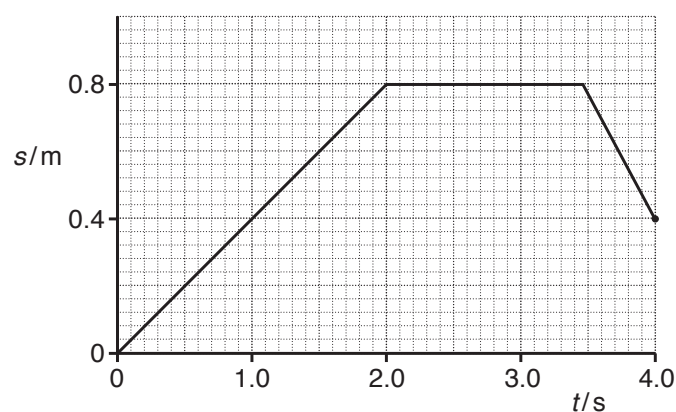


Fig. 20.2

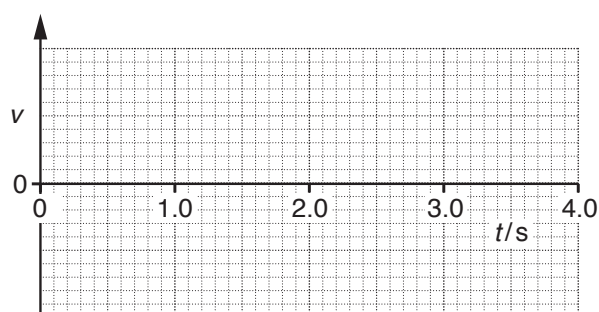


Fig. 20.3

- (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]**
- (ii) Describe how the kinetic energy and the gravitational potential energy of the load varies from $t = 0$ to $t = 2.0$ s.

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..... **[2]**

- (iii) During the **downward** journey of the load, the string breaks at $t = 4.0$ 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.

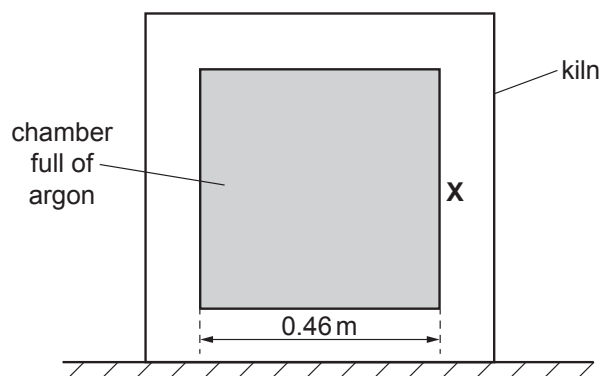
$$V = \dots\dots\dots \text{ms}^{-1} \text{ [2]}$$

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.

$$F = \dots\dots\dots \text{N [2]}$$

21 A kiln used to harden ceramics is shown below.



The internal chamber is a cube. Each side of this cube has length 0.46 m. The chamber is sealed and full of argon. Argon behaves as an ideal gas.

- (a) The kiln is initially at 20 °C.
The argon in the kiln has an initial pressure of 100 kPa.
- (i) Calculate the amount of argon n in the chamber in moles.

$n = \dots\dots\dots$ mol [2]

- (ii) The temperature of the kiln is increased from 20 °C to 1300 °C.

Calculate the pressure in kPa at 1300 °C.

pressure = $\dots\dots\dots$ kPa [2]

- (b) The temperature of the kiln is 1300°C .
A single atom of argon is travelling horizontally towards the vertical side **X** of the chamber.
The initial speed of this atom is 990 m s^{-1} . After collision, it rebounds at the same speed.

- (i) Calculate the change in momentum Δp of this atom.
- mass of argon atom = $6.6 \times 10^{-26}\text{ kg}$

$$\Delta p = \dots\dots\dots \text{ kg m s}^{-1} \text{ [2]}$$

- (ii) Assume that this atom does not collide with any other argon atoms inside the chamber. Instead, it travels horizontally, making repeated collisions with the opposite vertical walls of the chamber.

- 1 Show that the atom makes about 1000 collisions with side **X** in a time interval of 1.0 s.

[1]

- 2 Calculate the average force F on side **X** made by the atom.

$$F = \dots\dots\dots \text{ N [2]}$$

- (iii) Without calculation, explain how your answer to (ii)2 could be used to estimate the total pressure exerted by the atoms of the argon gas in the kiln.

