

PHYSICS



EXAM QUESTION PACK

TOPIC 2: MOTION AND FORCES

SCORE

/103

PERCENTAGE

%

STEMUP

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Q1.

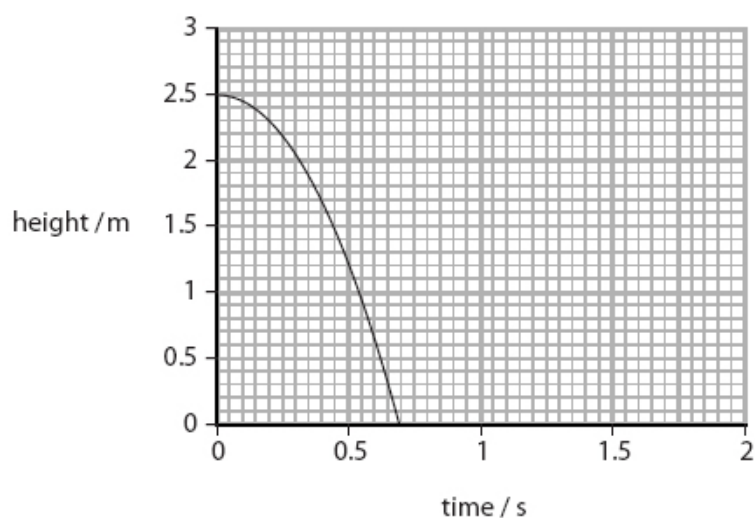
The man in the photograph balances a ball above the ground.



He lets the ball fall.

He starts a timer at the same time.

The graph shows how the height of the ball above the ground changes with time.



(i) From the graph, state the height of the ball above the ground when the timer was started.

(1)

height above ground = ... m

(ii) From the graph, state the time taken for the ball to reach the ground.

(1)

time = ... s

(iii) The ball bounces back to a height of 1.9 m.

Continue the line on the graph to show this.

(3)

(iv) Explain why the ball does not bounce back to its original height.

(2)

.....
.....

Q2.

Figure 4 shows two students investigating their reaction times.

Student B supports his left hand on a desk.

Student A holds a ruler so that the bottom end of the ruler is between the finger and thumb of student B.

When student A releases the ruler, student B catches the ruler as quickly as he can.

The investigation is repeated with the right hand of student B.

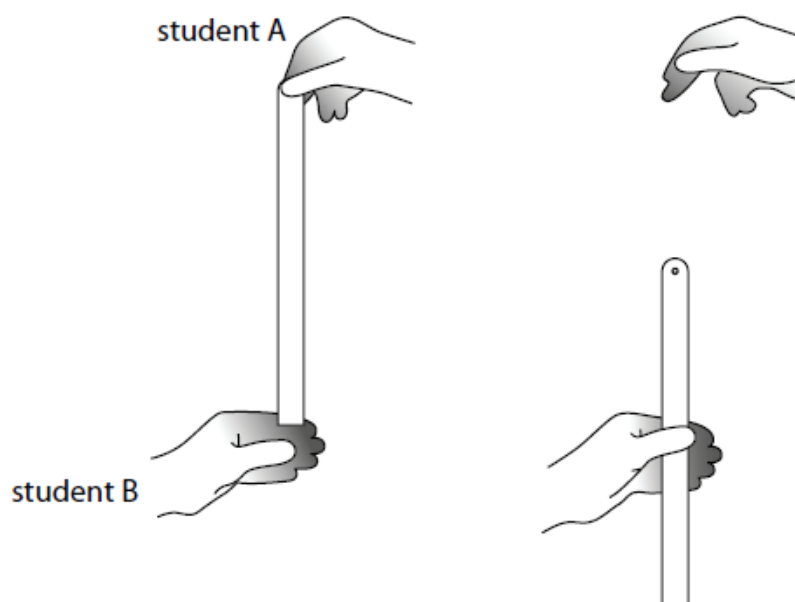


Figure 4

(a) The students took five results for the left hand and five results for the right hand.

Figure 5 shows their results.

which hand	distance dropped (cm)					average
	trial 1	trial 2	trial 3	trial 4	trial 5	
left	10.1	25.5	18.4	14.6	11.7	14
right	17.5	16.1	19.4	18.6	20.2	

Figure 5

(i) Calculate the average distance dropped for the right hand.

Give your answer correct to 2 significant figures.

(2)

distance = ... cm

(ii) Calculate the average time for the left hand.

Use the equation

$$\text{time}^2 = \frac{\text{distance}}{500}$$

(2)

average time = ... s

(b) Explain whether any of the readings are anomalous.

(2)

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(c) Give **two** ways that the students can improve the quality of their data other than ignoring anomalous results.

(2)

1

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2

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(d) Describe how the students could develop their investigation to investigate how reaction time changes with another variable.

(2)

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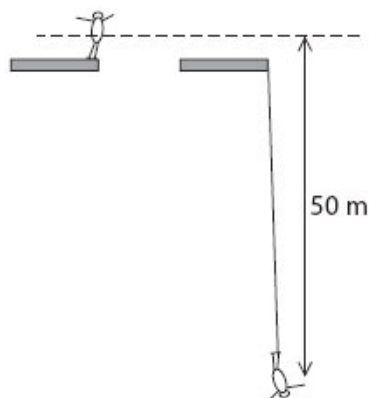
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(Total for question = 10 marks)

Q3.

A 60 kg student weighs 600 N.
He does a bungee jump.



The bungee cord becomes straight and starts to stretch when he has fallen 50 m.

Complete the sentence by putting a cross (☒) in the box next to your answer.

When his speed is 10 m/s his momentum is

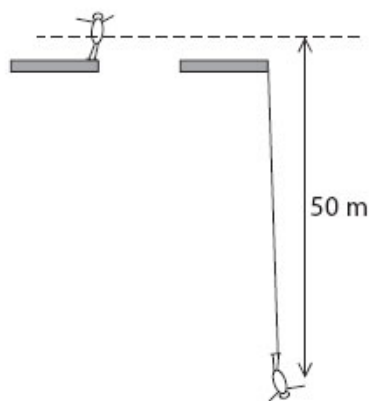
(1)

- ☒ **A** 600 kg m/s
- ☒ **B** 3 000 kg m/s
- ☒ **C** 6 000 N m/s
- ☒ **D** 30 000 N m/s

Q4.

A 60 kg student weighs 600 N.

He does a bungee jump.



The bungee cord becomes straight and starts to stretch when he has fallen 50 m.

(a) Complete the sentence by putting a cross (☐) in the box next to your answer.

He first stops moving

(1)

- ☐ **A** before all the energy has disappeared
- ☐ **B** before the bungee cord starts to stretch
- ☐ **C** when the bungee cord is stretched the most
- ☐ **D** when the elastic potential energy is zero

(b) Complete the sentence by putting a cross (☐) in the box next to your answer.

When his speed is 10 m/s his momentum is

(1)

- ☐ **A** 600 kg m/s
- ☐ **B** 3 000 kg m/s
- ☐ **C** 6 000 N m/s
- ☐ **D** 30 000 N m/s

(c) (i) Calculate the change in gravitational potential energy as the student falls 50 m.

Give the unit.

(3)

change in gravitational potential energy = ...unit

(ii) State at what point in the bungee jump the student has maximum kinetic energy.

(1)

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.....

(iii) Explain why his maximum kinetic energy is likely to be less than your answer to (c)(i).

(2)

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(Total for Question = 8 marks)

Q5.

Figure 10a shows a box falling towards a hard floor.

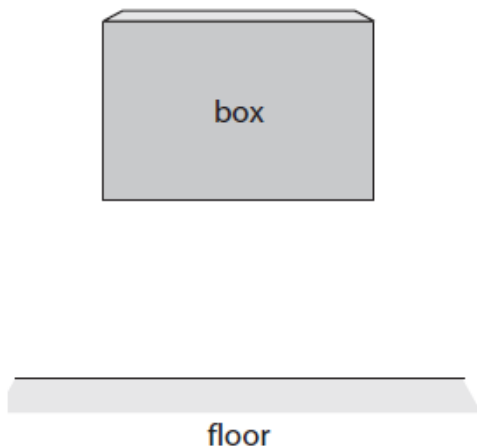


Figure 10a

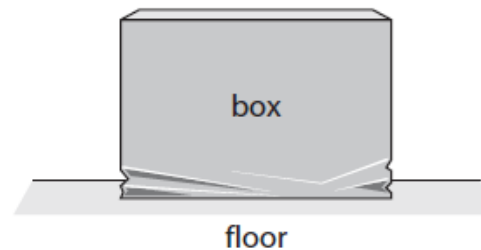


Figure 10b

The box hits the floor and crumples a little before it comes to rest as shown in Figure 10b.

