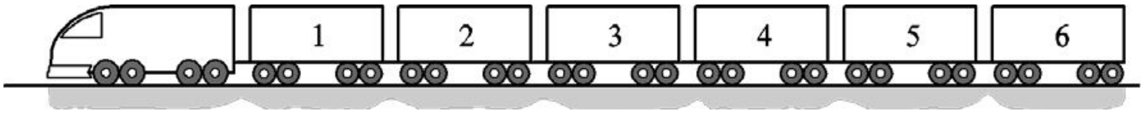
1 A train consisting of six trucks each of mass 6.0×10^4 kg is pulled at a constant speed by a locomotive of mass 24×10^4 kg along a straight horizontal track. The horizontal force resisting the motion of each truck is 4000 N.



The coupling between trucks 2 and 3 snaps.

What is the initial acceleration of the locomotive?

A 0.022 ms^{-2}
B 0.044 ms^{-2}
C 0.067 ms^{-2}
D 0.133 ms^{-2}

Your answer

[1]

2(a) A flat, circular disc moves across a horizontal table with negligible friction.

Fig. 19.1 shows the disc **X** of mass 50 g subject to a force *F*. **Fig. 19.2** shows the variation of the force *F* with time *t*.

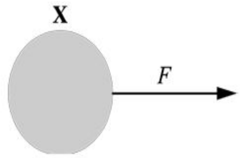


Fig. 19.1

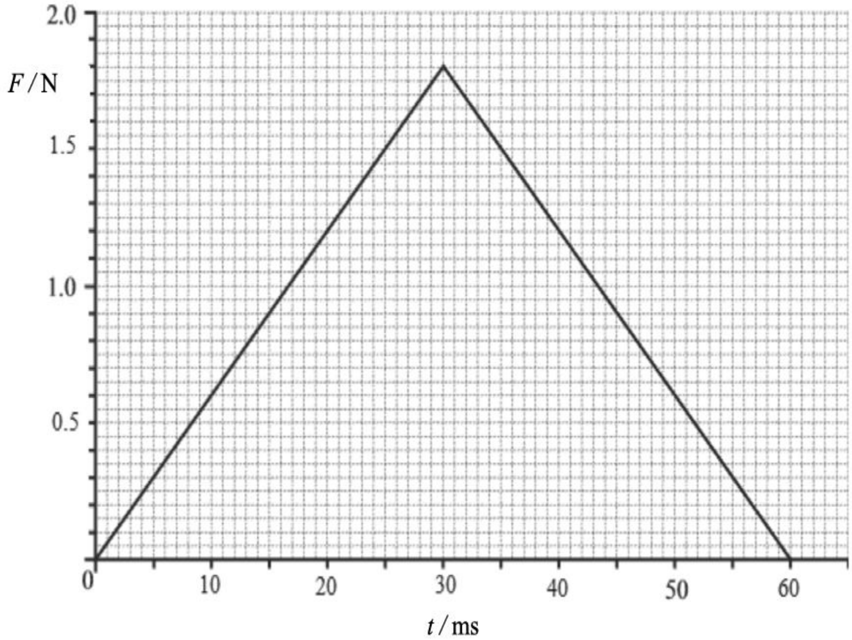


Fig. 19.2

The disc is initially at rest. Calculate the change in velocity of the disc caused by *F*.

change in velocity = ______________ ms^{-1} [2]

(b) In a different experiment disc **X** moving at 1.5 ms^{-1} collides elastically with two other discs **Y** and **Z** which are touching and at rest. All the discs are identical. The positions of the discs are shown in **Fig. 19.3**.

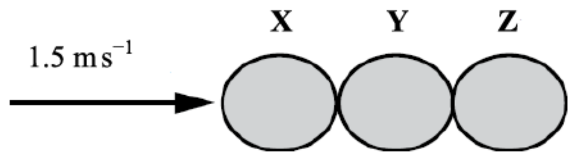


Fig. 19.3

(i) Draw arrows on **Fig. 19.3** to show the relative magnitude and direction of the forces which act on disc **Y** during the collision.

[1]

(ii) State the resultant force on **Y** during the collision.

____ **[1]**

(iii) Show that after the elastic collision **X** is at rest and **Z** moves with a velocity of 1.5 ms^{-1}.

[4]

3 Which physical quantity has the same base units as energy?

A moment
B momentum
C force
D pressure

Your answer ☐ **[1]**

4 A gas is at a temperature of 20°C. The mass of each molecule is 4.7×10^{-26} kg.

(i) Show that the root mean square (r.m.s.) speed the gas molecules is about 500 m s^{-1}.

[3]

(ii) A gas molecule makes a head-on collision with a **stationary** smoke particle. Fig. 20 shows the gas molecule and the smoke particle before and after the collision. The final speed of the smoke particle is 23 m s^{-1}.

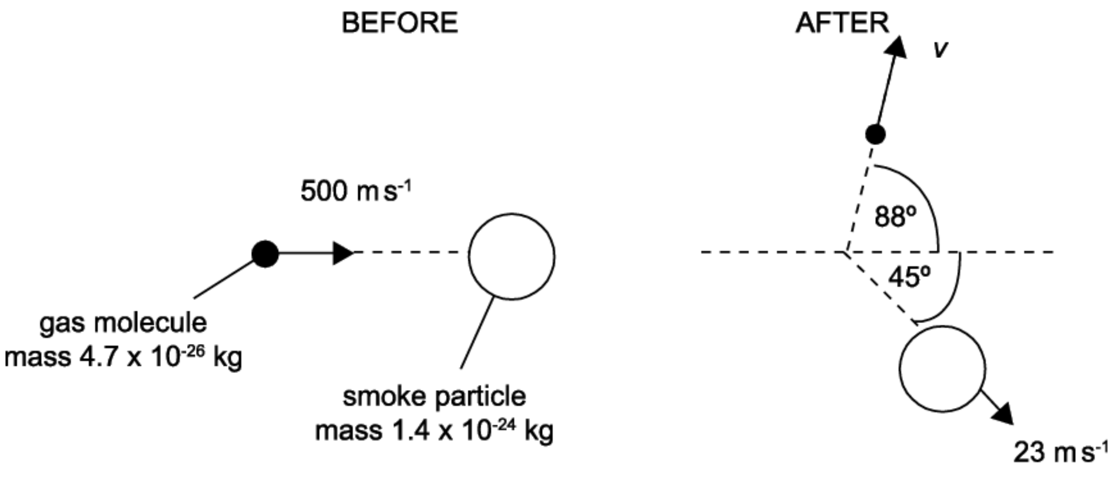


Fig. 20

1 State and explain the **total** momentum of the molecule and smoke particle after the collision in a direction perpendicular to initial velocity of the gas molecule.

[2]

2 Calculate the speed v of the gas molecule after the collision.

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

5 A cyclist moves along a horizontal road. She pushes on the pedals with a constant power of 250 W. The mass of the cyclist and bicycle is 85 kg. The total drag force is $0.4v^2$, where v is the speed of the cyclist.

(i) Calculate the energy provided by the cyclist each minute when the overall efficiency of the cyclist's muscles is 65%.

energy = ______________ J **[2]**

(ii) Calculate the drag force and hence the instantaneous acceleration of the cyclist when the speed is 6.0 ms^{-1}.

acceleration = ______________ ms^{-2} **[3]**

6 Apollo-11 was the first manned spacecraft to land on the Moon. Fig. 1.1 shows part of the equipment left on the surface by the astronauts and the forces acting upon it.

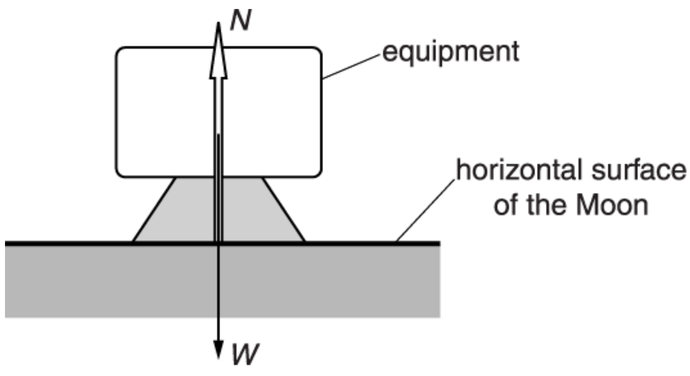


Fig. 1.1

According to Newton's third law interacting forces always occur in pairs. A student states that the normal contact force *N* is equal in magnitude to the weight *W* because of Newton's third law.

(i) Give **two** reasons why the student's statement is incorrect.

---

[2]

(ii) Use Newton's third law to state the magnitude and location of the force pairing up with the weight *W*.