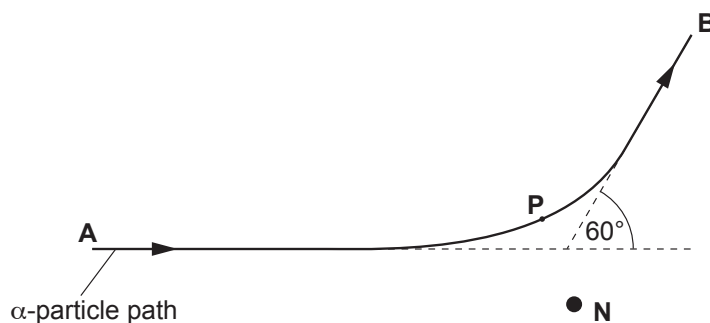
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 [2]

- 6 A beam of α -particles is incident on a thin gold foil. Most α -particles pass straight through the foil. A few are deflected by gold nuclei.

The diagram shows the path of one α -particle which passes close to a gold nucleus **N** in the foil. The α -particle is deflected through an angle of 60° as it travels from **A** to **B**.

P marks its position of closest approach to the gold nucleus.



- (a) Another α -particle in the beam is deflected by the same gold nucleus **N** through an angle of 30° .

Sketch its path onto the diagram above.

[2]

- (b) The distance between **P** and **N** is $6.8 \times 10^{-14} \text{ m}$.

Calculate the magnitude of the electrostatic force F between the α -particle (${}^4_2\text{He}$) and the gold nucleus (${}^{197}_{79}\text{Au}$) when the α -particle is at **P**.

$F = \dots\dots\dots \text{ N}$ [4]

Question 6 continues on page 18

- (c) The initial kinetic energy of each α -particle is 5.0 MeV.

Show that the magnitude of the initial momentum of each α -particle is about $10^{-19} \text{ kg ms}^{-1}$.
Take the mass of the α -particle to be $6.6 \times 10^{-27} \text{ kg}$.

[3]

- (d) The **magnitude** of the final momentum of the α -particle at **B** is equal to its initial value at **A**.

The gold nucleus **N** is initially at rest. During the passage of the α -particle from **A** to **B**, no other forces act on the two particles.

In the following questions label any relevant angles.

- (i) Draw two vectors in the spaces below to represent the initial momentum and the final momentum of the α -particle.

initial momentum at **A**

final momentum at **B**

[2]

- (ii) Draw a vector in the space below to represent the momentum of the nucleus **N** when the α -particle reaches **B**.

Explain how you determined this momentum.

.....
.....
..... [2]



- 1 The Earth's aurora is an atmospheric effect visible in the polar regions.

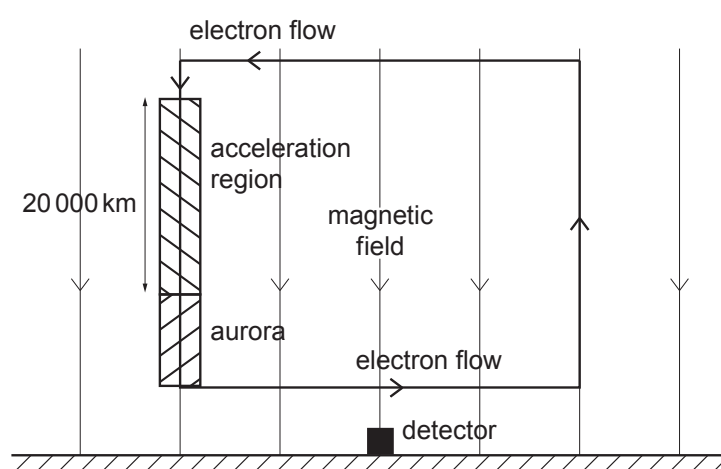
Electrons in the upper atmosphere initially move vertically downwards along one of the Earth's **magnetic** field lines. They are accelerated by an **electric** field.

These electrons collide with oxygen atoms causing atomic electrons to be excited to higher energy levels. The atomic electrons then return to lower energy levels, releasing photons of green light, red light and ultraviolet.

The accelerated electrons then travel horizontally through the atmosphere, before travelling vertically along a different magnetic field line, and then completing the circuit by travelling horizontally back to their starting point.

The situation is shown in **Fig. 1.1**.

Fig. 1.1



not to scale

- (a) The accelerated electrons are accelerated by electric fields parallel to the magnetic field lines.

The length of the acceleration region is 20 000 km and the electric field value is 0.2 mV/m. The electric field can be assumed to be uniform.

