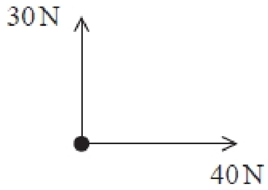
Newton's Law and Momentum

Q1.

The diagram shows the two forces acting on a point mass.



The mass accelerates.

Which of the following gives the angle between the direction of the acceleration and the 40 N force?

☐ **A** $\cos^{-1}(30/40)$

☐ **B** $\sin^{-1}(40/50)$

☐ **C** $\tan^{-1}(30/40)$

☐ **D** $\tan^{-1}(40/50)$

(Total for question = 1 mark)

Q2.

An object is acted on by a vertical force of 25 N and a horizontal force of 34 N.

The angle to the horizontal of the resultant force is given by

☐ **A** $\cos^{-1}(25/34)$

☐ **B** $\sin^{-1}(34/25)$

☐ **C** $\tan^{-1}(25/34)$

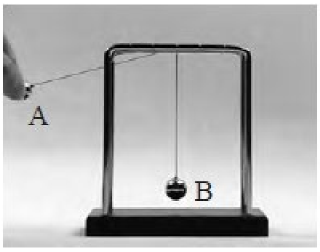
☐ **D** $\tan^{-1}(34/25)$

(Total for question = 1 mark)

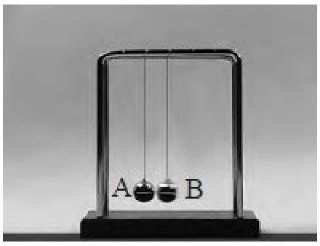
Q3.

Two small identical solid metal spheres, A and B, are suspended by light inextensible threads from a frame.

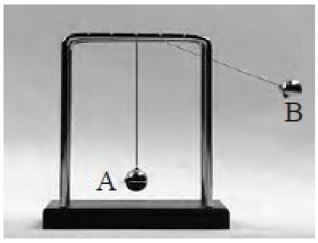
* Sphere A is pulled to one side as shown and released. Sphere A collides with sphere B and stops and sphere B swings upwards. The time intervals between the photographs below are the same.



Photograph 1



Photograph 2



Photograph 3

Using Newton's laws of motion, explain the motion of the spheres during the collision in terms of the forces acting on them.

(6)

(Total for question = 6 marks)

Q4.

Some sports place high stresses on the bones in the body, which can result in injury.

A gymnast of mass 45 kg dismounts from a beam. Her centre of mass is displaced through 1.6 m vertically before her feet touch the ground.

As she lands, the bones in the lower part of her legs experience a force from the ground.

The time between hitting the ground and coming to rest is 0.90 s.

(i) Calculate the mean force from the ground on the gymnast.

(4)

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Mean force from the ground = ...

(ii) Explain how bending both knees when landing helps the gymnast prevent an injury.

(3)

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(Total for question = 7 marks)

Q5.

Two ice skaters are gliding across the horizontal ice surface at an ice rink.

(Source: © ITAR-TASS News Agency/Alamy Stock Photo)

Initially the skaters move together with a speed of 5.6 m s^{-1}.

The male skater pushes the female skater forwards. After being pushed, she has a forward speed of 7.5 m s^{-1}.

Calculate the speed of the male skater immediately after pushing the female skater forwards.

mass of male skater = 66 kg
mass of female skater = 52 kg

(3)

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Speed of male skater = ...

(Total for question = 3 marks)

Q6.

(a) A vehicle that skids can leave a mark on the road surface. This skid mark can be used to calculate the velocity of the vehicle at the start of the skid.

At a test track a car of mass 1500 kg was collided into the back of a stationary car of mass 1200 kg. The two cars skidded along the road together, leaving skid marks of length 7.5 m. The cars decelerated at 5.6 m s^{-2} to a stop at the end of the skid.

Calculate the velocity with which the car of mass 1500 kg collided with the stationary car.

(3)

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Velocity = ...