---

[1]

7(a) A solar-powered ion propulsion engine creates and accelerates xenon ions. The ions are ejected at a constant rate from the rear of a spacecraft, as shown in Fig. 2.1.

The ions have a fixed mean speed of 3.2×10^4 ms^{-1} relative to the spacecraft.

The initial mass of the spacecraft is 5.2×10^3 kg.

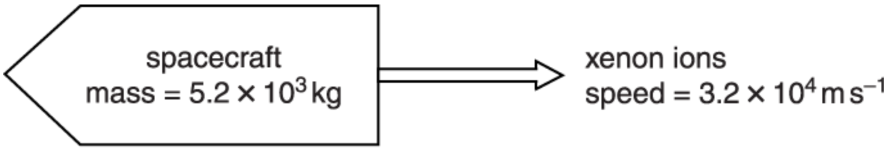


Fig. 2.1

(i) Calculate the mass of one xenon ion.

molar mass of xenon = 0.131 kg mol^{-1}

mass = ______________________________ kg **[1]**

(ii) The engine is designed to eject 9.5×10^{18} xenon ions per second.

Determine the initial acceleration of the spacecraft.

acceleration = ______________________________ m s^{-2} **[3]**

(iii) State in words the law that you have used to solve **(ii)**.

In your answer, you should use appropriate technical terms spelled correctly.

--- **[1]**

(iv) State and explain how you would expect the acceleration of the spacecraft to change, if at all, while the engine is running.

--- **[3]**

(b) A small rocket is used to detach a satellite of mass 180 kg from the spacecraft. Fig. 2.2 shows the variation of the force *F* created by the rocket on the satellite with time *t*.

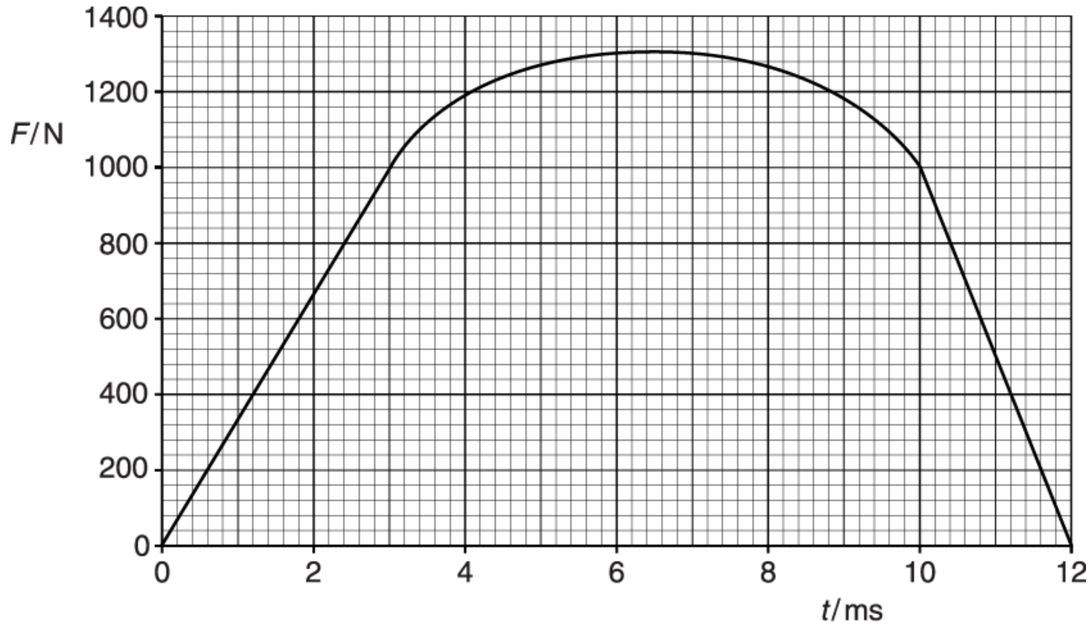


Fig. 2.2

Use Fig. 2.2 to

(i) determine the change in the velocity of the satellite as a result of the force **F** applied for the period of 12 ms.

change in velocity = ____________________________ m s^{-1} **[4]**

(ii) describe how the acceleration of the satellite varies between 0 and 10 ms.

____

____

____

____

____ **[2]**

8 This question is about the operation of an electrically powered shower designed by an electrical firm.

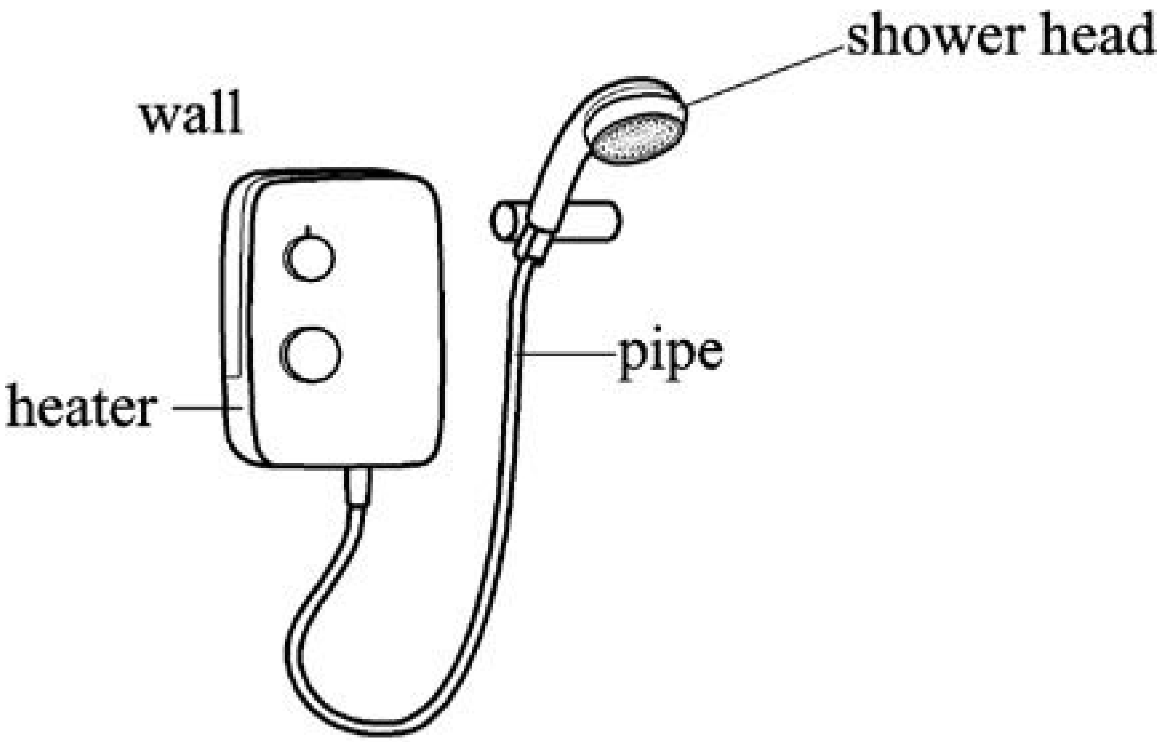


Fig.1.1

Water moves at constant speed through a pipe of cross-sectional area $7.5 \times 10^{?5}$ m^2 to a shower head shown in **Fig. 1.1.** The maximum mass of water which flows per second is 0.070 kg s^{-1}.

(i) Show that the maximum speed of the water in the pipe is about 0.9 m s^{-1}.

density of water = 1000 kg m^{-3}

[2]

(ii) The total cross-sectional area of the holes in the shower head is one quarter that of the pipe. Calculate the maximum speed of the water as it leaves the shower head.

maximum speed = ____________________ m s^{-1} **[1]**

(iii) Calculate the magnitude of the force caused by the accelerating water on the shower head.

force = ____________________ N **[2]**

(iv) Draw on to **Fig. 1.1** the direction of the force in **(iii)**.

[1]

9(a) State Newton's first law of motion.

--- [1]

(b) Newton's third law suggests that forces always occur in pairs when two objects interact.

(i) State **two** ways in which the forces in such a pair are identical.

--- [2]

(ii) State **two** ways in which these forces are different.

--- [2]

(c) Fig. 2.1 shows a fireman using a hosepipe held at 55° to the horizontal. The cross-sectional area of the hosepipe nozzle is 3.3×10^{-4} m^2. Water is ejected from the nozzle at 25 m s^{-1}.