- (i) Calculate the kinetic energy gained by the electrons as they pass through the electric field, in joules.

kinetic energy = ...J [3]

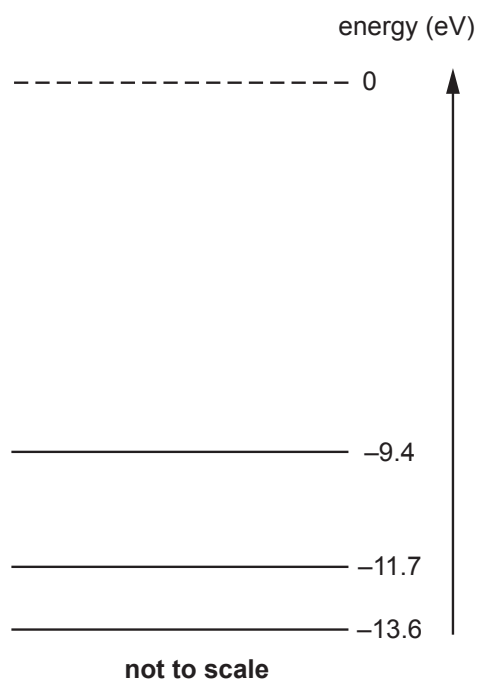
- (ii) State and explain the direction of the electric field required to accelerate the electrons **downwards**.

.....

.....

..... [2]

- (b) A simplified energy level diagram for atomic oxygen is shown below.



Determine the wavelength of the green light emitted.

Fully justify your answer.

wavelength = ... m [4]

- (c) The horizontal current closest to the Earth produces a magnetic field which can be detected at ground level.

With reference to **Fig. 1.1**, state and explain the direction of this magnetic field.

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..... [2]

- (d) Suggest **two** ways that the horizontal current may affect the atmosphere.

1

.....

2

..... [2]

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MARK SCHEMES

official mark schemes



7	B	1	
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1	D	1	
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3	A	1	
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11	C		1	
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1	C	1	
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20	(a)	$F = \frac{\Delta mv}{\Delta t}$ or $F\Delta t = \Delta mv$ or (resultant force) = rate of change of momentum area under graph = Δmv or Δp or change in momentum or impulse	B1 B1	Allow p instead of mv Allow: proportional for equals (rate of change of momentum)
	(b)	area under graph = $0.5 \times 2.0 \times 900 = 900$ (N s) $(mU = 900)$ $U = 13$ (m s ⁻¹)	C1 A1	Not: (initial force/mass)
	(c)	The graph showing a (smooth) curve of continuously/always decreasing magnitude of gradient (with respect to time). Curve starts at $(0,U)$ and stops at $(2.0,0)$	M1 A1	Note: curve must not be asymptotic at either end of the curve.
Total			6	

Question	Answer	Marks	Guidance
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21	(a)	Both forces act on the same object (AW) The types of forces are different / one force is gravitational and the other force is electrostatic	B1 B1	 Allow: one force is gravitational (and the other is not)
	(b)	$T = 60/1600$ or $T = 3.75 \times 10^{-2}$ (s) $(v = \pi \times 0.50/3.75 \times 10^{-2})$ speed = 42 (m s ⁻¹) uncertainty = 3 (m s ⁻¹)	C1 A1 A1	Allow: $f = 26.7$ or $\frac{1600}{60}$ (Hz) or $\omega = 168$ (s ⁻¹) Note: v must be to 2 or more SF Note: uncertainty must be to 1 SF Allow: ecf on candidate's value for speed i.e. uncertainty = candidate's value / 16 (to 1 SF) Allow for 2 marks max: 84 ± 5 (m s⁻¹)
	(c)	$mv^2/r = mg$ or $v^2/r = g$ $v^2 = 9.81 \times 0.25$ $v = 1.6$ (m s ⁻¹)	C1 C1 A1	Allow: $v^2/r = a$ <u>and</u> $a = g$ or $mv^2/r = ma$ <u>and</u> $a = g$ Allow: any subject Allow: any subject Note: qualified 2.21 (ms ⁻¹) scores 2 marks.
		Total	8	



17	a		Net force is proportional to rate of change of momentum	B1	Allow “equal to” for ‘proportional’ Allow use of resultant or total for net Allow symbols provided they are defined. NOT force = mass x acceleration
	b	i	Horizontal = 43 (.3) (m s ⁻¹) Vertical = 25 (m s ⁻¹)	B1 B1	ignore sign Allow answers in incorrect order for 1 mark MAX Allow H = 7.7 (m s ⁻¹), V = -49.4 (m s ⁻¹) 1 mark MAX
		ii	Correct application of N3L Plus ONE from: (Direction of) momentum of air has changed or direction of air flow has changed There is a force on the air (from the model)	B1 B1 B1	force on air is equal (and opposite) to force on model
		iii	$F = \frac{\Delta p}{\Delta t}$ $F = 35 \times 25$ (divided by 1) $F = 880$ (N)	C1 C1 A1	ecf candidate's vertical velocity in (i) Allow 875 Allow 870
			TOTAL	8	