(b) In practice, the velocity of the car is not exactly the same as that calculated.

Explain why.

(2)

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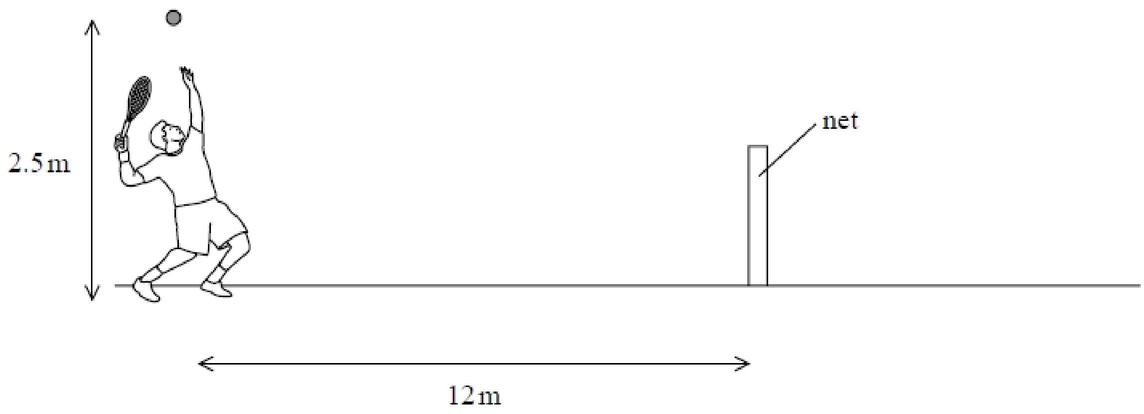
(Total for question = 5 marks)

Q7.

A tennis player uses a racket to hit a ball over a net.



The player stands 12 m from the net. He throws the ball vertically upwards and hits the ball at a height of 2.5 m above the ground. The ball leaves the racket **horizontally** with a velocity of 25 m s^{-1}. The ball has a mass of 0.06 kg.

The ball is in contact with the racket for 0.04 s.

Calculate the average force on the ball.

(3)

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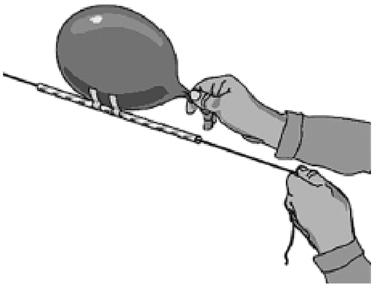
Average force = ...

(Total for question = 3 marks)

Q8.

A length of string is threaded through a drinking straw. The string is fixed at one end and held at the other so that it is at 30° to the horizontal. A balloon is inflated and attached to the straw. When the balloon is released, the air escapes from the balloon and the balloon and straw start to move up the string.



Calculate the minimum force on the balloon due to the escaping air if the balloon is to move in this way.

mass of straw and balloon = 11 g

(3)

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Minimum force = ...

Q9.

A website about the physics of baseball states, "The bat hits the ball with a force equivalent to 2 tonnes."

In a baseball game, a ball travelling at 40 ms^{-1} is in contact with a bat for 0.70 ms and has a speed after impact of 49 ms^{-1}.

1 tonne = 1000 kg
mass of ball = 0.15kg

Evaluate the statement from the website.

(4)

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Q10.

A uniform paving slab is to be used as a garden step.

State what is meant by the centre of gravity of an extended body.

(1)

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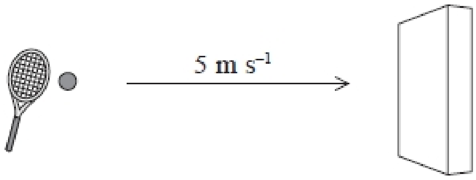
(Total for question = 1 mark)

Q11.

A tennis ball of mass 0.06kg moves towards a wall at a velocity of 5 m s^{-1} as shown.