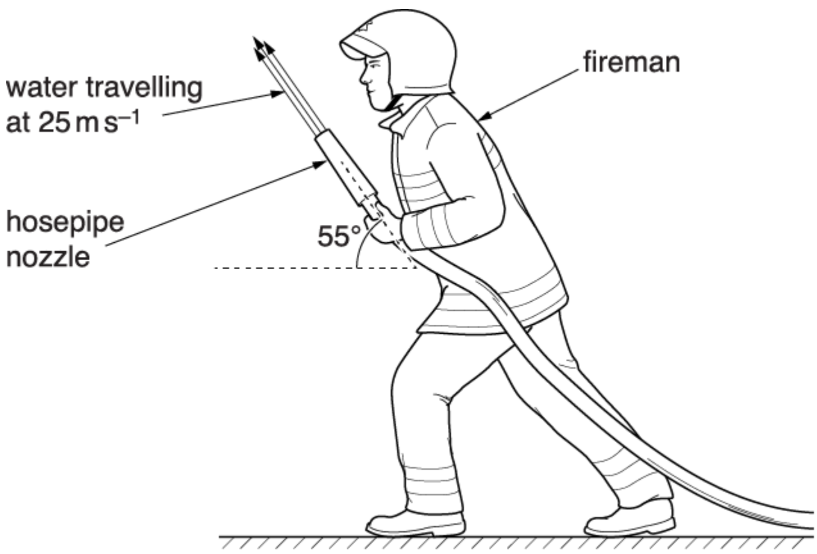


Fig. 2.1

(i) Show that the rate at which water is ejected from the nozzle is about 8.3 kg s^{-1}.

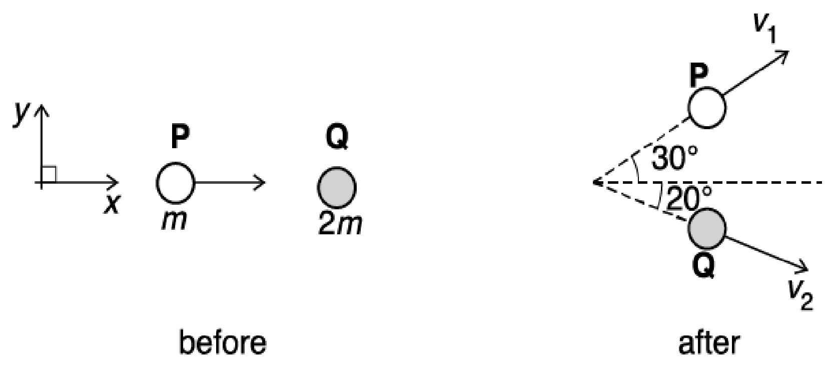
density of water = 1.0×10^3 kg m^{-3}

[1]

(ii) The mass of the fireman is 92 kg. Determine the vertical component of the force exerted by the ground on the fireman's feet.

force = _____________________________ N **[3]**

10 A ball **P** of mass m has a velocity in the positive x-direction. It makes a collision with a stationary ball **Q** of mass $2m$. After the collision, the ball **P** has velocity v_1, ball **Q** has velocity v_2 and the balls travel in the directions shown in the diagram below.



After the collision, the total momentum of the balls in the x-direction is p_x and the total momentum in the y -direction is p_y.

Which row is correct for p_x and p_y?

	p_x	p_y
A	$2mv_2 \cos 20° + mv_1 \cos 30°$	0
B	$2mv_2 \sin 20° + mv_1 \sin 30°$	0
C	$2mv_2 \cos 20° + mv_1 \cos 30°$	$2mv_2 \sin 30° + mv_1 \sin 20°$
D	$2mv_2 \sin 20° + mv_1 \sin 30°$	$2mv_2 \cos 30° + mv_1 \cos 20°$

Your answer

[1]

11(a) A ball of mass 160 g is at rest. The ball is hit with a stick.

Fig. 19.1 shows the variation of the force F exerted by the stick on the ball with time t.

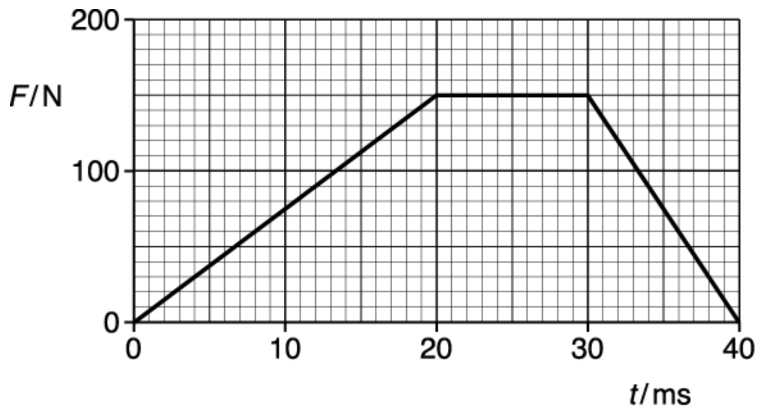


Fig. 19.1

Use Fig. 19.1 to determine the **final** velocity v of the ball as it leaves the stick.

v = ______________________________ m s^{-1} **[3]**

(b) Sketch a graph on Fig. 19.2 to show the variation of the velocity of the ball between t = 30 ms and t = 40 ms. You do not need to show any values on the vertical axis.

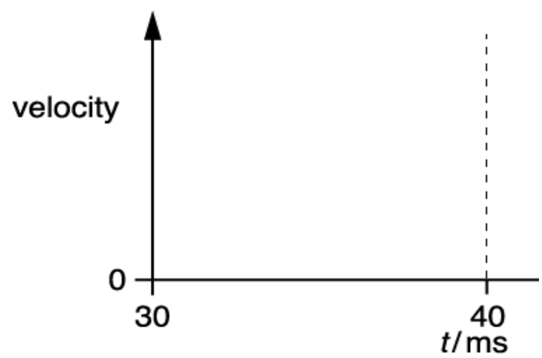


Fig. 19.2

[2]

(c) After time t = 40 ms, the ball travels along the horizontal ground.

The ball experiences a constant friction of 0.80 N.

Calculate the time T for it to come to a stop.

T = ____________________________ s **[2]**

Fig. 3.1 shows a simple representation of a hydrogen iodide molecule. It consists of two ions $^{1}_{1}H^{+}$ and $^{127}_{53}I^{-}$, held together by electric forces.

Fig. 3.1

Fig. 3.2 shows a simple mechanical model of the molecule consisting of two unequal masses connected by a spring of force constant *k* and negligible mass. The ions oscillate in simple harmonic motion when disturbed.

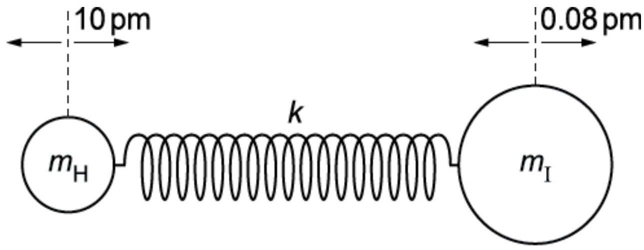


Fig. 3.2

(i) The approximate acceleration *a* of the hydrogen ion, mass m_H, is given by the equation

$$a = -\left(\frac{k}{m_H}\right)x$$

where *k* is the force constant of the spring and *x* is the displacement of the ion.
The ions oscillate with a frequency of 6.6×10^{13} Hz. The mass m_H is 1.7×10^{-27} kg.
Show that the value of *k* is about 300 N m^{-1}.

[3]

(ii) Use Newton's laws of motion and a requirement for simple harmonic motion to explain why the amplitude of oscillation of the iodine ion, mass m_I, is about 0.08 pm when the amplitude of oscillation of the hydrogen ion is about 10 pm.

[4]

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]**

14(a) A stationary uranium-238 nucleus $\left({}^{238}_{92}\text{U}\right)$ decays into a nucleus of thorium-234 by emitting an alpha-particle.

The chemical symbol for thorium is Th. Write a nuclear equation for this decay.

[2]

(b) The mass of the uranium nucleus is 4.0×10^{-25} kg. After the decay the thorium nucleus has a speed of 2.4×10^{5} m s^{-1}.

Calculate the kinetic energy, in MeV, of the alpha-particle.

kinetic energy = ____________________ MeV **[4]**

(c) The uranium-238 $\left({}^{238}_{92}\text{U}\right)$ nucleus starts the decay chain which ends with a nucleus of lead-206 $\left({}^{206}_{82}\text{Pb}\right)$.
Show that 14 particles are emitted during this decay chain. Explain your reasoning.

[3]

15(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.

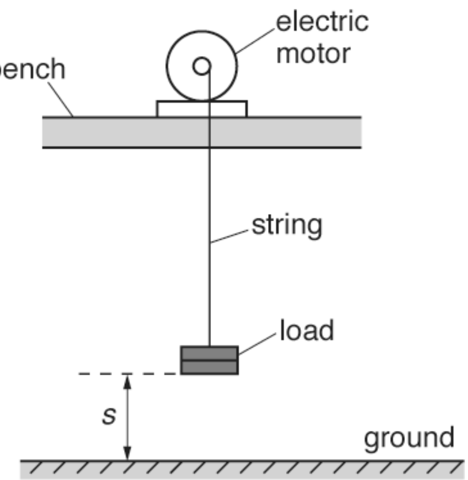


Fig. 20.1

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.