22	(a)	(i)	$T_{\text{asteroid}}^2 = 3.5^3$ $T = 6.5 \text{ (yr)}$	C1 A1	Accept substitution of given formula with AU in metres (giving time in seconds) Answer to 3sf is 6.55 (yr)
		(ii)	$R = 3.5 \text{ AU} = 3.5 \times 1.5 \times 10^{11} = 5.3 \times 10^{11} \text{ (m)}$ $v = 2\pi R/T = 16 \text{ (kms}^{-1}\text{)}$ $KE = \frac{1}{2}mv^2 = 1.3 \times 10^9 \text{ J}$	C1 C1 A1	ECF from (a)(i) for T Note: $v = R/T$ is XP Allow ECF from v Allow $1.2 \times 10^9 \text{ (J)}$ if no premature rounding in calculation Answer is $1.26 \times 10^9 \text{ (J)}$ to 3sf Alternative method $mv^2/r = GMm/r^2 \text{ (C1)}$ $\frac{1}{2}mv^2 = m \times \frac{1}{2}GM/r = \frac{1}{2} \text{ of GPE (C1)}$ $= 1.3 \times 10^9 \text{ J from graph (A1)}$
	(b)	(i)	Potential difference from graph = $0.9 - 0.25 = 0.65 \text{ GJ kg}^{-1}$ GPE = mass $\times$ potential difference = 6.5 GJ	C1 A1	If calculated value is 0.89-0.25 Ignore sign Allow ECF from the graph
		(ii)	The Sun is at one focus	B1	
			TOTAL	8	

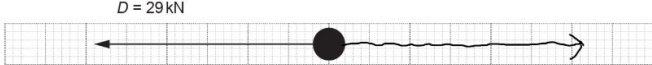
3	(a)	the rocket exerts a (backwards) force on the (hot) gas (so) the gas exerts a (forwards) force on the rocket (this forwards) force must be greater than the weight of the rocket / there is a resultant force (which causes acceleration / a change in momentum)	B1 B1 B1	Ignore incorrect numbering or general statements of Newton's Laws throughout Allow engine for rocket Allow (burning) fuel for gas but not air Note that 'rocket expels gas backwards' is in the stem and so gains no credit Allow engine for rocket Allow gas pushes the rocket forwards Allow net or unbalanced for resultant
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3	(b)	*	Level 3 (5–6 marks) Expect a correct calculation of H with correct assumptions and a clear evaluation supported with a calculation <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Expect Either a correct calculation of H but no evaluation or Some calculation and some evaluation or Incorrect calculations but a clear evaluation <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Expect Either Limited calculation (e.g. $3100 \sin 75^\circ$ seen, AB or BC calculated but not H, use of suvat but with wrong v) or Limited assumptions stated (note that ‘g is always 9.81’ is in stem) or Limited evaluation (e.g. g would be smaller at C than A) <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6 Use level of response annotations in RM Assessor Indicative scientific points may include: Calculation vertical component of velocity at B = $3100 \sin 75^\circ$ (= 2994 m s^{-1}) <u>AB</u> - Assume (force and mass constant so) constant acceleration - Use of suvat, $u = 0$, $v = 2994$, $t = 50$ $s = 74.9 \text{ km}$ <u>BC</u> - Assume no air resistance - Use of suvat, $u = 2994$, $v = 0$, $a = -9.81$ $s = 457 \text{ km}$ Total $H = 457 + 74.9 \approx 530 \text{ km}$ Evaluation $g \propto \frac{1}{r^2}$ $\frac{g_C}{g_A} = \frac{r_A^2}{r_C^2} = \frac{6400^2}{(6400+530)^2} = 0.85$ 15% drop in g from A to C (or 17% increase from C to A) but use ECF for H - therefore constant g is a poor assumption $g_C \approx 8.3$ or 8.4 if $g_A = 9.81$ but use ECF for H - If g is smaller, then H would increase
			Total	9



16	(a)	(i)	Reference to area (under the curve) Construct rectangle or square plus triangle/ trapezium	B1 B1	Allow: reference to counting squares. Accept: annotation on the graph such as shapes Ignore: reference to integration Accept for 2 marks: Attempt to calculate number of squares (under the curve) and multiply by area of one square (even if the candidate has got the area of one square wrong)
		(ii)	Tangent drawn at (12, 54) Change in y / change in x =1.4	M1 A1	Allow value that rounds to 2sf in the range 1.3 - 1.7 to 2sf
		(iii)	Change in velocity = 56 ms^{-1} Change of momentum = $56 \times 1700 = 95000$ (kg ms^{-1})	C1 A1	Answer is 95200 to 3sf
	(b)	(i)			Accept 'air resistance' or 'friction' for 'drag' throughout