The tennis ball hits the wall perpendicularly and rebounds at the same speed.

What is the change in momentum of the ball?

(1)

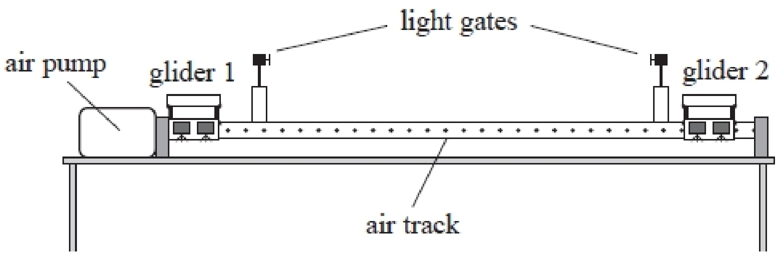
- ☐ **A** 0.60kg m s^{-1}
- ☐ **B** 0.30kg m s^{-1}
- ☐ **C** −0.30kg m s^{-1}
- ☐ **D** −0.60kg m s^{-1}

(Total for question = 1 mark)

Q12.

A teacher uses a linear air track to provide a frictionless surface for two gliders, each of mass *m*. She uses this, with a pair of light gates connected to a computer, to investigate a collision between the gliders.

The gliders are each given a small push and travel towards the centre of the track. The gliders collide and move off together.



The teacher asked a student to justify the change in velocity of glider 1 using Newton's laws of motion.

The student began his explanation with the statement:

"During the collision there is a force on glider 2"

Complete the explanation to justify the change in velocity of glider 1, making reference to Newton's laws of motion where appropriate.

(4)

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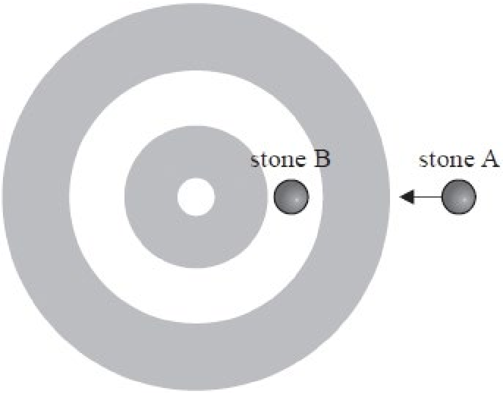
(Total for question = 4 marks)

Q13.

In the sport of curling, two teams of 'curlers' take turns sliding polished granite stones across an ice surface towards a circular target marked on the ice.

commons.wikimedia.org

* Stone B is stationary. Stone A travels towards the target and makes a direct hit on stone B as shown. Both stones have mass *m*.



The collision is elastic. Just before the collision stone A has a velocity *v*. After the collision stone B moves off with velocity *v*.

Discuss how the relevant conservation laws apply to this collision.

(6)

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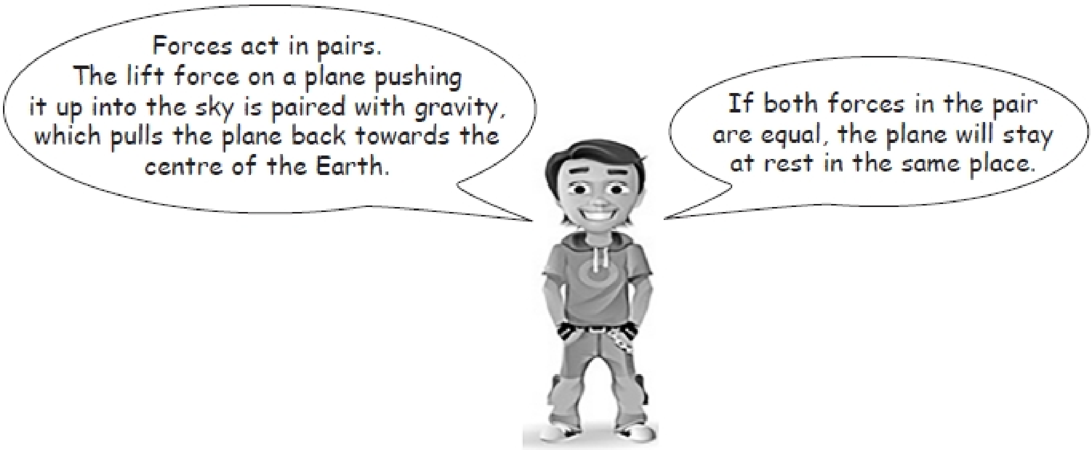
(Total for question = 6 marks)