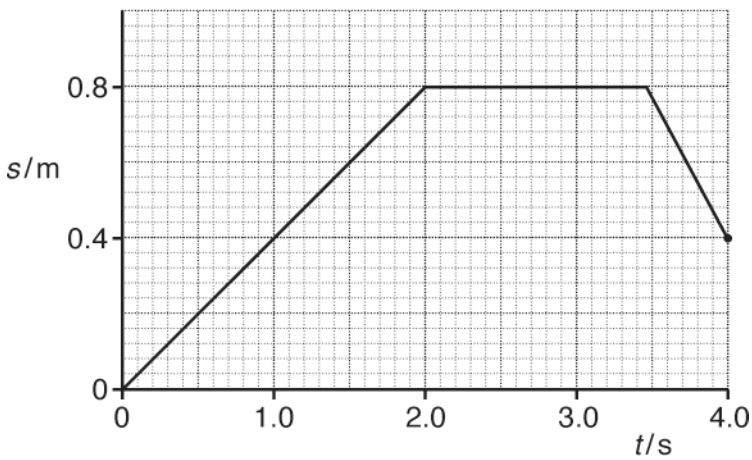


Fig. 20.2

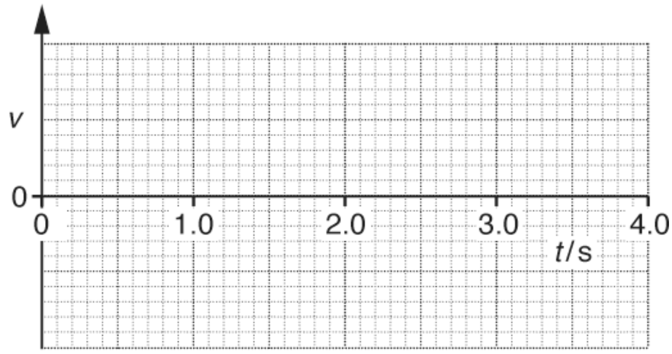


Fig. 20.3

(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.

--- **[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 = ______________________________ ms^{-1} **[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]**

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

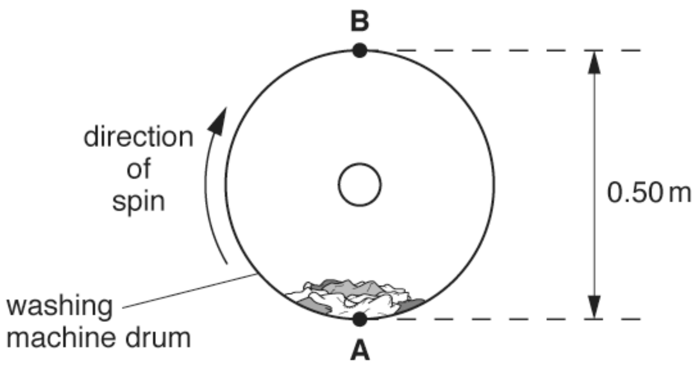


Fig. 21

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

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]

17

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.

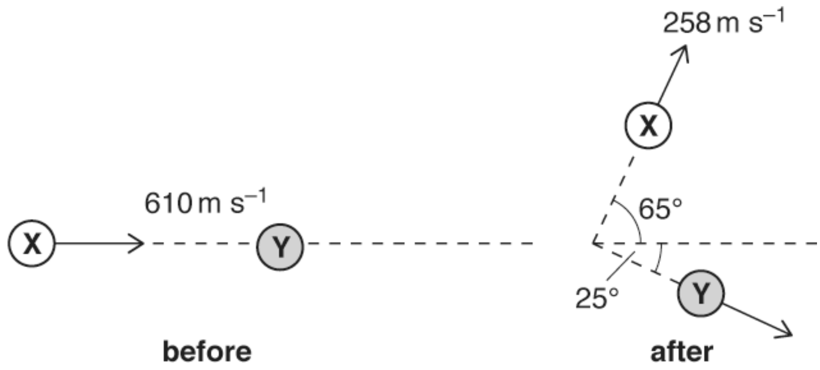


Fig. 22

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

____

____ **[1]**

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

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

18(a) 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*.

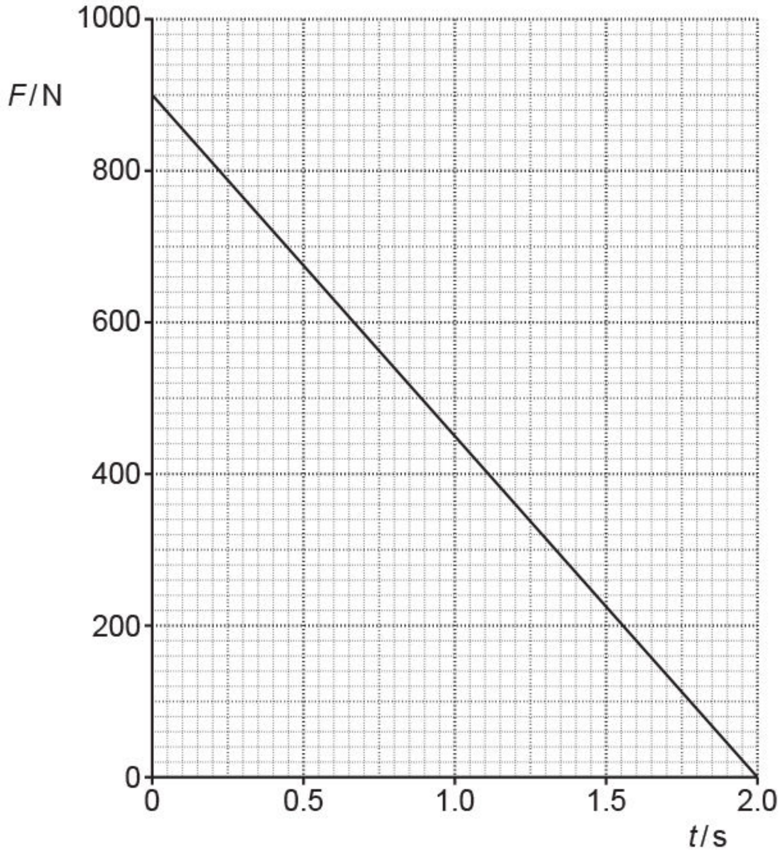


Fig. 20.1

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

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

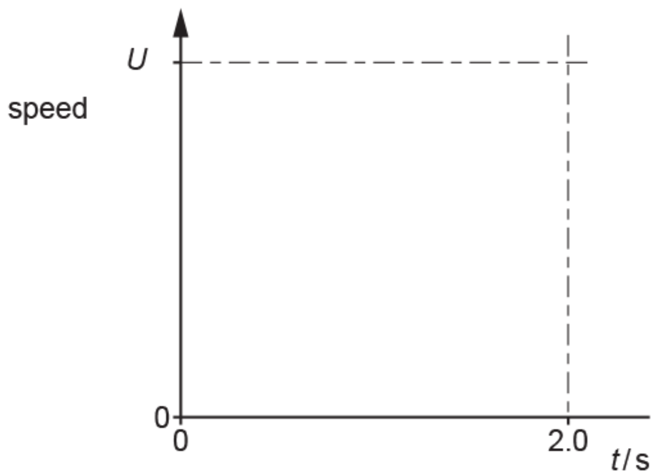
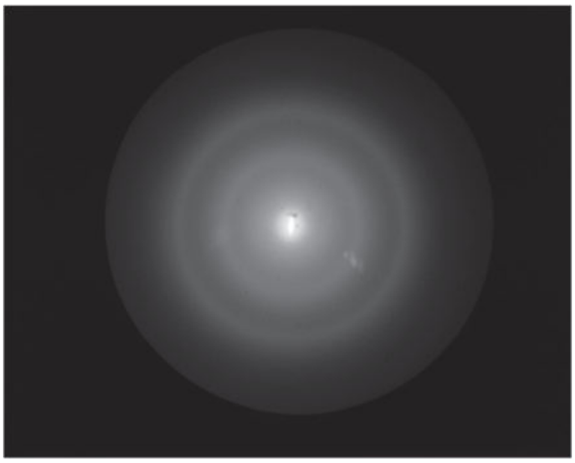


Fig. 20.2

[2]

19 * A student is investigating electron diffraction. A beam of electrons is directed towards a thin slice of graphite in an evacuated tube.