Question			Answer	Mark	Guidance
			Any two from: Drag force is increasing (so resultant decreases) (Zero resultant when or towards end) drag = driving force/friction from wheels Idea that drag force is increasing at a decreasing rate (so resultant decreases at a decreasing rate)	B1 B1 B1	Accept reference to drag force function ($F = kv^2$)
		(ii)	(Area under graph =) impulse / related to the product of time and force / change in momentum	B1	
	(c)	(i)	Tyre (or wheel) exerts a force on the road backwards / to the left / opposite to direction of motion Road exerts (equal and) opposite force (of the same type) on the tyre / AW	M1 A1	Check diagram Allow “car” for “tyre” Accept alternatives such as “forward” or “to the right”
		(ii)	Candidate's gradient from 1(a)(ii) $\times 1700$ evaluated	B1	Allow 1.5 (from stem) $\times 1700 = 2600$ N NOTE: range in acceptable gradients for (a)(ii) gives force between 2210-2720
		(iii)	$F = \text{Resultant } (2400) + D = 31000(\text{N}) = 31 \text{ (kN)}$	B1	Ignore PoT on answer line

Question			Answer	Mark	Guidance
			Arrow drawn from the circle to the right to scale i.e. 	B1	Allow ECF for resultant from part (ii) and/or D If using 1.5 from stem, $F=32000$ to 2sf Allow +/- half a small square by eye i.e. 31-32 squares Allow candidate's arrow consistent with number on answer line
			Total	14	

6	(a)	(i)	$\text{strain} = \frac{\text{extension}}{\text{original length}}$	B1	Allow (strain is) extension per unit length Allow compression for extension Allow $\varepsilon = \frac{x}{L}$ with terms defined
6	(a)	(ii)	use of area = πr^2 $F = \text{Young modulus} \times \text{strain} \times \text{area}$ $F = 130 \times 10^9 \times 10^{-21} \times \pi \times (1.0 \times 10^{-3})^2$ $4(.08) \times 10^{-16} \text{ (N)}$	C1 C1 A1	Allow use of $\pi d^2/4$ or $\pi (d/2)^2$ Note area = $3.14 \times 10^{-6} \text{ (m}^2\text{)}$ Allow calculation using $E = \frac{F}{A}$ and $F = EA$ i.e. stress = $130 \times 10^9 \times 10^{-21} = 1.3 \times 10^{-10}$ and $F = 1.3 \times 10^{-10} \times \pi \times (1.0 \times 10^{-3})^2$ Allow 2 marks for $4(.08) \times 10^n \text{ (N)}$
6	(a)	(iii)	strain is <u>very small</u> / <u>very small</u> force required to produce similar strain difficult to distinguish signal from background noise / signal will be hidden by the effect of other forces	B1 B1	Ignore references to measuring instruments/detectors

6	(b)	(i)	$F = -\frac{GM^2}{D^2}$	B1	Accept correct formula without negative sign
6	(b)	(ii)	one from: $\frac{Mv^2}{D/2} = \frac{GM^2}{D^2}$ $v = \frac{\pi D}{T}$ one from: $E = -\frac{GM^2}{D} + 2\left(\frac{1}{2}Mv^2\right)$ $E = -\frac{GM^2}{D} + 2\left(\frac{1}{4}\frac{GM^2}{D}\right)$ steps leading to $E = k (\pi^2 G^2 M^5)^{1/3} (1/T^{2/3})$	M1 M1 A1	Allow m for M throughout GPE must be negative for this marking point Note this comes from substituting $v^2 = \frac{GM}{2D}$ eg use of $v^2 = \frac{GM}{2D}$ and $v = \frac{\pi D}{T}$ to obtain $D^3 = \frac{GMT^2}{2\pi^2}$ and $E^3 = -\frac{G^3 M^6}{8D^3}$

6	(b)	(iii)	A to C = $0.4247 - 0.4173 (= 7.4 \times 10^{-3})$ or C to E = $0.4293 - 0.4247 (= 4.6 \times 10^{-3})$ E = $-2.04 \times 10^{46} \times (7.4 \times 10^{-3})^{-2/3} (= -5.38 \times 10^{47})$ or E = $-2.04 \times 10^{46} \times (4.6 \times 10^{-3})^{-2/3} (= -7.38 \times 10^{47})$ $(7.38 - 5.37) \times 10^{47} = 2(.0) \times 10^{47} \text{ J}$	C1	Accept 7.2×10^{-3} to 7.6×10^{-3} Accept 4.4×10^{-3} to 4.8×10^{-3}
				C1	Accept -5.28×10^{47} to -5.47×10^{47} Accept -7.17×10^{47} to -7.60×10^{47}
				A1	Accept 1.69×10^{47} to 2.32×10^{47}
6	(b)	(iv)	$\Delta t = 0.4273 - 0.4214 = 5.9 \times 10^{-3} \text{ s}$ $P (= \frac{E}{t}) = \frac{2.01 \times 10^{47}}{5.9 \times 10^{-3}} = 3.4 \times 10^{49} \text{ (W)}$	C1	Accept 5.8×10^{-3} to 6.1×10^{-3}
				A1	Allow calculation using value of E calculated in 6(b)iii Expect 3.30×10^{49} to 3.47×10^{49} if 2.01×10^{47} used
Total				15	