The momentum of the box just before it hits the floor is 8.7 kg m/s.

The box comes to rest 0.35 s after it first hits the floor.

(i) Calculate the magnitude of the force exerted by the floor on the box.

Use an equation selected from the list of equations at the end of this paper.

(2)

force exerted by the floor on the box = ... N

(ii) State the magnitude and direction of the force exerted by the box on the floor.

(2)

magnitude

direction

(Total for question = 4 marks)

Q6.

Figure 8 shows two ice skaters during a performance.



Figure 8

(i) The two ice skaters are travelling together in a straight line at 3.50 m/s.

Their total momentum is 371 kgm/s.

The man has a mass of 64.5 kg.

Calculate the mass of the woman.

(4)

mass = ... kg

(ii) Calculate the kinetic energy of the man.

(2)

kinetic energy = ... J

(Total for question = 6 marks)

Q7.

Figure 7 is a velocity/time graph showing a 34 s part of a train's journey.

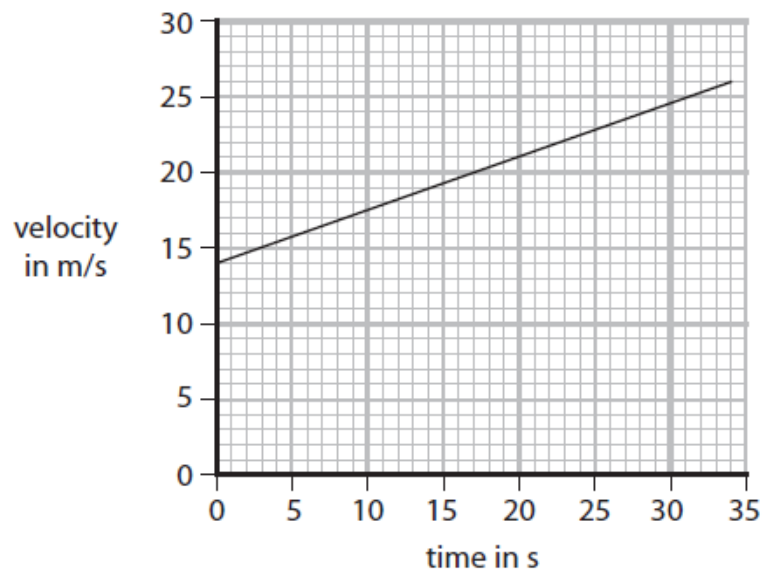


Figure 7

(i) Calculate the acceleration of the train in the 34 s.

Give your answer to an appropriate number of significant figures.

(3)

acceleration = ... m/s^2

(ii) Calculate the distance the train travels in the 34 s.

(3)

distance m

(Total for question = 6 marks)

Q8.

Figure 9 shows a skier on a slope.

The skier travels down the slope with a constant acceleration.

The speed of the skier is measured at points P and Q.

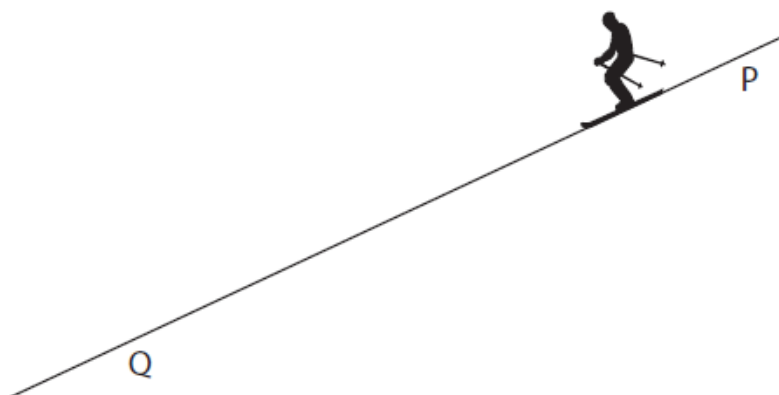


Figure 9

The table in Figure 10 gives some data about the skier making one downhill run.

acceleration	3.0 m/s^2
speed at P	7.6 m/s
speed at Q	24 m/s

Figure 10

(i) Calculate the distance from P to Q.

Use an equation selected from the list of equations at the end of this paper.

(3)

distance from P to Q = ... m

(ii) Calculate the time taken for the skier to travel from P to Q.

(3)

time from P to Q = ... s

(Total for question = 6 marks)

Q9.

Figure 5 shows a racket and a tennis ball.

The tennis ball is travelling towards the racket at a velocity of 8.2 m/s.

The ball is hit back in the opposite direction at a velocity of 15 m/s.

The ball has a mass of 0.075 kg.

The ball is in contact with the racket for 12 ms.

(i) Calculate the average force exerted by the ball on the racket.

Use the equation

$$F = \frac{mv - mu}{t}$$

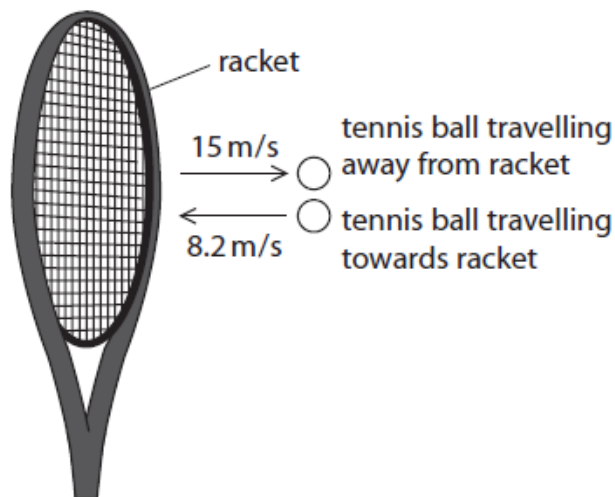


Figure 5

(3)

force = ... N

(ii) Describe how Newton's Third Law of Motion applies to the collision between the racket and the ball.

(2)

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(Total for question = 5 marks)

Q10.

In a science fiction story, lightning is used as an energy source for accelerating a car.

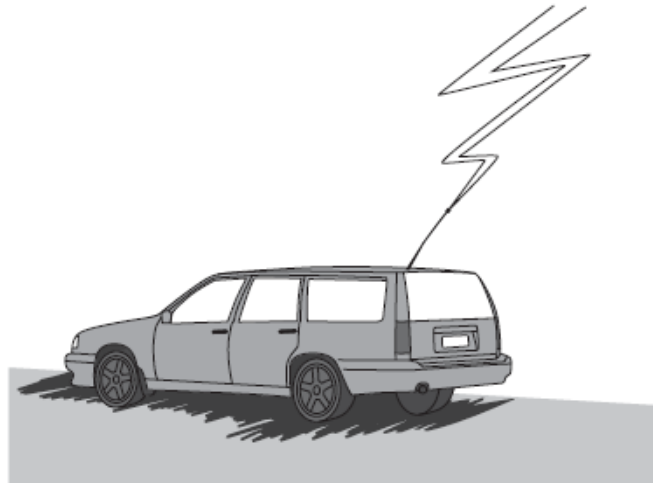


Figure 6

In the story, the car has a kinetic energy of 960 kJ at a speed of 40 m/s.

(i) Calculate the mass of the car.

(4)

mass = ... kg

(ii) Only 5% of the energy of the lightning bolt is transferred to the kinetic energy of the car.

Calculate the total energy of the lightning bolt in MJ.

(2)

energy = ... MJ

(Total for question = 6 marks)

Q11.

Figure 11 shows a ball held in a clamp at **R**, above the ground.

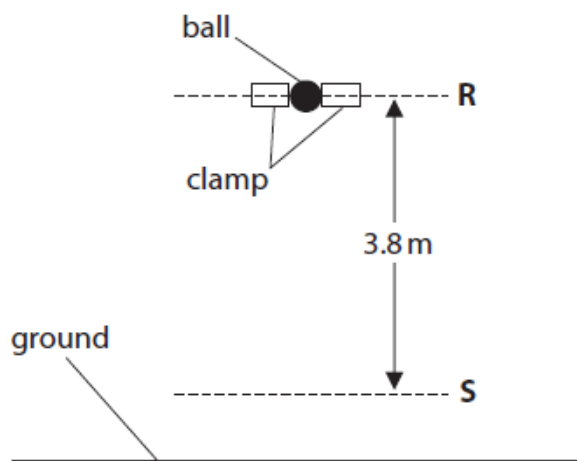


Figure 11

The ball is released from the clamp and falls.