The electrons are accelerated by a potential difference of 2000 V. The diagram below shows the pattern formed on the fluorescent screen of the evacuated tube.



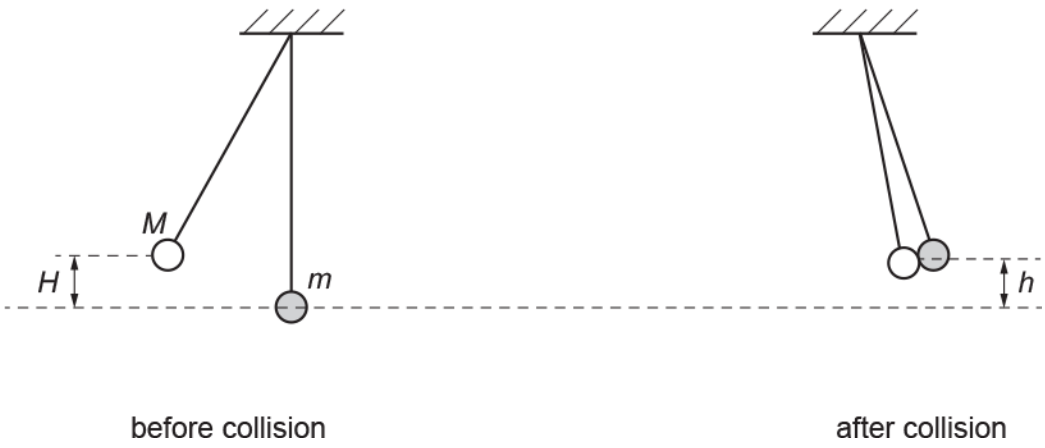
Describe and explain how the pattern changes as the potential difference is increased. Include how the de Broglie wavelength λ of the electron is related to the potential difference V.

[6]

20 * 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.



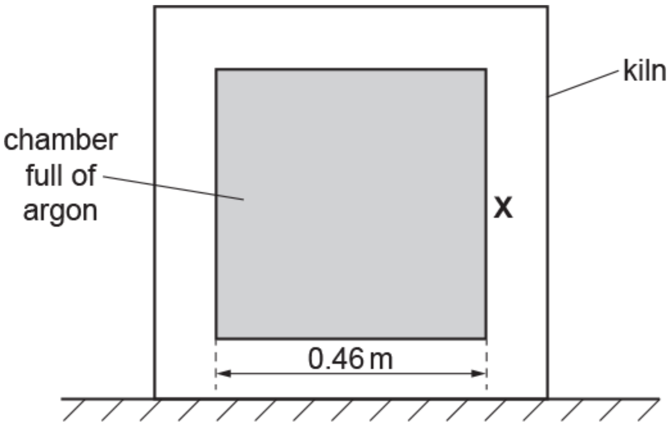
The bob of mass M is pulled back to a vertical height of H from its rest position. It is released and collides with the bob of mass m. The two bobs then stick together and reach a maximum vertical height h from the rest position.

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]

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.

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 = 6.6×10^{-26} kg

Δp = ... kg m s^{-1} **[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.

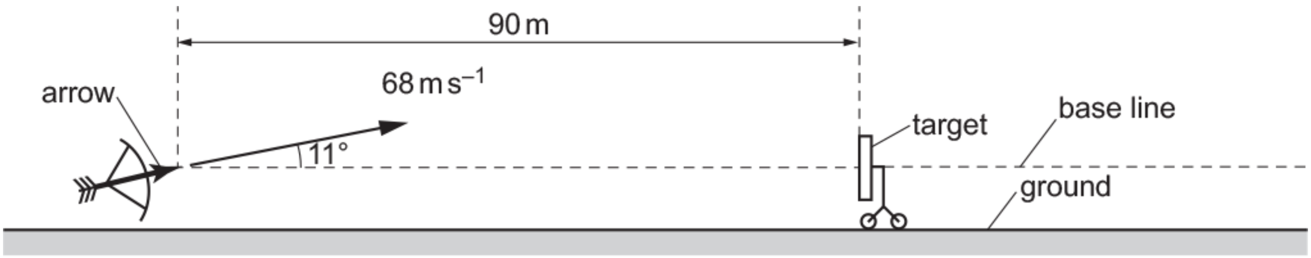
F = ... N **[2]**

(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.

---

[2]

22(a) An archer fires an arrow towards a target as shown below.



The diagram is **not** drawn to scale.

The centre of the target is at the same height as the initial position of the arrow.
The target is a distance of 90 m from the arrow.
The arrow has an initial velocity of 68 m s^{-1} and is fired at an angle of 11° to the horizontal.

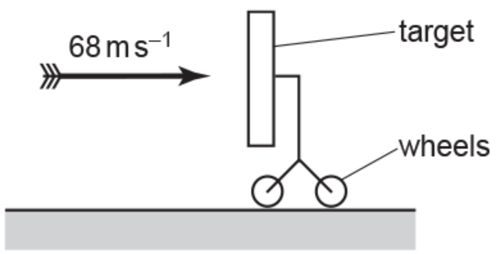
Air resistance has negligible effect on the motion of the arrow.

The arrow misses the target.

Calculate the horizontal distance, measured along the base line, by which the arrow misses the target.

horizontal distance = ... m **[3]**

(b) The arrow is now fired horizontally at 68 m s^{-1} into the target at very close range.



The arrow sticks into the target. The collision between the arrow and the target is inelastic.

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

--- **[1]**

(ii) The target is mounted on wheels. The target has a much larger mass than the mass of the arrow.

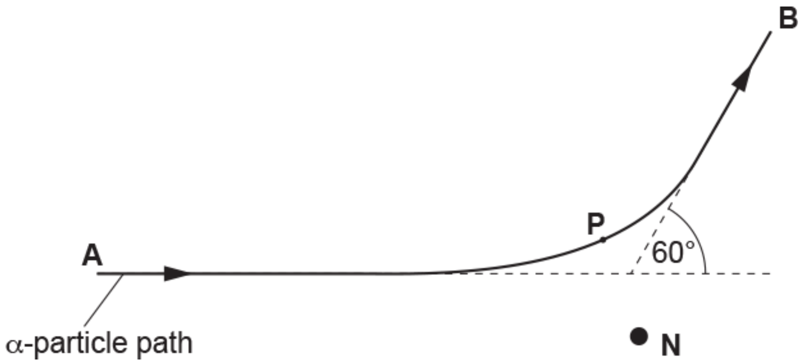
Using ideas of momentum, explain the velocity of the target immediately after the arrow sticks into the target.

--- **[2]**

23(a) 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.



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} kg m s^{-1}.
Take the mass of the α-particle to be 6.6×10^{-27} kg.

[3]