13	A		1	
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11	D	1	
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12	A	1	
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3	C		1	
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6	A		1	
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7	A		1	
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6	B	1	
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8	C	1	
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13	A		1	
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3	B	1	
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6	B	1	
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19*		Level 3 (5–6 marks) Clear description of experiment and measurements and clear analysis. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description of experiment and some measurements and some analysis. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description of experiment or Limited measurements or Limited analysis <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	B1× 6	Indicative scientific points may include: Description • Release method • Ensure bob is not pushed • Repeat experiment for same H • Repeat for different H • Centre of mass of single bob and joined bob considered • Keep bob string taught Measurements • Measure heights h and H with ruler • Use centre of mass of bob or another suitable method • Use video camera to record motion • Use of datalogger and appropriate sensor to measure H and h • Measure mass with (top pan) balance Analysis • Construct a table of h and H • Plot graph of h against H • LoBF should pass through origin. • Determine gradient or calculate h/H repeatedly • $\text{gradient} = \left(\frac{M}{M+m}\right)^2$ (gradient must be consistent with the plot) • Masses substituted into above expression and checked against experimental gradient
		Total	6	



22	(a)	(i)	<u>KE</u> is conserved (as well as momentum)	B1	Allow: No <u>KE</u> lost
		(ii)	Attempt at conservation of momentum in x- or y- direction Correct expression of conservation of momentum in x- or y- direction / correct determination for velocity of Y of 55(3) m s⁻¹ $p = 3.7 \times 10^{-24} \text{ (kg m s}^{-1}\text{)}$	C1 Allow confusion of sin and cos at this stage Allow attempt at conservation of KE C1 Allow any subject e.g. $p \cos(25^\circ) + m \times 258 \cos(65^\circ) = m \times 610$ or $p \sin(25^\circ) = m \times 258 \sin(65^\circ)$ or $(p)^2 + (m \times 258)^2 = (m \times 610)^2$ or $\frac{1}{2} mv^2 + \frac{1}{2} m (258)^2 = \frac{1}{2} m (610)^2$ A1 Answer is $3.67 \times 10^{-24} \text{ (kg m s}^{-1}\text{)}$ to 3 sf	



Question	Answer	Marks	Guidance
(b)*	Level 3 (5–6 marks) Clear explanation and correct calculation. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some explanation and limited calculation, or limited explanation and correct calculation. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited explanation and missing or incomplete calculation. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response (NR) or no response worthy of credit (0).	B1x6	Indicative scientific points may include: Explanation - At a certain temperature all atoms have the same <u>average</u> kinetic energy - Helium behaves as an ideal gas $E_K = \frac{3}{2} kT$ - Mean / r.m.s speed of atoms is less than the escape velocity - Atoms have range of speeds / velocity or mention of Maxwell-Boltzmann distribution - Faster atoms have escaped the Earth (over long period of time) - Earth was significantly hotter in the (ancient) past Calculation $T = 283 \text{ K}$ $\frac{1}{2} m \overline{c^2} = \frac{3}{2} kT$ $c_{r.m.s.} = \sqrt{\frac{3kT}{m}}$ $c_{r.m.s.} = 1.3 \text{ km s}^{-1}$
	Total	10	



3	(a)	(i)	$L (= 4\pi r^2 \sigma T^4) = 4 \times \pi \times (7.0 \times 10^8)^2 \times 5.67 \times 10^{-8} \times 5800^4$ $L = 3.95 \times 10^{26} \text{ (W)}$	M1 A0	Mark is for substitution of values Allow σ for 5.67×10^{-8}
		(ii)	By ratios: $25 = 1.7^2 \times (T/5800)^4$ $T^4 = 9.8 \times 10^{15}$ $T = 9950 \text{ (K)}$	C1 C1 A1	or $T^4 = \frac{25L}{4\pi\sigma(1.7r)^2}$ $= \frac{25 \times 3.95 \times 10^{26}}{4\pi \times 5.67 \times 10^{-8} \times (1.7 \times 7 \times 10^8)^2}$ ECF for L in a(i) but only if $L = 4 \times 10^{26}$ to 1s.f. ECF for incorrect σ in a(i) Allow 9.9×10^{15} (using $L = 4 \times 10^{26}$) Allow 10,000 K
	(b)		see next page	B1 x 6	
			Total	10	