Q14.

* The following extract comes from a section on forces, on a website written for children.



Criticise this extract.

(6)

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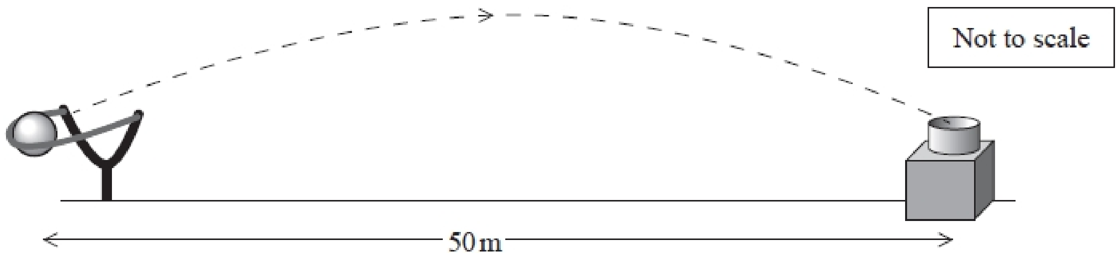
(Total for question = 6 marks)

Q15.

A fairground game requires the player to catapult a ball towards a target to score points.

The ball is required to reach a target a horizontal distance of 50 m away, at the same vertical height, as shown.



During another launch, the catapult exerts a force on the ball of 9.0 N at 40° to the horizontal at the time of release.

Draw a labelled vector diagram to determine the resultant force acting on the ball at the time of release.

(4)

weight of ball = 2.0 N

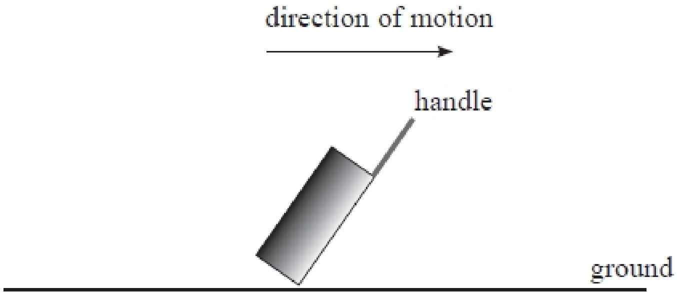
Magnitude of resultant force = ...

Angle of resultant force to the horizontal = ...

(Total for question = 4 marks)

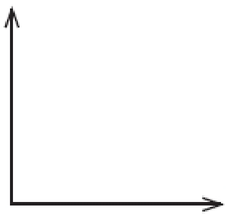
Q16.

A suitcase is being dragged along the ground by the handle in the direction shown.

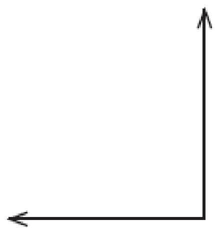


Which of the following shows the direction of the horizontal and vertical components of force acting on the ground due to the suitcase?