(b) 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]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1			B	1	
			Total	**1**	
2	a		Area under graph = 0.5 × 0.06 × 1.8 = 0.054 (Ns)	C1	
			0.05 × v = 0.054, therefore v = 1.1 (ms^{-1})	A1	
	b	i	Both forces shown in correct direction and arrows of same length.	B1	
		ii	Zero.	B1	
		iii	(Conservation of momentum) $u_x = v_x + v_z$	C1	
		iii	(Conservation of kinetic energy) $u^2_x = v^2_x + v^2_z$	C1	
		iii	Shows $v_x = 0$ by substitution	C1	
		iii	$v_z = u_x$ by substitution of $v_x = 0$	A1	
			Total	**8**	
3			A	1	
			Total	**1**	
4		i	T = 293 K	M1	
		i	3/2 kT = ½ mv^2	C1	
		i	3/2 × 1.38 × 10^{-23} × 293 = ½ × 4.7 × 10^{-26} × v^2	M1	
		i	v = 510 (m s^{-1})	A0	Note answer is 509.8 m s^{-1} to 4 s.f.
		ii	**1.** Total vertical momentum after = 0 Total vertical momentum before = 0 (momentum is conserved)	B1 B1	
		ii	**2.** 4.7 × 10^{-26} × v × sin 88° = 1.4 × 10^{-24} × 23 × sin 45°	C1	
		ii	v = 480 (m s^{-1})	A1	**Allow** other correct methods.
			Total	**7**	
5		i	250 × 60 = 15000 J	C1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		i	energy = $\frac{15000}{0.65}$ = 2.3×10^4 (J)	A1	
		ii	drag force = $0.4 \times 6.0^2 = 14.4$ N	C1	
		ii	forward force = power / velocity = 250/6.0 = 41.7 N	C1	
		ii	acceleration = $\frac{41.7 - 14.4}{85} = 0.32$ m s^{-2}	A1	
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6		i	*N* & *W* act on the same body / Newton's 3rd Law forces should act on different bodies	B1	**Allow:** 3rd law pair to W acts on (centre of) Moon 3rd law pair to N acts on surface of Moon
		i	*N* & *W* are different types (of force) / are not same type	B1	**Allow:** *N* is electromagnetic / electrostatic / electrical / contact *W* is gravitational. **Allow:** Paired forces should be of the same type **Ignore** a general statement of Newton's 2nd or 3rd law **Examiner's Comments** This question was designed to allow students to demonstrate their understanding of Newton's third law. Although many were able to quote the law accurately, few were able to apply it correctly. Only a minority of candidates scored any marks at all, usually for stating that the pair forces must be of the same type and *N* and *W* were not. It was particularly disappointing to see the large number of misconceptions offered such as 'Newton's laws only apply on Earth', '*N* and *W* should be applied at the same point' and 'There is no gravity on the Moon'. Newton's third law continues to present a challenge to the majority of candidates.
		ii	Equal to / same as *W* acting on (the centre of) the Moon	B1	Do not allow 'acts on **surface** of Moon' Diagram is not sufficient for this mark **Examiner's Comments** This was a discriminating question with the more able candidates performing well. Many candidates attempting the question failed to read the word '*location'* and gave answers referring to just the magnitude and direction of the force.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
7	a	i	$m = \frac{0.131}{6.02 \times 10^{23}}$ $m = 2.18 \times 10^{-25}$ (kg)	A1	**Examiner's Comments** Most candidates were able to score the mark for dividing the molar mass of xenon by Avogadro's number. A small number, however, obtained answers which were many orders of magnitude greater than the required value. Candidates are advised to ask themselves the simple question 'Is this a reasonable answer' before moving on to the next question. This check often suggests an error has occurred which may hopefully be found and corrected thus avoiding an unnecessary loss of marks.
		ii	mass of xenon ejected / s = $m_{Xe} = 2.2 \times 10^{-25} \times 9.5 \times 10^{18}$ ($= 2.07 \times 10^{-6}$)	C1	Possible ECF
		ii	$F_{Xe} = \left(m_{Xe} \frac{\Delta v}{\Delta t}\right) = 2.2 \times 10^{-25} \times 9.5 \times 10^{18} \times 3.2 \times 10^{4}$ ($= 0.06627$) $a_S = \left(\frac{F_{Xe}}{m_s}\right) = \frac{2.2 \times 10^{-25} \times 9.5 \times 10^{18} \times 3.2 \times 10^{4}}{5.2 \times 10^{3}}$	C1	**Allow:** $5.2 \times 10^{3}\ \Delta v = 2.07 \times 10^{-6} \times 3.2 \times 10^{4}$ $\Delta v = 1.3\text{x}10^{-5}$ $a_S = 1.3 \times 10^{-5}$ (m s^{-2})
		ii	$a_S = 1.3 \times 10^{-5}$ (m s^{-2})	A1	**Examiner's Comments** There were three stages to this calculation: firstly, the determination of the mass of xenon ejected per second which most were able to complete successfully; secondly, the application of Newton's second law to determine the force on the xenon ions and hence, by Newton's third law, the force on the spacecraft; finally, the acceleration which could be calculated from Newton's second law. The majority of candidates followed this process through accurately and presented their working logically. The most common error, made by weaker candidates, was the use of the spacecraft's mass to determine the force on the xenon. This resulted in excessively high acceleration

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Rate of change of **momentum** (of an object) is proportional to the resultant / net (external) force acting upon it. (AW) **OR** statement of law of Conservation **of momentum** in a closed system / no external forces	B1	 **Momentum** must be spelled correctly **Allow:** ' equal to' instead of 'proportional to' **Allow:** statement of Newton's 3rd Law provided it is clear the forces act on **different** bodies and **opposite** is spelled correctly **Examiner's Comments** The mark scheme was made particularly flexible here in order to reward candidates for accurately quoting either of Newton's second and third laws or a statement of conservation of linear momentum. This ensured that most candidates were in a position to score the mark. A significant number of candidates lost this mark by not making it clear that Newton's second law refers to the **resultant** force acting on the system.
		iv iv iv	Force (on spacecraft) is constant Mass (of spacecraft) decreases (as xenon is ejected) Acceleration increases	B1 M1 A1	Enter text here. **Not:** Weight (of spacecraft) or 'it is lighter' **Examiner's Comments** Most candidates realised that the mass of the spacecraft would decrease as xenon is ejected and this would cause an increase in acceleration. Only a minority were aware that this conclusion required the force on the spacecraft to be constant and correctly drew attention to this fact. On the whole this question discriminated well across the range of candidates.
	b	i i	Area under graph in range 10.5 to 11.5 (Ns) Area under graph in range 10.8 to 11.2 (Ns) $\Delta v = \frac{\text{impulse}}{m} = \frac{\text{area}}{m}$	C1 C1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		i	$= \frac{11.0}{180}$	C1	Possible FT for using their area / 180 Use of mass of spacecraft rather than satellite scores 1 out of last 2 marks.
		i	= 6.1×10^{-2} (*ms*$^{-1}$)	A1	**Examiner's Comments** Very many candidates realised that this question required them to calculate the impulse by finding the area under the curve. A wide variety of methods were seen but the poor layout made it difficult to follow the logic and identify specific errors. A significant number calculated this value by counting squares for the entire shape which inevitably consumed an excess of their time. The expected method of calculating the area of the trapezium from 0-12 ms at a height of 1000 N together with a rectangle from 4 to 9 ms of height 200 N using formulae, was not commonly seen. This method reduced the counting to a few small squares at the top of the graph. To reflect the time required to obtain a reasonably accurate area the examiners decided to award a maximum of 2 marks, dependent upon the accuracy of the value obtained. The candidate's area was then used to determine the change in velocity with error carried forward. This application resulted in good discrimination with about 75% scoring 2 or more marks. A small minority used the maximum force of 1300 N acting over a time of 12 ms; this approach received no credit.
		ii	From 0 to 3 (ms) acceleration increases linearly / uniformly / at constant rate / at a steady rate.	B1	**Allow:** upper limit on time in range 3.0 to 3.5 ms Do not credit use **of 'constantly'** for this mark

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(From 6.5 ms) onwards / later / at end the acceleration decreases	B1	Not 'decelerates' Examiner's Comments In this question it was common to see the phrase '*rate of acceleration'* used when clearly what was meant was '*acceleration'.* Candidates should note that 'rate of acceleration' is the 'jerk' experienced and this is the gradient of an acceleration against time graph. It is also inappropriate to talk of *'acceleration slowing down'*. For the first marking point credit was only given if the candidate identified the increase in acceleration and stated that this occurred linearly between 0 and 3 ms. A small latitude was allowed on the upper limit of this range of times but a significant number lost this mark through inaccurate reading of the scale on the graph. The second mark was awarded for candidates correctly identifying the period from 6.5 ms as one in which the acceleration decreased without specifying the manner of the changes. Unfortunately many incorrectly associated the negative gradient with negative acceleration or deceleration rather than negative jerk and lost the second mark.
			Total	14	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
8		i	$\rho = m/V = m/Av$; so $m = A\rho v$	C1	
		i	$7.5 \times 10^{-5} \times 1000 \times v = 0.070$	A1	
		i	giving $v = 0.93$ (m s^{-1})	A0	
		ii	3.7 (m s^{-1})	A1	Accept 3.72
		iii	$F = \Delta(mv)/\Delta t = 0.070 \times (3.72 - 0.93)$	C1	**ecf (ii)**
		iii	$F = 0.195$ (N)	A1	accept 0.19 or 0.2(0)
		iv	arrow into the shower head perpendicular to its face.	B1	award mark for a reasonable attempt.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
9	a		A body will remain at rest or keep travelling at constant velocity unless acted upon by a resultant/net (external) force (AW)	B1	**Allow** 'speed in straight line' for velocity **Allow** 'uniform motion' Examiner's Comments Many candidates could not be awarded this mark because their answer did not emphasise the need for a resultant force to be acting.
	b	i	They have equal magnitude/ same size	B1	**Allow** act for the same time
		i	They are the same type / nature	B1	**Allow** have same line of action Examiner's Comments It was clear that candidates had been well prepared for this Newton's third law question. As a result many were able to score highly in both parts. The most common error made was concerning the location of the forces.
		ii	Act in opposite directions	B1	**Not** act in different directions
		ii	Act on different bodies	B1	Examiner's Comments It was clear that candidates had been well prepared for this Newton's third law question. As a result many were able to score highly in both parts. The most common error made was concerning the location of the forces.
	c	i	$\frac{dm}{dt} = \rho Av$ $= 1\times10^{3}\times3.3\times10^{-4}\times25$ ($= 8.25$ kg s^{-1})	B1	Examiner's Comments Well answered by almost all candidates.
		ii	Weight (of fireman) = 92g / W = 92 × 9.8(1) (= 903 N)	C1	
		ii	Vertical component of water force = 8.25 × 25 sin 55 (= 169 N)	M1	**Allow** use of 8.3 leading to 170 N