H556/03

Mark Scheme

November 2020

Question			Answer	Marks	Guidance
3	(b)	*	Level 3 (5 - 6 marks) Clear expansion of three statements <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear, relevant and substantiated.</i> Level 2 (3 – 4 marks) Clear expansion of two statements or Limited attempt at all three <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Limited attempt at one or two statements <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Indicative scientific points may include: statement 1 • fusion reactions are occurring • which change H into He • and mass is lost which releases energy • energy released = $c^2\Delta m$ • Δm per second = luminosity / c^2 statement 2 • average k.e. of each proton is $\frac{3}{2}kT$ • high T means protons are travelling at high speed • so fast enough to overcome repulsive forces • and get close enough to fuse • p.e. = $e^2/4\pi\epsilon_0 r$ so T must be high enough for $\frac{3}{2}kT > e^2/4\pi\epsilon_0 r$ • r is approximately 3fm statement 3 • k.e. $\propto T$ so average energy at 10^7 K is only one thousandth of the average energy at 10^{10} K when protons might fuse • but M-B distribution applies so at the high energy end there will be a few p with enough energy • quantum tunnelling across potential barrier is possible • small probability of many favourable collisions to boost energy of p • 4 p must fuse to produce He; it is complicated process making probability of fusion much less • number of p in Sun is so huge that, even with such a small probability, 4×10^9 kg of p still interact s^{-1} • a larger probability means lifetime of the Sun would be shorter



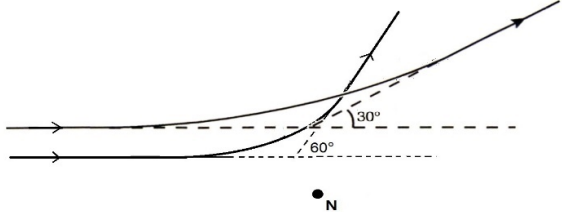
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Question	Answer	Marks	Guidance
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20	(a)		$E_k = \frac{1}{2} mv^2$ <u>and</u> $p = mv$ (Correct manipulation leading to) $E_k = \frac{1}{2} p^2/m$	M1	Allow: any subject
				A1	Allow: $E_k = p^2/(2m)$
	(b)	(i)	From $t = 0$ to $t = 2.0$ s: a non-zero horizontal line From $t = 2.0$ to $t = 3.5$ s: line showing $v = 0$ From $t = 3.5$ to $t = 4.0$ s: non-zero horizontal line showing v is <u>opposite</u> in direction <u>and</u> magnitude larger than that of line drawn at $t = 0$ to $t = 2.0$.	B1 B1 B1	Judgement by eye
		(ii)	KE is constant. GPE increases linearly / proportional to t	B1 B1	Allow: 'at constant rate' for 'linear' Not: unqualified 'constantly'
		(iii)1	$V^2 = 0.80^2 + 2 \times 9.81 \times 0.40$ $V = 2.9 \text{ (m s}^{-1}\text{)}$	C1 A1	Allow 1 mark for $(2 \times 9.81 \times 0.40)^{1/2} = 2.8 \text{ (m s}^{-1}\text{)}$
		(iii)2	$F = 0.12 \times 2.9/0.025$ $F = 14 \text{ (N)}$	C1 A1	Possible ECF from (iii)1 Note: use of 2.8 m s^{-1} gives $F = 13(.44 \text{ N})$ Note: $1.4 \times 10^n \text{ (N)}$ scores 1 mark
			Total	11	

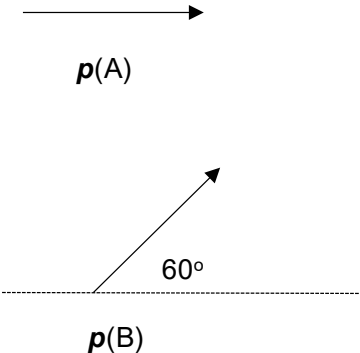
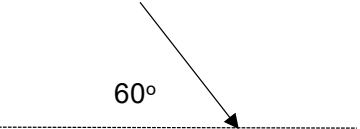
21	(a)	(i)	$(pV = nRT)$ $100 \times 10^3 \times (0.46)^3 = n \times 8.31 \times (273 + 20)$ $n = 4.0$	C1 A1	Note $T = 20$ is XP Not 1 SF answer of 4 Note answer is 4.00 to 3SF
		(ii)	$\frac{100}{293} = \frac{p}{1573}$ or $p \times (0.46)^3 = n \times 8.31 \times 1573$ pressure = 540 (kPa)	C1 A1	Note $T = 1300$ is XP Allow use of correct, unrounded n
	(b)	(i)	$(p =) 6.6 \times 10^{-26} \times 990$ or $6.5(3) \times 10^{-23} \text{ (kg m s}^{-1}\text{)}$ $(\Delta p =) 2 \times 6.6 \times 10^{-26} \times 990$ $\Delta p = 1.3 \times 10^{-22} \text{ (kg m s}^{-1}\text{)}$	C1 A1	Ignore sign of answer
		(ii)1	$990/[2 \times 0.46] (= 1080)$	B1	
		(ii)2	$(F = \Delta p/\Delta t)$ $(F =) 1.3 \times 10^{-22} \times 1000$ $F = 1.3 \times 10^{-19} \text{ N}$	C1 A1	Possible ECF from (b)(i) Note 1080 would give $1.4 \times 10^{-19} \text{ (N)}$
		(iii)	Use of $p = F/A$ or pressure = (total) force/area Idea of multiplying by total number of atoms	B1 B1	Allow particles or molecules for atoms
			Total	11	