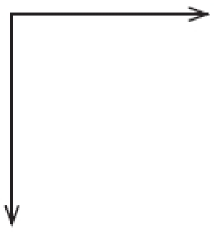
☐ **A**



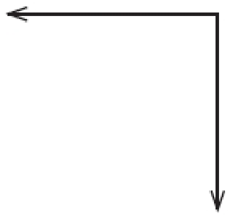
☐ **B**



☐ **C**



☐ **D**

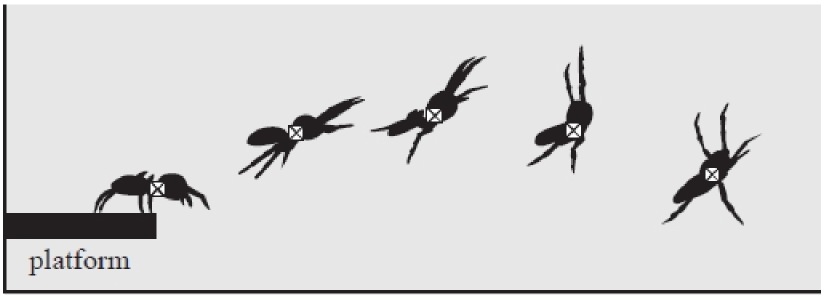


(Total for question = 1 mark)

Q17.

Scientists have been studying a type of jumping spider that can jump up to six times its body length.

The scientists photographed a spider at 0.02 s intervals, during a jump. The picture is taken from the photograph and is shown actual size.



(i) Deduce whether the images show that the motion in the *x*-direction is independent of the motion in the *y*-direction. You should take measurements using the cross marking the centre of gravity of the spider.

(4)

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(ii) Show that the initial velocity of the spider at the start of the jump is about 1 m s^{-1}. You should take measurements using the cross marking the centre of gravity of the spider.

(5)

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(iii) The spider achieves this jump by extending its two back legs by 3.0 mm.

Calculate the average force the spider exerts in each leg to achieve the jump.
mass of spider = 150 mg

(3)

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Average force = ...

(Total for question = 12 marks)

Q18.

A space rocket lifts off vertically.

The rocket lifts off because

☐ **A** the exhaust gases exert a force on the ground.

☐ **B** the exhaust gases exert a force on the rocket.

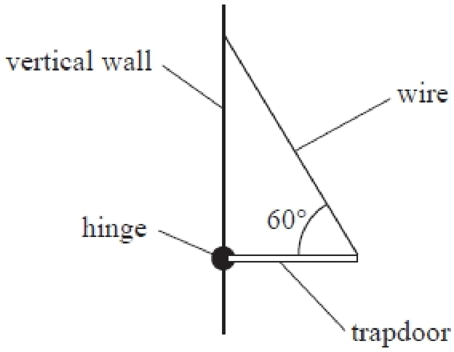
☐ **C** the ground exerts a force on the rocket.

☐ **D** the rocket exerts a force on the ground.

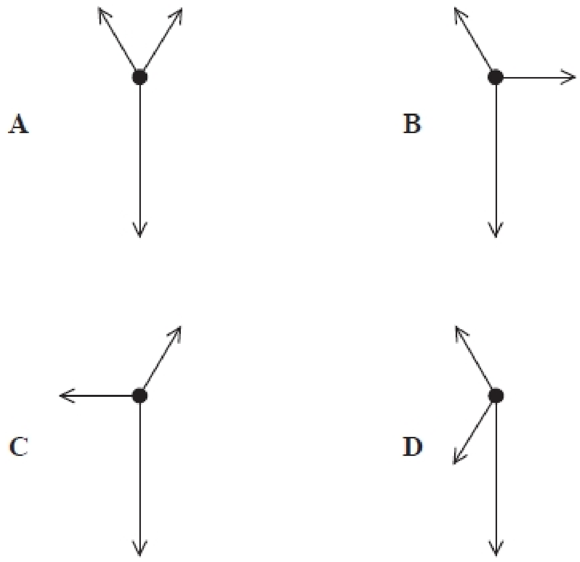
(Total for question = 1 mark)

Q19.

A trapdoor is fixed to a vertical wall with a hinge. A wire is attached to the other end of the trapdoor and inclined at an angle of 60°, as shown. The wire holds the trapdoor horizontal.