S is 3.8 m below **R**.

At **S** the momentum of the ball is 0.40 kg m/s.

Calculate the mass of the ball.

Acceleration due to gravity, g , = 10 m / s²

(4)

mass of the ball kg

(Total for question = 4 marks)

Q12.

Figure 9 shows a small steel ball held at a height, h , above the ground.

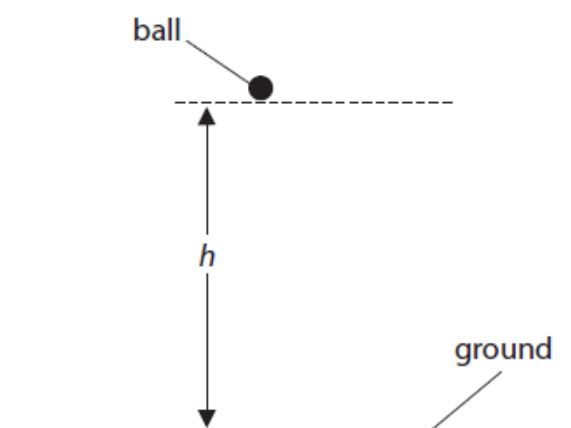


Figure 9

The ball is released and allowed to fall to the ground.

The height h is 1.4 m.

Calculate the time, t , for the ball to reach the ground.

Use the equation

$$t^2 = \frac{2h}{g}$$

$$g = 10 \text{ m/s}^2$$

(2)

$t = \dots\dots\dots$ s

(Total for question = 2 marks)

Q13.

A car travelling at 15 m/s comes to rest in a distance of 14 m when the brakes are applied.

Calculate the deceleration of the car.

Use an equation selected from the list of equations at the end of this paper.

(3)

deceleration = $\dots\dots\dots$ m/s²

(Total for question = 3 marks)

Q14.

The photograph shows a man dropping an egg inside a padded box from a height.



He is investigating to see if the padding stops the egg from breaking.

The velocity of the container was 18 m/s as it hit the floor.

The mass of the container was 0.5 kg.

Calculate the momentum of the container.

(2)

momentum = ...kg m/s

Q15.

(a) A car accelerates at a constant rate of 1.83 m/s^2 along a flat straight road.

The force acting on the car is 1.870 kN.

Calculate the mass of the car.

Give your answer to three significant figures.

(3)

mass = ... kg

(b) The car accelerates from rest for 16 s.

Calculate the speed of the car after 16 s.

(3)

speed = ... m/s

(c) The car starts on another journey.

Figure 6 shows the graph of the car's movement.

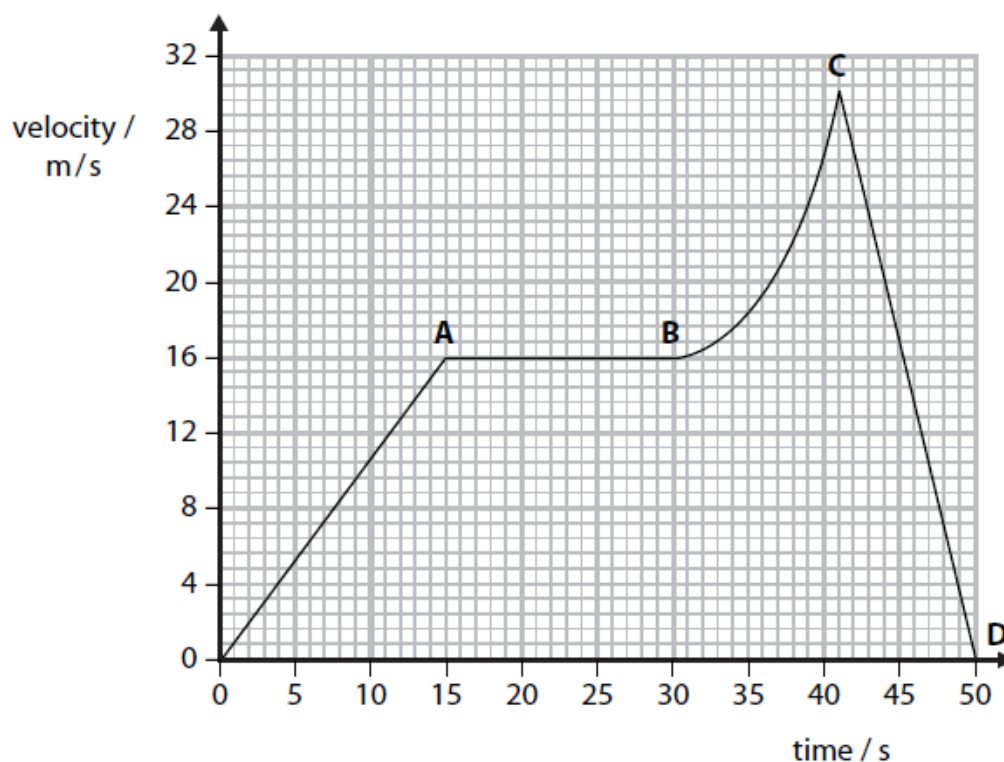


Figure 6

Show that the distance travelled when the car is moving at a constant speed is greater than the distance travelled when the car is slowing down.

(4)

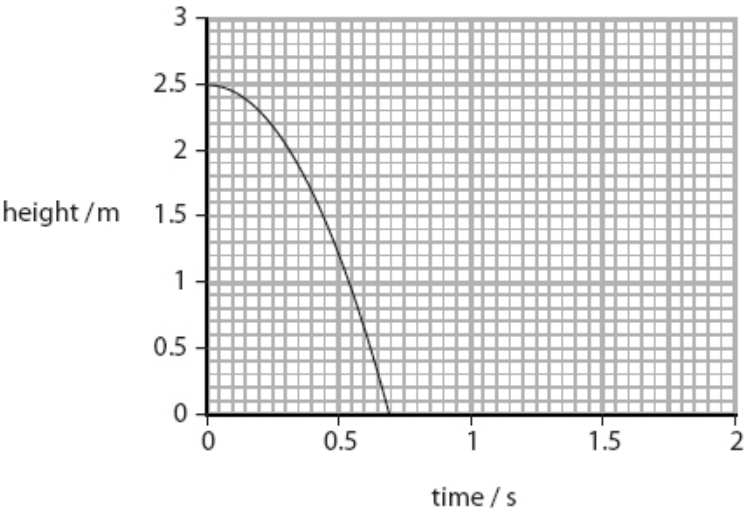
(Total for question = 10 marks)

Q16.

(a) The man in the photograph balances a ball above the ground.



He lets the ball fall.
 He starts a timer at the same time.
 The graph shows how the height of the ball above the ground changes with time.



(i) From the graph, state the height of the ball above the ground when the timer was started.

(1)

height above ground = ... m

(ii) From the graph, state the time taken for the ball to reach the ground.

(1)

time = ... s

(iii) The ball bounces back to a height of 1.9 m.
 Continue the line on the graph to show this.

(3)

(iv) Explain why the ball does not bounce back to its original height.

(2)

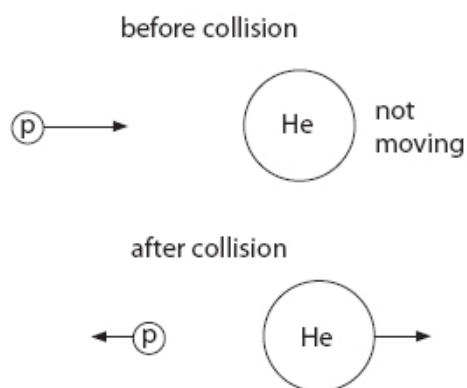
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(b) The diagram shows a collision between a proton (p) and a helium nucleus (He).



(i) The table gives some information about the collision.

		before collision	after collision
proton	kinetic energy (arbitrary units)	12.5	4.5
helium nucleus	kinetic energy (arbitrary units)	0	8

Use information from the table to show that the collision is elastic.

(2)

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(ii) State the name of one device that can be used to accelerate protons to very high speeds.

(1)

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(Total for Question = 10 marks)

Q17.