6	(a)		B1	Path is initially horizontal and further up the page than original
		$Q = 79e$ and $q = 2e$ $F = (1/4\pi\epsilon_0)Qq/r^2$ $= 79 \times 2 \times (1.6 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (6.8 \times 10^{-14})^2]$ $= 7.9 \text{ (N)}$	B1	Path <u>ends</u> at 30° to horizontal (angle must be labelled) in the direction shown
6	(b)		C1	
			C1	
			C1	Apply ECF for wrong charge(s), e.g. Q and/or $q = e$, or $Q = 79$ and/or $q = 2$, etc
			A1	
6	(c)	(k.e. =) $E = 5.0 \times 10^6 \times 1.6 \times 10^{-19}$ $v = \sqrt{(2E/m)}$ or $= \sqrt{(2 \times 8.0 \times 10^{-13} / 6.6 \times 10^{-27})} = 1.6 \times 10^7 \text{ (ms}^{-1}\text{)}$ $p (= mv) = 6.6 \times 10^{-27} \times 1.6 \times 10^7$ giving $p = 1.1 \times 10^{-19} \text{ (kg m s}^{-1}\text{)}$	C1	$E = 8(.0) \times 10^{-13} \text{ J}$
			C1	or ($E = p^2/2m$ so) $p = \sqrt{(2mE)}$ Note: A value of $v = 1.6 \times 10^7 \text{ (ms}^{-1}\text{)}$ automatically scores both C1 marks even if the calculation for E is not shown
			A1	or $p (= \sqrt{(2mE)}) = \sqrt{(2 \times 6.6 \times 10^{-27} \times 8.0 \times 10^{-13})}$ giving $p = 1.0 \times 10^{-19} \text{ (kg m s}^{-1}\text{)}$ Full substitution of values must be shown and answer (if calculated) must be correct

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6	(d)	(i)	Example (not to scale):  $p(A)$ 60° $p(B)$	B1	horizontal arrow (judge by eye), in the direction shown
				B1	arrow drawn at an angle of 60° to the horizontal (angle must be shown), in the direction shown
		(ii)	Example (not to scale):  60° (Can apply principle of) conservation of momentum (since no external forces are acting)	B1	arrow drawn at an angle of 60° to the horizontal (angle must be shown), in the direction shown
				B1	
			Total	13	



1	(a)	(i)	$V (= Ed) = 0.2 \times 10^{-3} \times 20,000 \times 10^3$ or $V = 4000 \text{ (V)}$ $W (= QV) = 1.6 \times 10^{-19} \times 4000$ $6.4 \times 10^{-16} \text{ (J)}$	C1 C1 A1	Allow $F (= QE) = 1.6 \times 10^{-19} \times 0.2 \times 10^{-3}$ or $F = 3.2 \times 10^{-23} \text{ (N)}$ Allow $W (= Fd) = 3.2 \times 10^{-23} \times 20,000 \times 10^3$
1	(a)	(ii)	electrons move in opposite direction to (electric) field/conventional current (so electric field is) upwards	M1 A1	Allow electrons are negatively charged
1	(b)		$11.7 - 9.4 (= 2.3 \text{ eV})$ $\lambda = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{2.3 \times 1.6 \times 10^{-19}}$ $5.4 \times 10^{-7} \text{ (m)}$ Correct reasoning to select 540 nm - the middle wavelength (from red, green, UV) - the middle frequency - the middle photon energy - the middle-sized electron transition	C1 C1 A1 B1	Allow $13.6 - 11.7 (= 1.9 \text{ eV})$ or $13.6 - 9.4 (= 4.2 \text{ eV})$ Allow a <u>full</u> substitution with an energy level change of 9.4, 11.7 or 13.6 eV for this C1 mark only Allow an answer consistent with 1.9 eV or 4.2 eV (i.e. 296 nm or 654 nm gains 3 marks) Allow up to 4 marks for working backwards from stating wavelength of green light is ~550 nm i.e. $E = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{550 \times 10^{-9} \times 1.6 \times 10^{-19}}$ $E = 2.3 \text{ eV}$ $11.7 - 9.4 (= 2.3 \text{ eV})$



Question			Answer	Mark	Guidance
1	(c)		(conventional) current opposite to electron flow or (right) to left (magnetic field) out of the page	B1 B1	Allow annotation of figure to show circular magnetic field lines around current or arrow labelled current towards left on Fig 1.1
1	(d)		heating effect ionisation of atoms / lightning strikes	B1 B1	 Allow (ionisation causes) horizontal force / acceleration of gas (due to $F = BIL$ / motor effect)
			Total	13	