Which of the following shows the free-body force diagram for the trapdoor?



☐ **A**

☐ **B**

☐ **C**

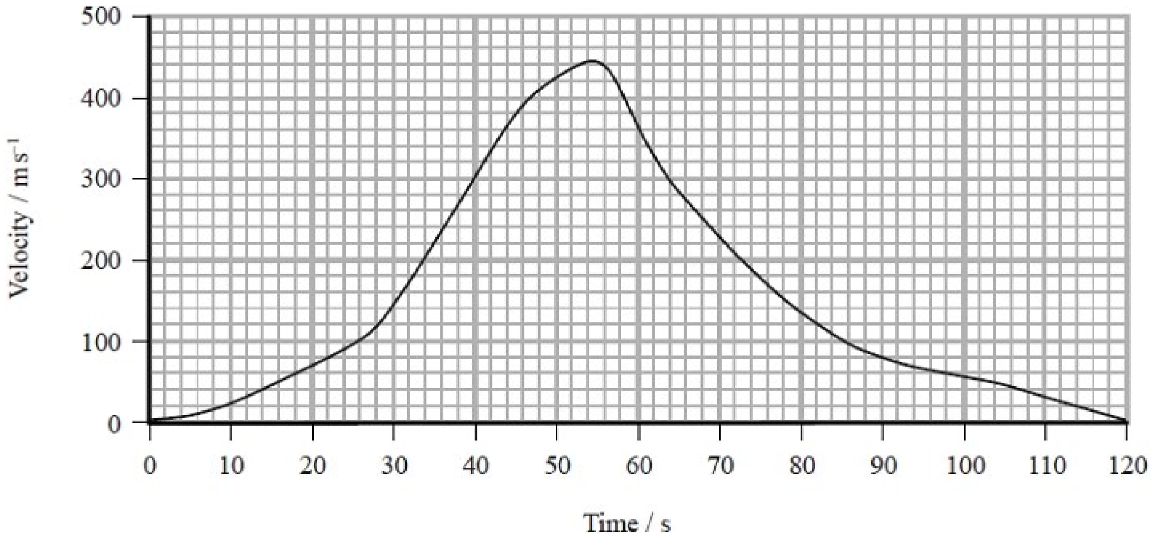
☐ **D**

(Total for question = 1 mark)

Q20.

The world land speed record of 341 m s^{-1} was set in October 1997. In an attempt to break this record, a new supersonic car has been developed called the Bloodhound.

The developers of the Bloodhound have used computer modelling to produce a velocity-time graph for the predicted motion of the car, on a straight track, during the record attempt.



The car has two different engines: a jet engine providing a thrust of 89 kN and a rocket engine providing a thrust of 120 kN.

(i) The jet engine runs throughout the car's acceleration stage. The rocket engine runs for only part of that stage.

State the time at which the rocket engine is started during the car's predicted motion.

(1)

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(ii) Use the graph to determine the maximum positive acceleration of the car.

(2)

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Maximum positive acceleration of the car = ...

(iii) Calculate a value for the frictional force acting on the car when the positive acceleration is a maximum.

(3)

mass of car including fuel at this time = 7790 kg

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Frictional force during maximum positive acceleration =

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(Total for question = 6 marks)

Q21.

A 'Gauss gun' can be made from five ball bearings of equal mass and two magnets, as shown.

Pairs of ball bearings are placed to the right of two strong magnets. A single ball bearing is released from the left, as shown. The ball bearing is attracted to, and collides with, the first magnet. This and all subsequent collisions can be assumed to be elastic.

Explain what happens to make the last ball bearing on the right subsequently move off with a large velocity.