* Figure 13 shows two objects, Q and R, before and after they collide.



Figure 13

The arrows show the direction of movement of the objects.
The arrows are not to scale.

Explain how momentum is conserved in the collision.

Use Newton's third law and Newton's second law in your answer.

Newton's second law can be written as

$$\text{force} = \frac{\text{change in momentum}}{\text{time}}$$

(6)

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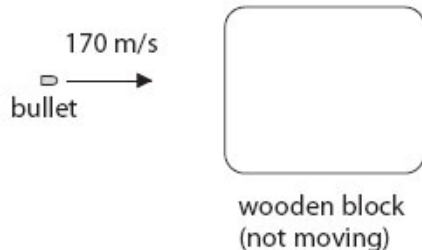
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(Total for question = 6 marks)

Q18.

(a) The diagram shows a bullet moving towards a wooden block.



- (i) The bullet is moving with a velocity of 170 m/s.
The mass of the bullet is 0.030 kg.

Show that the momentum of the bullet is about 5.0 kg m/s.

(1)

- (ii) The bullet collides with the wooden block and sticks in it.
The bullet and the wooden block move off together.
The mass of the wooden block is 0.80 kg.

Calculate the velocity of the wooden block and bullet immediately after the collision.

(3)

velocity = ...m/s

- (iii) The collision between the bullet and the wooden block is an inelastic collision.

State what is meant by an **inelastic collision**.

(2)

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- (b) An electron and a positron collide and annihilate each other.

Two photons are produced.

(i) Explain why two photons must be produced, rather than just one.

(2)

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(ii) Calculate the minimum total energy of the photons produced when an electron and positron collide.

Use the equation

$$E = mc^2$$

mass of an electron = 9.1×10^{-31} kg

speed of light = 3.0×10^8 m/s

(2)

energy = ...J

(Total for Question = 10 marks)

Q19.

The force that keeps an object moving in a circular path is known as the

(1)

- ☐ **A** balancing force
- ☐ **B** centripetal force
- ☐ **C** reaction force
- ☐ **D** resistance force

(Total for question = 1 mark)

Q20.

(a) A cyclotron accelerates charged particles.

(i) Describe the shape of the path a charged particle takes in the cyclotron.

(1)

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(ii) Explain how radioactive isotopes can be produced using cyclotrons.

(3)

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(b) (i) Complete the sentence by putting a cross (X) in the box next to your answer.

In an **inelastic** collision there is conservation of

(1)

- ☐ **A** kinetic energy
- ☐ **B** momentum
- ☐ **C** kinetic energy and momentum
- ☐ **D** velocity

(ii) State why momentum has the unit kg.m/s.

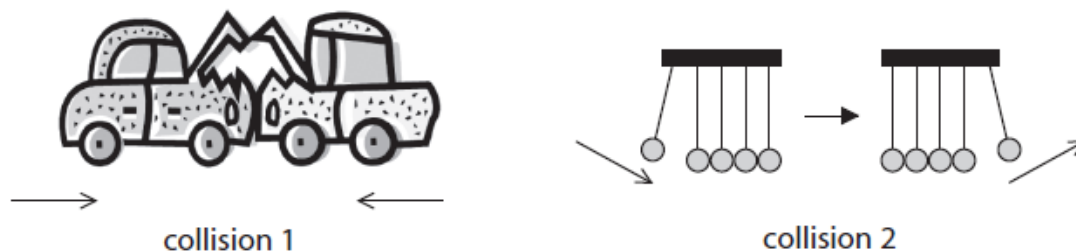
(1)

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*(iii) Different types of collision are shown in the diagrams.

Analyse both collisions in terms of momentum and kinetic energy.



(6)

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(Total for Question = 12 marks)

Q21.

Students investigate conservation of momentum using two identical trolleys.

A card is then added to trolley A.

Some of the apparatus is set up as shown in Figure 4.

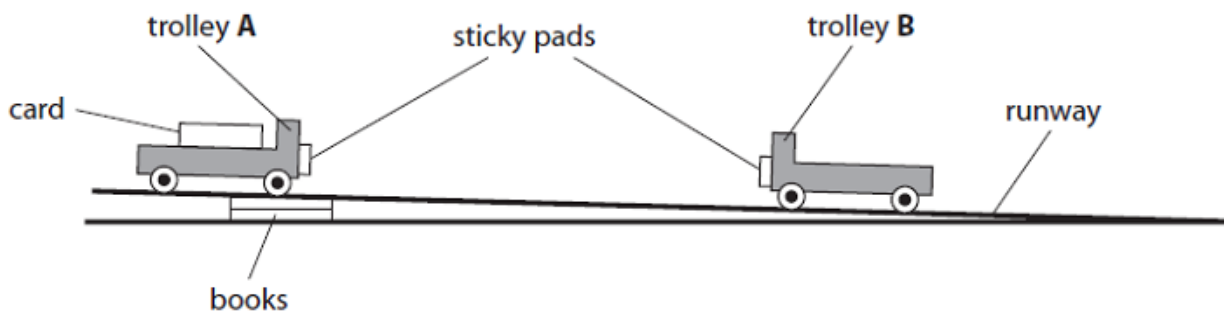


Figure 4

(i) Describe an investigation the students could carry out to show that momentum is conserved when these two trolleys collide.

You may add to the diagram to help with your answer.

(4)

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(ii) Give a reason for the runway being at a slope.

(1)

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(Total for question = 5 marks)

Q22.

A student lifts a toy car from a bench and places the toy car at the top of a slope as shown in Figure 1.

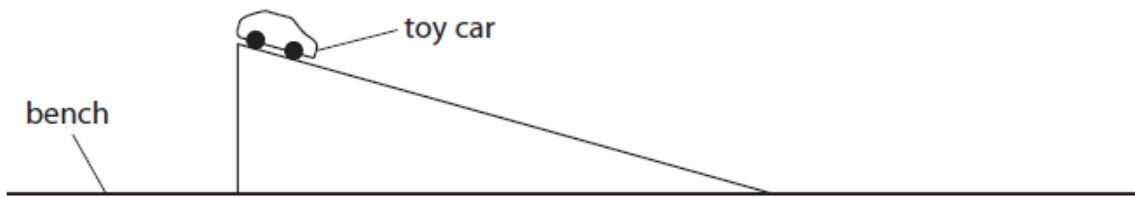


Figure 1

The student lets the toy car roll down the slope.

Describe how the student could find, by experiment, the speed of the toy car at the bottom of the slope.

(4)

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(Total for question = 4 marks)

Q23.

Figure 2 shows a way of projecting a small trolley up a sloping track.

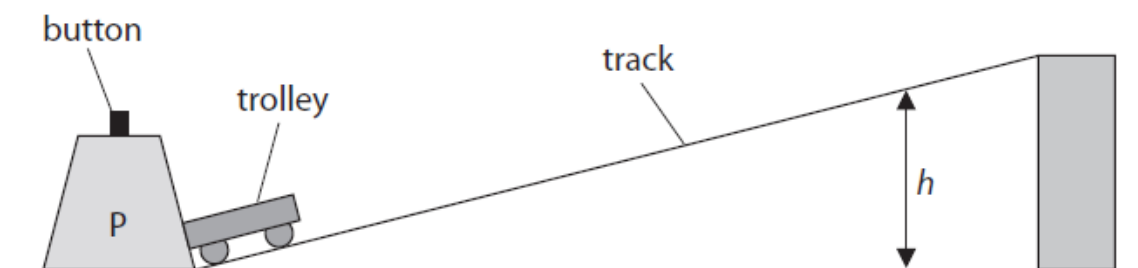


Figure 2

When the button is pressed, a spring is released in P that projects the trolley up the track.

The trolley travels up the track, stops and then rolls back down.

The spring in P always exerts the same force when projecting the trolley.

A student investigates how the mass of the trolley affects the maximum vertical height, h , reached by the trolley.

Describe how the student could extend the investigation to determine the average speed of the trolley as it rolls back down the track.

(3)

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(Total for question = 3 marks)

Q24.

A pilot begins to land an aircraft.

(a) The height of the aircraft decreases from 200 m above the ground to 100 m.

(i) What happens to the gravitational potential energy of the aircraft?

Put a cross (☐) in the box next to your answer.

(1)

- ☐ **A** it becomes zero
- ☐ **B** it decreases
- ☐ **C** it does not change
- ☐ **D** it increases

(ii) The velocity of the aircraft remains constant.

What happens to the kinetic energy of the aircraft?