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Vertical component of contact force = 169 + 903 = 1100 N	A1	**Note** answer to 3 sf is 1070 N **Note:** a **bald** $\frac{92g}{\sin 55}=1100$ is WP scores 0/3 **Examiner's Comments** Most candidates realised that the weight of the fireman was required in order to calculate the force exerted by the ground. However, only a minority were aware that the vertical component of the water force would create an additional component. It was rare to see a diagram used to support the answer. The most commonly seen error was the attempt to include a resolved component of the weight of water ejected.
			Total	9	
10			A	1	
			Total	1	
11	a		$mv - mu = F\Delta t$ (u = 0) / area under graph = Δp	C1	**Allow** 'impulse' for Δp
			$mv = \frac{0.010 + 0.040}{2} \times 150$	C1	**Allow** alternative methods for finding area.
			mv = 3.75 or $v = \frac{3.75}{0.16}$		
			v = 23 (m s^{-1})	A1	**Note** answer to 3 s.f. is 23.4 m s^{-1}
	b		Curve upwards with decreasing gradient.	M1	
			Curve starts at a non-zero velocity at t = 30 ms.	A1	
	c		$F\Delta t = mv - mu$		**Allow** other correct methods
			$T = \frac{0.16 \times 23}{0.80}$	C1	Possible ECF from **(a)**
			T = 4.6 (s)	A1	**Note** the answer is 4.7 (s) when 23.4 (m s^{-1}) is used
			Total	7	

Question			Answer/Indicative content	Marks	Guidance
12		i	$a = 4\pi^2f^2 \times$	C1	condition for SHM
		i	so $k = (m4\pi^2f^2) = 1.7 \times 10^{-27} \times 4 \times 9.87 \times 43.7 \times 10^{26}$	B1	substitution
		i	$k = 292$ ($N\ m^{-1}$)	A1	**ecf** if incorrect mass used
		ii	(N2 gives) $F_H = m_Ha_H$ and $F_I = m_Ia_I$	B1	**allow** total momentum = 0 at all times
		ii	(N3 gives) $F_H = F_I$ *can be implicit*	B1	SHM gives $v = 2\pi fx_{max}$
		ii	SHM gives $a\ \alpha\ (–)x$	B1	so $m_HX_H = m_Ix_I$
		ii	hence $x_H/x_I = a_H/a_I = m_I/m_H = 127$	B1	**accept** $127 = x_H/x_I \approx 10/0.08 = 125$
			Total	7	
13			A	1	**Examiner's Comments** This question was more challenging still. In this question, candidates often forgot that the impulse provided by the hockey stick is in the opposite direction to the momentum of the puck, again giving option A as the correct answer.
			Total	1	

Question			Answer/Indicative content	Marks	Guidance
14	a		${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + \ldots\ldots$ ${}^{4}_{2}He$ or ${}^{4}_{2}\alpha$	B1 B1	**allow** proton and / or nucleon number to the right of symbol **allow** γ-photon; zero for any other extra particle **Examiner's Comments** Most candidates made a good start to the paper writing a correct equation for the nuclear decay.
	b		$mv = (4.00 – 0.0665) \times 10^{-25} \times 2.40 \times 10^5$ $= 9.44 \times 10^{-20}$ $v = 9.44 \times 10^{-20} / 6.65 \times 10^{-27} = 1.42 \times 10^7$ k.e. $= ½ \times 6.65 \times 10^{-27} \times (1.42 \times 10^7)^2$ $= 6.70 \times 10^{-13}$ (J) $6.70 \times 10^{-13} / 1.60 \times 10^{-13} = 4.19$ (MeV)	C1 C1 A1 B1	**allow** 0.07×10^{-25} for α-particle mass **max** 3 if use 4.00 instead of 3.93 in momentum eq'n **allow** ratio of masses 234 and 4 **or** calculations using 234u and 4u **allow** $p^2/2m$ calculation for k.e. **accept** 4.0 to 4.2; **ecf** (calculated value of k.e. in J)/e **N.B.** the correct answer automatically gains all 4 marks **Examiner's Comments** One mark in this question was reserved for converting units from joule into mega electronvolt. This was the only mark awarded to half of the candidates. Few recognised this to be an isolated system, applying the conservation of momentum to solve the problem. Few appeared to realise that the mass of an alpha particle is given in the Data, Formulae, and Relationships Booklet, calculating it instead by summing the masses of neutrons and protons. The most common incorrect approach was to use the formula $E = mc^2$ or to equate the kinetic energies of the thorium nucleus and alpha particle.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		$\Delta A = 32 = 4n_\alpha$ so $n_\alpha = 8$ $\Delta Z = 10 = 2n_\alpha - n_\beta$ so $n_\beta = 6$ argument / reasoning given for both n_α and n_β	B1 B1 B1	**allow** 8 (decays), i.e no mention of α particles **allow** 10 – 16 = –6; **NOT** 14 – 8 = 6; **must state** β(–) particles e.g. change in mass number caused by α decay,change in proton number combination of α and β Examiner's Comments A significant number had no idea where to start and left the page blank. Of the rest most managed to decide on 8 alpha particles. A minority worked initially with the proton number rather than the nucleon number incorrectly choosing 5. The explanations about the choice of 6 beta particles were often just restricted to equating the numbers correctly rather than giving any description of the transformation of neutrons into protons.
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a		$E_k = {}^1/_2\ mv^2$ <u>and</u> $p = mv$	M1	**Allow:** any subject
			(Correct manipulation leading to) $E_k = {}^1/_2\ p^2/m$	A1	**Allow:** $E_k = p^2/(2m)$
	b	i	From $t = 0$ to $t = 2.0$ s: a non–zero horizontal line	B1	
			From $t = 2.0$ to $t = 3.5$ s: line showing $v = 0$	B1	
			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	Judgement by eye
		ii	KE is constant.	B1	
			GPE increases linearly / proportional to t	B1	**Allow:** 'at constant rate' for 'linear' Not: unqualified 'constantly' <u>Examiner's Comments</u> 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. ${}^1/_2$ 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			Answer/Indicative content	Marks	Guidance
		iii	$V^2 = 0.80^2 + 2 \times 9.81 \times 0.40$ $V = 2.9$ (m s^{-1})	C1 A1	**Allow** 1 mark for $(2 \times 9.81 \times 0.40)^{1/2} = 2.8$ (m s^{-1}) **Examiner's Comments** 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}.
		iv	$F = 0.12 \times 2.9/0.025$ $F = 14$ (N)	C1 A1	Possible ECF from **(iii)1** **Note:** use of 2.8 m s^{-1} gives F = 13(.44 N) **Note:** 1.4×10^{n} (N) scores 1 mark **Examiner's Comments** 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.
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16			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) <u>Examiner's Comments</u> 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.
			Total	2	

Question			Answer/Indicative content	Marks	Guidance
17		i	KE is conserved (as well as momentum)	B1	**Allow:** No KE 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} $p = 3.7 \times 10^{-24}$ (kg m s^{-1})	C1 C1 A1	**Allow** confusion of sin and cos at this stage **Allow** attempt at conservation of KE **Allow** any subject e.g. p cos(25°) + m × 258cos(65°) = m × 610 or p sin(25°) = m × 258sin(65°) or $(p)^2 + (m \times 258)^2 = (m \times 610)^2$ or $\frac{1}{2} mv^2 + \frac{1}{2} m (258)^2 = \frac{1}{2} m(610)^2$ Answer is 3.67×10^{-24} (kg m s^{-1}) to 3 sf Examiner's Comments 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.
			Total	4	

Question			Answer/Indicative content	Marks	Guidance
18	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) Examiner's Comments It was good to see that most candidates understood that Newton's second law of motion is more than the statement that *F=ma*. Many had successful attempts with some candidates missing that it is the rate of change of momentum, rather than the change of momentum that is required. About two-thirds of candidates also correctly indicated that the area under the graph represents the impulse or the change in momentum. In Question 20(b), some candidates assumed, incorrectly, that the maximum force multiplied by the time taken would give the change in momentum and so scored zero marks. Rather more simply divided the maximum force by the mass, which gave the right answer yet with incorrect physics. This approach also scored zero. In fact, more successful responses made it clear that the area of the triangle on the graph was the impulse and that that area gave a change in momentum of 900 Ns.