(3)

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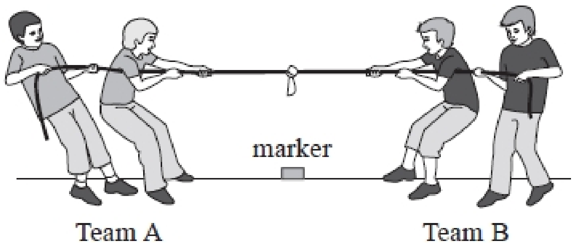
(Total for question = 3 marks)

Q22.

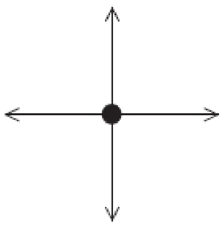
In a game of tug-of-war two teams of children pull on opposite ends of a rope. The team that pulls the other team over a marker wins the game.



(a) Initially Team A and Team B are stationary.

Add labels to the free-body force diagram for the child at the end of the rope for Team A at this instant.

(3)



*(b) Team B wins by pulling Team A over the marker.

By considering the forces on the children and on the rope explain, in terms of Newton's laws, the process by which Team A loses the game.

(6)

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(Total for question = 9 marks)

Q23.

Two objects of mass *m* travel towards each other on a smooth horizontal surface, each with velocity of magnitude *v*. The collision is elastic.

After the collision the

☐ **A** total kinetic energy is $2mv^2$

☐ **B** total kinetic energy is mv^2

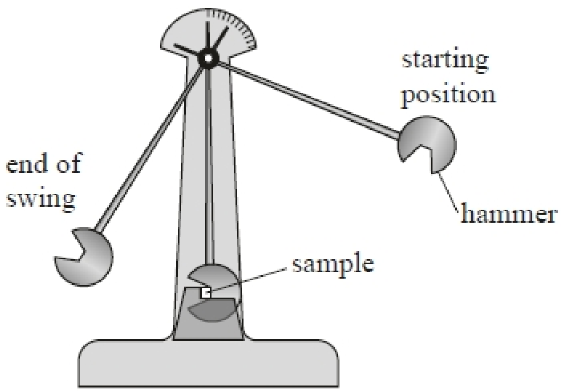
☐ **C** total momentum is $2mv$

☐ **D** total momentum is mv

(Total for question = 1 mark)

Q24.

Read the passage and answer the questions below.



(ref: Physics Review April 2015 p22)

The Charpy test is used by scientists to measure the fracture toughness of a material. A simple pendulum, with a hammer on the end, is held high and released so that it swings down and strikes the sample. The height from which the hammer is released is increased until the sample fractures. Some energy is absorbed by the sample in the impact but the hammer continues to move until it comes to rest at the top of its swing. Due to the law of conservation of energy the hammer will not swing up as high as its starting position. The difference in height between the start and end is proportional to the energy absorbed in the impact – the fracture toughness.

The hammer is released from a height of 13.0 cm above the lowest point of the swing.

Calculate the momentum of the hammer when it strikes the sample.

mass of hammer = 31 kg

(3)

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Momentum of hammer = ...

(Total for question = 3 marks)

Q25.

The photograph shows a small plastic container, its lid and some pellets of frozen carbon dioxide, known as dry ice. When at room temperature the dry ice gradually changes state directly from solid to gas.

Dry ice is placed in the container and the lid is put on. The container is turned upside down and placed on the floor. After a few minutes the pressure of the gas causes the container to fly into the air, leaving the lid and some dry ice behind.

A student investigated the motion of the container.

(a) The student obtained measurements of the maximum height reached by the container for a particular initial mass of dry ice. The student determined that the maximum height was 2.5 m.

Calculate the initial speed of the container.

(2)

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Initial speed = ...

(b) The student investigated how the maximum horizontal distance travelled by the container varies with launch angle.

Calculate the maximum horizontal distance the container would travel if launched at an initial speed of 6.5 m s^{-1} at an angle of 20° to the horizontal.

(5)

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Maximum horizontal distance = ...