Put a cross (☐) in the box next to your answer.

(1)

- ☒ **A** it becomes zero
- ☒ **B** it decreases
- ☒ **C** it does not change
- ☒ **D** it increases

(b) The aircraft lands with its wheels on the runway as shown.



The aircraft is moving forwards.

(i) Draw an arrow on the diagram to show the direction of the momentum of the aircraft.

(1)

(ii) The velocity of the aircraft when it lands is 75 m/s.

The mass of the aircraft is 130 000 kg.

Calculate the momentum of the aircraft.

(2)

momentum = ...kg m/s

(iii) The aircraft comes to a stop.

State the momentum change of the aircraft from when it lands to when it stops.

(1)

change in momentum = ...kg m/s

(c) When the aircraft lands, the momentum of each passenger also changes.

(i) Explain why it is more comfortable for a passenger if the aircraft takes a longer time to slow down.

(2)

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(ii) Suggest why some aircraft need a very long runway to land safely.

(2)

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(Total for Question is 10 marks)

Q25.

The photograph shows a man dropping an egg inside a padded box from a height.



He is investigating to see if the padding stops the egg from breaking.

(a) State the type of energy which the egg gains as it falls.

(1)

.....

(b) The weight of the egg is 0.6 N.

Calculate the work done on the egg to lift it up by 20 m. State the unit.

(3)

work done on egg = ...unit

(c) The velocity of the container was 18 m/s as it hit the floor.
The mass of the container was 0.5 kg.

Calculate the momentum of the container.

(2)

momentum = ...kg m/s

.....

*(d) A student stands on the ground with an egg in his hand.
He throws the egg vertically upwards.
The egg rises to a height of 10 m.
Then the egg falls and lands on the ground.

Describe the energy changes of the egg during this sequence of events.

(6)

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(Total for Question = 12 marks)

Q26.

Shot-put is an Olympic event.

The shot is a heavy ball.

An athlete throws the shot as far as possible.

A sports scientist analyses an athlete's throw to help improve performance.

(a) The scientist takes pictures of the athlete every 0.1 s during one throw.

Figure 3 shows the pictures of one throw.

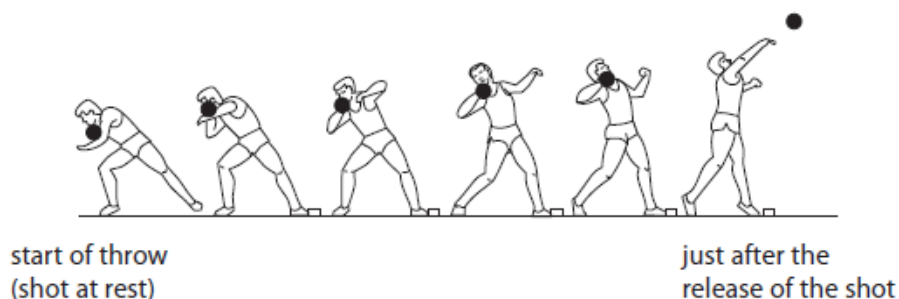


Figure 3

(i) Estimate the amount of time during the throw when the shot is in the athlete's hand.

(1)

time = ... s

(ii) Explain how the scientist could improve this method of analysing the throw.

(2)

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(iii) The average acceleration of the shot while in the athlete's hand is 20.6 m/s^2 .

The mass of the shot is 7.26 kg .

Calculate the average force that the athlete applies to the shot during the throw.

(2)

force = ... N

(iv) In another throw, the shot is in the athlete's hand for 0.48 s .

The average acceleration during this time is 23 m/s^2 .

Calculate the velocity of the shot as it leaves the athlete's hand.

(3)

velocity = ... m/s

(b) In one throw, the shot continues to rise by another 1.3 m after it leaves the athlete's hand.

The mass of the shot is 7.26 kg.

Calculate the amount of gravitational potential energy gained by the shot.

(2)

gravitational potential energy gained = ... J

(Total for question = 10 marks)

Q27.

Figure 9 is a diagram showing a rocket that is sent into space to try and change the path of a small asteroid.

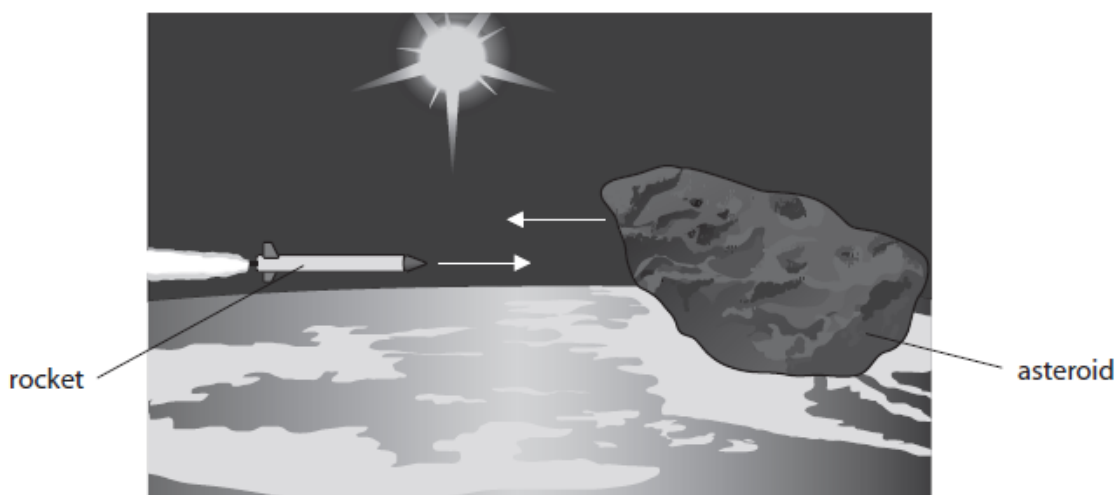


Figure 9

Newton's third law, when applied to the collision of the rocket and the asteroid as shown in Figure 9, can be stated as follows:

The force exerted by the rocket on the asteroid is equal and opposite to the force exerted by the asteroid on the rocket.

Explain how this statement links to the conservation of momentum in the collision.

(4)

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(Total for question = 4 marks)

Q28.

Shot-put is an Olympic event.
The shot is a heavy ball.
An athlete throws the shot as far as possible.

A sports scientist analyses an athlete's throw to help improve performance.

The scientist examines the images to find ways of increasing the momentum of the shot when it leaves the athlete's hand without the athlete using any extra force.

The scientist advises the athlete to

lean further down at the start
and make his arm straight before he releases the shot.

Explain the scientific principles behind this advice.

(3)

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(Total for question = 3 marks)

Q29.

Figure 8 shows a rocket soon after it takes off from the ground.



(Source: © Alones/Shutterstock)

Figure 8

The force that the rocket engines produce remains constant during the first few seconds after take-off.

Explain what happens to the acceleration during the first few seconds.

(3)

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(Total for question = 3 marks)

Q30.

Figure 9 shows a small steel ball held at a height, h , above the ground.

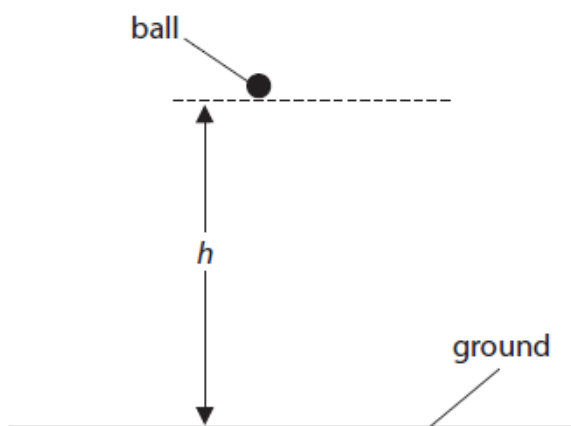


Figure 9

Two students use the arrangement shown in Figure 9.

They use a stopwatch to time the ball falling through the height of 1.4 m.

The students repeat the measurement many times, but their average value for t is different from the calculated value.

(i) Suggest a reason why the students' value for t is different from the calculated value.

(1)

.....

.....

(ii) Suggest **one** improvement the students could make to their procedure so that their value for t is closer to the calculated value.