Question			Answer/Indicative content	Marks	Guidance
	b		area under graph = 0.5 x 2.0 x 900 = 900 (N s) (*mU* = 900) *U* = 13 (m s^{-1})	C1 A1	**Not**: (initial force/mass) __Examiner's Comments__ It was good to see that most candidates understood that Newton's second law of motion is more than the statement that *F=ma*. Many had successful attempts with some candidates missing that it is the rate of change of momentum, rather than the change of momentum that is required. About two-thirds of candidates also correctly indicated that the area under the graph represents the impulse or the change in momentum. In Question 20(b), some candidates assumed, incorrectly, that the maximum force multiplied by the time taken would give the change in momentum and so scored zero marks. Rather more simply divided the maximum force by the mass, which gave the right answer yet with incorrect physics. This approach also scored zero. In fact, more successful responses made it clear that the area of the triangle on the graph was the impulse and that that area gave a change in momentum of 900 Ns.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	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. <u>Examiner's Comments</u> Successful candidates spotted that the resultant force, the acceleration and hence the gradient of this speed- time graph decreased in magnitude with time. A constant gradient, ie a straight line between (0,U) and (2.0,0), can only be achieved by a constant decelerating resultant force. This gives a curve that starts off (0,U) with a steep negative gradient and finishes with a small negative gradient at (2.0,0).
			Total	6	

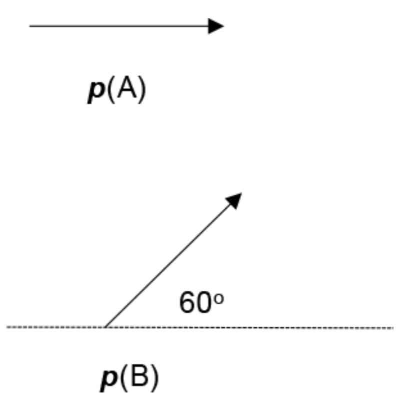
Question			Answer/Indicative content	Marks	Guidance
19			**Level 3 (5–6 marks)** Description and explanation of pattern changes **and** quantitatively explains link between de Broglie wavelength and potential difference. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Clear description of how pattern changes and explanation of pattern changes and qualitatively explains link between de Broglie wavelength and potential difference **or** limited description of how pattern changes and quantitatively explains link between de Broglie wavelength and potential difference. *There is a line of reasoning presented with some structure.* *The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description of how pattern changes and limited attempts to explain qualitatively the link between de Broglie wavelength and potential difference **or** qualitatively explains link between de Broglie wavelength and potential difference. *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.* **0 marks** No response or no response worthy of credit.	B1 ×6	***Indicative scientific points may include:*** ***Description of pattern changes*** • Rings become closer (not just smaller) • Rings become brighter ***Qualititative explanation of pattern changes in terms of de Broglie wavelength and potential difference*** • Electrons gain greater energy • Electrons have a greater speed • Electrons have a greater momentum • Implies smaller wavelength • Smaller wavelength means less diffraction • Shorter wavelength gives shorter path differences between areas of constructive and destructive interference ***Quantitative explanation of pattern changes in terms of de Broglie wavelength and potential difference*** • $eV = \frac{1}{2}mv^2$ • $p = mv$ • $v^2 \alpha V$ or $p^2 \alpha V$ • $\lambda = \frac{h}{p}$ or $\lambda \alpha \frac{1}{v}$ • $\lambda = \frac{h}{\sqrt{2meV}}$ or $\lambda \propto \frac{1}{\sqrt{V}}$ <u>**Examiner's Comments**</u> This question tested an understanding of electron diffraction. Many candidates gave a good qualitative explanation of how the pattern would change. High achieving candidates clearly demonstrated how the de Broglie wavelength λ was related to the potential difference V by equating the energy eV to kinetic energy, then using the definition of momentum and the de Broglie wavelength. Some candidates confused speed v with potential difference V. Many candidates gave a good qualitative explanation. Many candidates did not state that the rings would become brighter.

Question			Answer/Indicative content	Marks	Guidance
					AfL Candidates should be able to describe how to use light gates. In particular, candidates should be able to indicate the measurements that are needed to determine speed and acceleration. Candidates should state that the light gates should be connected to a timer or data-logger. **AfL** When analysing experimental data, candidates should be able to determine appropriate graphs to plot which will give a straight line (if the given relationship is true). Candidates should also be able to describe how unknown quantities may be determined using the gradient and / or *y* -intercept. **Misconception** There is some confusion between the equations to use for photoelectric effect and the equations to use when considering the de Broglie wavelength. For the de Broglie wavelength, a common misconception is to relate the energy to wavelength by the equation for the energy of a photon, $E = \frac{hc}{\lambda}$
			Total	6	

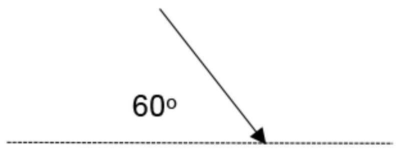
Question			Answer/Indicative content	Marks	Guidance
20			**Level 3 (5–6 marks)** Clear description of experiment **and** measurements **and** clear analysis. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some description of experiment **and** some measurements **and** some analysis. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description of experiment **or** Limited measurements **or** Limited analysis *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.* **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*** • 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	

Question			Answer/Indicative content	Marks	Guidance
21		i	(p =) $6.6 \times 10^{-26} \times 990$ **or** $6.5(3) \times 10^{-23}$ (kg m s^{-1}) (Δp =) $2 \times 6.6 \times 10^{-26} \times 990$ $\Delta p = 1.3 \times 10^{-22}$ (kg m s^{-1})	C1 A1	 **Ignore** sign of answer
		ii	990/[2 × 0.46] (= 1080) ($F = \Delta p/\Delta t$) (F =) $1.3 \times 10^{-22} \times 1000$ $F = 1.3 \times 10^{-19}$ N	B1 C1 A1	 Possible ECF from **(b)(i)** **Note** 1080 would give 1.4×10^{-19} (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	**7**	
22	a		(t =) 2 × 1.3 **or** 2.6 (s) (x =) 68 cos11° × 2.6 or 174 (m) horizontal distance = 174 – 90 horizontal distance = 84 (m)	C1 C1 A1	 **Note** answer is 86 (m) if 1.32 s is used **Note** answer is 87 (m) if 1.3226… s is used **Allow** 1.3 × 68 cos11° for 1 mark **Allow** 3 or –3 m for 2 marks
	b	i	A collision in which kinetic energy is lost	B1	**Allow** KE is not conserved
		ii	Conservation of momentum Idea that velocity is to the right **and** velocity is very small / much smaller than 68 (m s^{-1})	B1 B1	**Not** 'goes backwards'
			Total	**6**	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
23	a		(k.e. =) $E = 5.0 \times 10^{6} \times 1.6 \times 10^{-19}$ $v = \sqrt{(2E/m)}$ **or** $= \sqrt{(2 \times 8.0 \times 10^{-13} / 6.6 \times 10^{-27})} = 1.6 \times 10^{7}$ (ms^{-1}) p (= mv) = $6.6 \times 10^{-27} \times 1.6 \times 10^{7}$ giving $p = 1.1 \times 10^{-19}$ (kg m s^{-1})	C1 C1 A1	$E = 8(.0) \times 10^{-13}$ J **or** ($E = p^2/2m$ so) $p = \sqrt{(2mE)}$ **Note:** A value of $v = 1.6 \times 10^{7}$ (ms^{-1}) automatically scores both C1 marks even if the calculation for E is not shown **or** p (= $\sqrt{(2mE)}$) = $\sqrt{(2 \times 6.6 \times 10^{-27} \times 8.0 \times 10^{-13})}$ giving $p = 1.0 \times 10^{-19}$ (kg m s^{-1}) Full substitution of values must be shown and answer (if calculated) must be correct <u>Examiner's Comments</u> This question provided an excellent opportunity for candidates to produce immaculate responses: identify the physics involved, select and write down the correct formula, do the necessary conversion (MeV to J), rearrange the formula, substitute correctly and then write the final response in standard form to a correct number of significant figures. Some of the common errors were: • forgetting to convert 5.0 MeV into J • not showing a full substitution of values (which is necessary for a 'show that' question) • not calculating the response to more than 1 s.f. (which is necessary for a 'show that' question).
	b	i	Example (not to scale): 	B1 B1	horizontal arrow (judge by eye), in the direction shown arrow drawn at an angle of 60° to the horizontal (angle must be shown), in the direction shown

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Example (not to scale):  (Can apply principle of) conservation of momentum (since no external forces are acting)	B1 B1	arrow drawn at an angle of 60° to the horizontal (angle must be shown), in the direction shown **Examiner's Comments** This was not an easy question but, even so, a good number of candidates did well. The marks were given for the direction (rather than for the magnitude) of the momentum vectors. Some of the common errors were: • forgetting to label relevant angles • not using arrows to show direction • drawing a vector triangle without any indication of which arrow was meant to be the final momentum.
			Total	7	