(1)

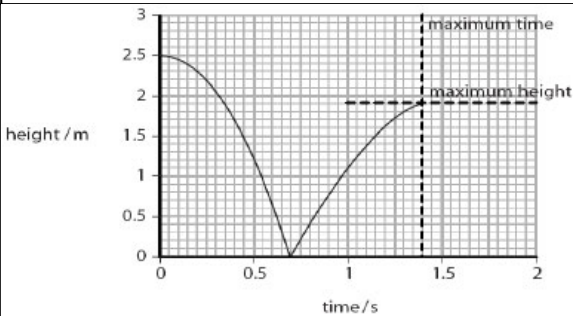
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(Total for question = 2 marks)

Mark Scheme

Q1.

	Answer	Acceptable answers	Mark
(i)	2.5 (m)	Allow answers between (and including) 2.45 & 2.55	(1)
(ii)	0.7 (s)	Allow answers between (and including) 0.68 & 0.72	(1)
(iii)	 line: same shape as original (1) peak at 1.9 m (1) time taken < 0.7 s (1)	Ignore any part of the graph after the peak	(3)
(iv)	An explanation linking: <u>energy</u> lost (1) in collision with ground / air resistance (1)	Inelastic collision worth (2) as sound or heat	(2)

Q2.

Question number	Answer	Additional guidance	Mark
(a)(i)	Calculating the mean (1) 18.36 Rounding to 2 s.f. (1) 18 (cm)	award full marks for correct numerical answer without working	(2)

Question number	Answer	Additional guidance	Mark
(a)(ii)	Rearrangement (1) $t = \sqrt{\frac{\text{distance}}{500}}$ Substitution and answer (1) time = 0.17 (s)	award full marks for correct numerical answer without working allow answers which round to 0.17, e.g. 0.1673	(2)

Question number	Answer	Additional guidance	Mark
(b)	An explanation that combines identification via a judgement (1 mark) to reach a conclusion via justification/reasoning (1 mark): 25.5 is an anomalous result (1) (because) it is much further away from the mean than the other results (1)	ignore 19	(2)

Question number	Answer	Mark
(c)	- Take more readings (1) - Idea that a third student should also measure the reaction time (1)	(2)

Question number	Answer	Additional guidance	Mark
(d)	An answer that combines the following points to provide a logical description of the plan/method/experiment: - using a larger group of students/large population of students (1) - and measure how their reaction time varies with age/height (1)	allow any suitable variable	(2)

Q3.

Answer	Acceptable answers	Mark

A 600 kg m/s	(1)
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Q4.

	Answer	Acceptable answers	Mark
(a)	C when the bungee cord is stretched the most		(1)
(b)	A 600 kg m/s		(1)
(c)(i)	Substitution: (1) 60 × 10 × 50 or 600 × 50 Evaluation: (1) 30 000 Unit: (1) J / Nm	give two marks for correct answer no working J / joule 30 kJ for full marks	(3)
(c)(ii)	After falling 50 m / when the cord becomes straight/when cord starts to stretch	tension starting to increase at terminal velocity ignore maximum velocity/speed	(1)
(c)(iii)	An explanation linking any two of not all GPE is transferred to KE (1) some {of the GPE transfers to thermal energy /work is done} (1) due to drag (1)	not all GPE goes to KE maximum energy is same (value) as GPE before falling /speed does not reach the speed at which he should fall some lost as heat/sound (of rope or movement through air) (air) resistance / friction ignore wind	(2)

Q5.

Question number	Answer	Additional guidance	Mark
(i)	substitution (1) (force =) $\frac{8.7}{0.35}$ evaluation (1) 25 (N)	use of force = $\frac{\text{change in momentum}}{\text{time}}$ allow numbers that round to 25 e.g 24.8571 award full marks for correct answer without working.	(2) A02

Question number	Answer	Additional guidance	Mark
(ii)	(magnitude) 25 (N) (1) (direction) down(wards)/ towards floor (1)	ecf from i allow arrow drawn pointing down "south"	(2) A03

Q6.

Question number	Answer	Additional guidance	Mark
(i)	substitution (1) $371 = (64.5 + m) \times 3.5$ rearrangement (1) $m + 64.5 = 371 / 3.5$ evaluation of total mass (1) $m + 64.5 = 106 \text{ (kg)}$ evaluation of woman's mass (1) $m = 106 - 64.5$ $= 41.5 \text{ (kg)}$	full marks will be awarded for correct numerical answer without working	(4)

Question number	Answer	Additional guidance	Mark
(ii)	substitution (1) $KE = \frac{1}{2} \times 64.5 \times 3.5^2$ evaluation (1) 395 (J)	allow answers which round to 395 e.g. 395.0625 full marks will be awarded for correct numerical answer without working	(2)

Q7.

Question number	Answer	Additional guidance	Mark
(i)	attempt to use correct data from graph or equation (1) substitution (1) $(a =) \frac{26 - 14}{34}$ evaluation to 2 sf (1) 0.35(m/s ²)	quoting $a = \frac{(\Delta)v}{t}$ or $a =$ gradient (of line) 0.3529... scores mp1 and mp2 $\frac{26}{34}$ scores mp1 independent mark award full marks for correct answer without working.	(3) AO2

Question number	Answer	Additional guidance	Mark
(ii)	attempt to calculate area under the line (1) calculates EITHER area of triangle OR area of rectangle (1) 204 (m) or 476 (m) evaluation (1) 680 (m)	accept count squares use of $v^2 - u^2 = 2ax$ $x = \frac{v^2 - u^2}{2a}$ allow ecf from (i) award full marks for correct answer without working award 1 mark for final answer 408 (m)	(3) AO2

Q8.

Question Number	Answer	Additional guidance	Mark
(i)	substitution in $v^2 - u^2 = 2ax$ (1) $24^2 - 7.6^2 = 2 \times 3 \times x$ rearrangement (1) $(x =) \frac{24^2 - 7.6^2}{6}$ evaluation (1) 86 (m)	accept rearrangement and substitution in either order allow numbers that round to 86 (m) award full marks for the correct answer without working	(3)

Question Number	Answer	Additional guidance	Mark
(ii)	recall and substitution (1) $(a = \frac{v-u}{t}) \quad 3.0 = \frac{24-7.6}{t}$ rearrangement (1) $t = \frac{v-u}{a}$ OR $(t =) \frac{24-7.6}{3.0}$ evaluation (1) 5.5 (s)	Allow alternative method: average speed = distance / time i.e. $15.8 = 86(.37) / \text{time}$ $(t =) 86(.37) / 15.8$ allow numbers that round to 5.5 (s) OR numbers that round to 5.4 if using alternative method and distance = 86 award full marks for the correct answer without working no marks for $t = d / (v-u) = 86(.37) / (24-7.6)$ giving 5.3 s as an answer	(3)

Q9.

	Answer	Additional guidance	Mark
(i)	conversion of time to s (1) (t =) 0.012 OR 12×10^{-3} OR 1.2×10^{-2} substitution (1) $(F =) \frac{(0.075 \times -15.0) - (0.075 \times 8.2)}{0.012}$ OR $(F =) \frac{(0.075 \times 15.0) - (0.075 \times -8.2)}{0.012}$ OR $(F =) \frac{0.075 \times (15.0 + 8.2)}{0.012}$ evaluation (1) (-)150 (N)	substitution and conversion in either order ignore signs on velocity accept time to any power of ten for substitution mark $(F =) \frac{(1.125) + (0.615)}{0.012}$	(3) AO2

		145 (N) scores 3 marks 145 (N) to any other power of ten scores 2 marks maximum 42.5 (N) scores 2 marks maximum 42.5 (N) to any other power of ten scores 1 mark maximum 93.75 (N) or 51.25(N) 1.933 scores 1 mark maximum award full marks for correct answer without working	
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	Answer	Additional guidance	Mark
(ii)	Any two from: (forces are) equal / same size (1) (forces are) opposite (direction) (1) (forces) act on different bodies (1) same type of force (1)	no marks awarded for answers in terms of energy (forces are) one to the left, one to the right one (force) acts on racket, one acts on ball both are contact forces if no other marks awarded, allow action and reaction (acting) for 1 mark	(2) AO1

Q10.

Question number	Answer	Additional guidance	Marks
(i)	recall $K.E. = \frac{1}{2} m v^2$ (1) rearrangement (1) $(m =) 2 \times K.E. \div v^2$ substitution (1) $(m =) 2 \times 960\,000 \div 40^2$ Evaluation (1) = 1200 (kg)	award full marks for the correct answer without working rearrangement and substitution in either order Ignore POT until evaluation	(4)

Question number	Answer	Additional guidance	Marks
(ii)	Use of efficiency equation (1) $\frac{960}{5}$ evaluation (1) =19 (MJ)	award full marks for correct numerical answer without working accept 19.2 (MJ)	(2)

Q11.

Question number	Answer	Additional guidance	Mark
	Two stage calculation		(4) A02
	substitution ₁ (1)	use of $v^2 - u^2 = 2ax$ OR $\frac{1}{2}mv^2 = mgh$	
	$(v^2 - 0 =) 2 \times 10 \times 3.8$	76	
	evaluation of v (1)		
	$(v =) 8.7 \text{ (m/s)}$	allow numbers that round to 8.7 e.g. 8.718	
	substitution ₂ (1)		
	$0.40 = m \times 8.7$	use of $p = mv$	
	rearrangement and evaluation (1)		
	$(m =) 0.046 \text{ (kg)}$	allow numbers that round to 0.046 e.g. 0.04598 award full marks for correct answer without working.	

Q12.

Question number	Answer	Additional guidance	Mark
	substitution (1) $(t^2 =) \frac{2 \times 1.4}{10}$ evaluation (1) $(t =) 0.53 \text{ (s)}$	0.28 allow numbers that round to 0.53 e.g. 0.52915 award full marks for correct answer without working.	(2) AO2

Q13.

Question Number	Answer	Additional guidance	Mark
	rearrangement (1) $a = \frac{(v^2 -)u^2}{2x}$ substitution (1) $a = \frac{(-)15^2}{2 \times 14}$ evaluation (1) deceleration = 8(.04) (m/s ²)	rearrangement and substitution in either order 225/28 for 2 marks accept – 8(.04) award full marks for the correct answer with no working	(3) AO 2 1

Q14.

	substitution: 0.5 × 18 evaluation 9.0	(1) (1)	9	(2)
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	give full marks for correct answer no working	
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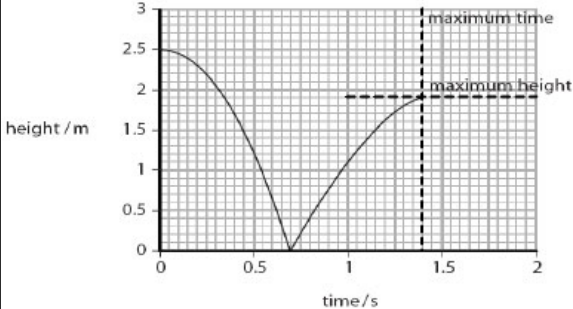
Q15.

Question number	Answer	Additional guidance	Mark
(a)	Rearrangement (1) $m = \frac{f}{a}$ Substitution and conversion (1) $m = \frac{1870}{1.83}$ Answer and rounding to 3 s.f. (1) 1020 (kg)	maximum 2 marks if kN not converted to N award full marks for correct numerical answer without working	(3)

Question number	Answer	Additional guidance	Mark
(b)	Rearrangement of $\frac{(v-u)}{t} = a$ (1) $v = u + at$ Substitution (1) $v = 0 + 1.83 \times 16$ Answer (1) 29.3 (m/s)	award full marks for correct numerical answer without working	(3)

Question number	Answer	Mark
(c)	Correctly identifies data points from the graph to calculate areas (1) Calculates area under AB (1) 240 m Calculates area under CD (1) 135 m distance travelled at constant speed = 240 m is greater than distance travelled when slowing down = 135 m (1)	(4)

Q16.

	Answer	Acceptable answers	Mark
(a)(i)	2.5 (m)	Allow answers between (and including) 2.45 & 2.55	(1)
(a)(ii)	0.7 (s)	Allow answers between (and including) 0.68 & 0.72	(1)
(a)(iii)	 line: same shape as original (1) peak at 1.9 m (1) time taken < 0.7 s (1)	Ignore any part of the graph after the peak	(3)
(a)(iv)	An explanation linking: energy lost (1) in collision with ground / air resistance (1)	Inelastic collision worth (2) as sound or heat	(2)
(b)(i)	shown using data Any two from kinetic energy before = $12.5 + 0$ (=12.5) (1) kinetic energy after = $4.5 + 8$ (=12.5) (1) Kinetic energy is the same before and after the collision (1)	Kinetic energy is conserved/no energy lost	(2)
(b)(ii)	cyclotron (1)	named particle accelerator accept CERN	(1)

Q17.

Question Number	Answer	Mark
*	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. AO1 (6 marks) • momentum = mass × velocity • action and reaction are equal and opposite (N 3) • force of R on Q = -force of Q on R • $\frac{\text{change in momentum of Q}}{\text{time}} = -\frac{\text{change in momentum of R}}{\text{time}}$ • time of collision same for both • change in momentum of Q = - change in momentum of R • no overall change in momentum • R accelerates because of force from Q • transfer of momentum between Q and R	(6) AO 1 1

Level	Mark	Descriptor
	0	• No rewardable material.
Level 1	1-2	• An explanation that demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) • Presents an explanation with some structure and coherence. (AO1)
Level 2	3-4	• An explanation that demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) • Presents an explanation that has a structure which is mostly clear, coherent and logical. (AO1)
Level 3	5-6	• An explanation that demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) • Presents an explanation that has a well-developed structure which is clear, coherent and logical. (AO1)

Q18.

Answer	Acceptable answers	Mark

(a)(i)	momentum = 0.03×170 (1)	Accept 5.1 seen	(1)
(a)(ii)	momentum before = momentum after (1) $5.1 = 0.83 \times v$ (1) $v = 6.1$ (m/s) (1)	allow $5.0 = 0.80 \times v$ for 1 mark max $5.0 = 0.83 \times v$ $v = 6.0$ (m/s) allow ecf from (a)(i) give full marks for correct answer, no working	(3)
(a)(iii)	Statement to include any two from - kinetic energy is not conserved (1) (lost ke) appears as heat/sound (1) - momentum is conserved (1)	ke not conserved / some ke lost no momentum lost	(2)
(b)(i)	an explanation linking - momentum (must be) conserved (1) - so must have positive and negative momentum (1)	photons move in opposite directions indication of movement in opposite directions (e.g. opposite velocities)	(2)
(d)(ii)	$E = (2 \times) 9.1 \times 10^{-31} \times [3 \times 10^8]^2$ (1) $= 1.6 \times 10^{-13}$ (J) (1)	8.2×10^{-14} (0.82×10^{-13}) for 1 mark give full marks for correct answer, no working	(2)

Q19.

Question Number	Answer	Additional guidance	Mark
	☐ B centripetal force The only correct answer is B (correct term for circular motion) A is not correct – incorrect term C is not correct – incorrect term D is not correct – incorrect term		(1)

Q20.

Question Number	Answer	Acceptable answers	Mark
(a)(i)	Circular/spiral/circle		(1)

Question Number	Answer	Acceptable answers	Mark
(a)(ii)	An explanation linking three of the following. • (fast moving) <u>protons</u> (1) • absorbed by (1) • nuclei (1) • (produces)unstable nuclei (1)	bombard / hit /strike / collide with stable atoms / stable element	(3)

Question Number	Answer	Acceptable answers	Mark
(b)(i)	B momentum		(1)

Question Number	Answer	Acceptable answers	Mark
(b)(ii)	(Momentum/it>equals mass x <u>velocity</u>	$p = m \times v$ kilograms / kg is the mass and metres per second / m/s is the <u>velocity</u> Accept "times" for x	(1)

Question Number		Indicative Content	Mark
QWC	* (b) (iii)	An explanation including some of the following points Diagram 1 • Moving in opposite directions before collision • inelastic collision • stationary after collision • momentum zero after collision • (therefore) total momentum must have been zero before collision • (therefore) cars were moving at the same speed in opposite directions (assuming cars have equal mass) • both cars had kinetic energy before the collision • KE zero after collision • KE converted into heat, sound, elastic potential energy etc. Diagram 2 • Elastic collision / almost elastic collision • Momentum conserved • Momentum transferred from first to last sphere • KE conserved / almost conserved • (because) last sphere reaches same height as first sphere • Three spheres always have zero momentum • Small amount of energy transferred to sound/heat	(6)

Level	0	No rewardable content
1	1 - 2	• A limited analysis of ONE collision which is given by a correct statement e.g. In collision 1, kinetic energy has been lost OR In collision 2 momentum is transferred from the first to the last sphere. • the answer communicates ideas using simple language and uses limited scientific terminology • spelling, punctuation and grammar are used with limited accuracy
2	3 - 4	• a simple analysis of BOTH collisions considering BOTH momentum AND kinetic energy correctly for each one e.g. In collision 1, momentum is conserved and the kinetic energy of the cars changes. In collision 2, momentum and the kinetic energy is conserved. • answer communicates ideas showing some evidence of clarity and organisation and uses scientific terminology appropriately • spelling, punctuation and grammar are used with some accuracy
3	5 - 6	• a detailed analysis of BOTH collisions considering momentum AND kinetic energy for each collision correctly for each AND detailed reference to EITHER diagram. e.g. In collision 1, the momentum before and after the collision is zero because momentum is always conserved, but the KE is lost. In collision 2, all the momentum and KE is transferred to the last sphere because it gets to the same height as the first one. • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors

(Total marks for question = 12 marks)

Q21.

	Answer	Additional guidance	Mark
(i)	a description using any four of the following points in a logical order: measure the mass / weight of the trolley(s) / weigh the trolley(s) (1) determine the speed of trolley A (1) put one light gate (connected to data logger) further down the runway than trolley A and another beyond trolley B (1) trolleys A and B stick together (1) measure combined velocity / speed of A and B (1) calculate momentum of trolley A before collision and A and B after collision (1) check for equality / velocity after collision is half that before collision (1) repeat and take mean / average (1)	allow determine / find / calculate use (average) speed = distance / time to calculate speed of trolley A may be shown on diagram measure distance and time in appropriate places calculate (total) momentum before and after collision (total) momentum before equals (total) momentum after	(4) AO1

	Answer	Additional guidance	Mark
(ii)	{compensating for / reducing effect of / overcoming / balancing / cancelling effect of} friction OR so that trolley A travels at a constant speed / doesn't slow down	do not accept reducing / cancelling friction do not accept so trolley accelerates down slope	(1) AO3

Q22.

Question number	Answer	Additional guidance	Mark
	A description to include: measurement of (relevant) distance (1) measurement of (relevant) time (1) use of speed = $\frac{\text{distance}}{\text{time}}$ (1) detail (1)	one of distance down slope or distance along bench or length of toy car/card 'record the distance the car travels and time it' scores 2 marks For example: speed down slope $\times 2$ <u>mark</u> distance along bench use a light gate speed gun at the bottom of the slope Repeating AND averaging	(4)

Q23.

Question Number	Answer	Additional guidance	Mark
	A description including: measure appropriate distance (1) measure appropriate time (1) use (average) speed = $\frac{\text{distance}}{\text{time}}$ (1)	e.g. distance along runway from max height to P e.g. start the watch when trolley stops stop the watch when trolley hits spring accept $s = \frac{d}{t}$	(3)

Q24.

	Answer	Acceptable answers	Mark
(a)(i)	B it decreases		(1)
(a)(ii)	C it does not change		(1)
(b)(i)	horizontal arrow (judge by eye), pointing to the right anywhere on the diagram 		(1)
(b)(ii)	substitution: (1) $130\,000 \times 75$	give full marks for correct answer, no working	(2)

	evaluation: (1) 9 750 000 (kgm/s) (Ns)	Ignore minus sign 9.75×10^6 (kgm/s) (Ns)	
(b)(iii)	9 750 000 kgm/s	same value as answer to (b)(ii) Ignore minus sign	(1)
(c)(i)	An explanation linking two of the following: • force is smaller/less (1) • momentum changes more slowly (1) • lower deceleration (1) • use of the formula (1)	pressure is smaller/less slower deceleration force is proportional to rate of change of momentum/ $F = (mv - mu)/t$	(2)
(c)(ii)	Any two from: (for loaded aircraft) • has more mass (1) • has more momentum (1) • has more k.e. (1) • higher velocity • brakes need to do more work (1)	accept reverse argument for empty aircraft heavier/more passengers/more cargo higher speed/moving faster	(2) expert

Total marks for question = 10 marks

Q25.

	Answer	Acceptable answers	Mark
(a)	kinetic (energy)	Movement (energy) KE	(1)
(b)	substitution: 0.6×20 (1) evaluation 12 (1) J (1)	give 2 marks for correct answer no working unit is an independent mark joules, Nm, kgm^2/s^2 , Ws	(3)
(c)	substitution: 0.5×18 (1) evaluation 9.0 (1)	9 give full marks for correct answer no working	(2)

QWC		*(d)	a description including some of the following points: • chemical to kinetic while in his hand • kinetic (gradually) to potential while rising / from • eventually all potential at 10 m with a little thermal energy • some mention of conservation of energy • potential (gradually) to kinetic as falls / 10 m-0 • with a little more thermal (heat) energy • at 0 m sound energy • at 0 m thermal (heat) energy
Level	0	No rewardable content	
1	1 - 2	• a limited description which identifies a change in one relevant type energy or a transfer of energy from one form to another e.g. kinetic energy increases OR kinetic energy changes to sound. • the answer communicates ideas using simple language and uses limited scientific terminology • spelling, punctuation and grammar are used with limited accuracy	
2	3 - 4	• a simple description giving detail of a relevant energy change/transfer e.g. kinetic energy changes into potential energy as it moves upwards OR kinetic energy increases as it falls. • the answer communicates ideas showing some evidence of clarity and organisation and uses scientific terminology appropriately • spelling, punctuation and grammar are used with some accuracy	
3	5 - 6	• a detailed description of a sequence of relevant energy changes /transfers e.g. kinetic energy is transferred into potential energy as it rises. This then changes back into kinetic energy as it falls back down. • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors	

Q26.

Question number	Answer	Additional guidance	Mark
(a)(i)	0.45 (s) (1)	Allow any value ≥ 0.4 and ≤ 0.5	(1)

Question number	Answer	Additional guidance	Mark
(a)(ii)	An explanation that combines improvement of the experimental procedure (1 mark) and justification/reasoning which must be linked to the improvement (1 mark) • take pictures more frequently (1) • in order to determine exact time of the release. (1)	other responses may be acceptable	(2)

Question number	Answer	Additional guidance	Mark
(a)(iii)	Substitution (1) $F = 7.26 \times 20.6$ Evaluation (1) 150 (N)	Accept 149.6 (N) full marks will be awarded for correct numerical answer without working	(2)

Question number	Answer	Additional guidance	Mark
(a)(iv)	Rearrangement (1) $v = a \times t$ Substitution (1) $v = 23 \times 0.48$ Evaluation (1) 11 m/s	Accept 11.04(m/s) full marks will be awarded for correct numerical answer without working	(3)

Question number	Answer	Additional guidance	Mark
(b)	Substitution (1) $PE = 7.26 \times 10 \times 1.3$ Evaluation (1) 94.4 (J)		(2)

Q27.

Question number	Answer	Additional guidance	Mark
	An explanation linking any four from force(s) associated with change(s) in momentum (use of Newton's second law) (1) detail of momentum changes, involving time (1) time of collision is same for both (1) (therefore) momentum change is the same for both (1) equal and opposite forces mean equal and opposite momentum changes (1) (total) momentum before a collision = (total) momentum after collision (1) (conservation of momentum requires) no external forces acting (1)	$F = \frac{mv - mu}{t}$ $F = ma$ $\frac{m_1 v_1 - m_1 u_1}{t} = - \frac{(m_2 v_2 - m_2 u_2)}{t}$ with explanation leading to $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$ for both marks	(4) Exp

Q28.

Question number	Answer	Additional guidance	Mark
	An explanation that combines up to 3 points of application of knowledge and reasoning/justification • Momentum increased if final velocity can be increased (1) • Distance (while in athlete's hand) is greater (1) • Time whilst subject to force is longer (1) • using the equation $F = (mv - mu)/t$ (1)	Ignore references to shot after it has left the athletes hand accelerating for a longer time use of $v = u + at$ or use of $v^2 - u^2 = 2ax$	(3)

Q29.

Question number	Answer	Additional guidance	Mark
	An explanation linking three of: acceleration increases (1) as $F = ma$ (1) (and) mass decreases (1) due to burning/using fuel (1)	independent mark	(3) AO1

Q30.

Question number	Answer	Additional guidance	Mark
(i)	(students') reaction time (is significant compared with recorded time) (1)	g is really 9.8	(1) AO2

Question number	Answer	Additional guidance	Mark
(ii)	One from use light gates (1) use automatic timer (1) Use time lapse/ stroboscopic photography (1) drop from greater height (1)	ignore repeats or more people	(1) AO3