(c) The student added dry ice to the container again and placed it on its side on the floor. When the lid was forced off, the container moved forward at a speed of 5.5 m s^{-1} and the lid moved backwards. The pellets of dry ice remained in their original position.

mass of container = 4.3 g
mass of lid = 1.6 g

(i) Calculate the initial speed of the lid.

(3)

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Initial speed of lid = ...

(ii) Explain why the dry ice remained at the original position.

(2)

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(Total for question = 12 marks)

Q26.

A student is travelling forwards at constant speed on a skateboard.

The student jumps forward off the skateboard.

Explain how Newton's laws of motion apply to the student and the skateboard as he jumps forward off the moving skateboard.

(6)

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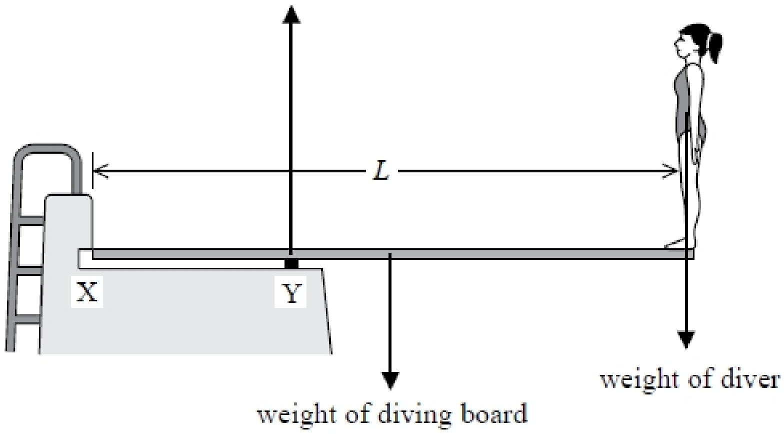
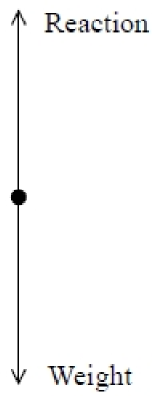
(Total for question = 6 marks)

Q27.

The diagram shows a diver of weight 680 N on a diving board.



The free-body force diagram for the diver standing on the board is shown.



The two forces shown do **not** form a Newton third law pair.

Give **two** reasons why.

(2)

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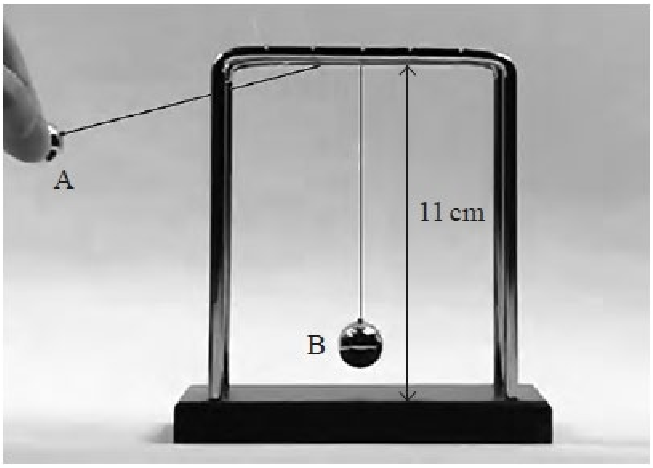
(Total for question = 2 marks)

Q28.

Two small identical solid metal spheres, A and B, are suspended by light inextensible threads from a frame.

The photograph shows sphere A just before it was released.



Determine the momentum of sphere A just before the collision. You should take measurements from the photograph.

height of frame = 11 cm
mass of sphere = 0.022 kg

(5)

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Momentum of sphere A = ...

(Total for question = 5 marks)

Q29.

A trolley, mass 0.50 kg, has a speed of 2.0 m s^{-1}. A second trolley, mass 1.0 kg, has a speed of 2.0 m s^{-1}. The two trolleys are travelling in opposite directions and collide.

Which of the following could be a correct value of total momentum, in kg m s^{-1}, after the collision?

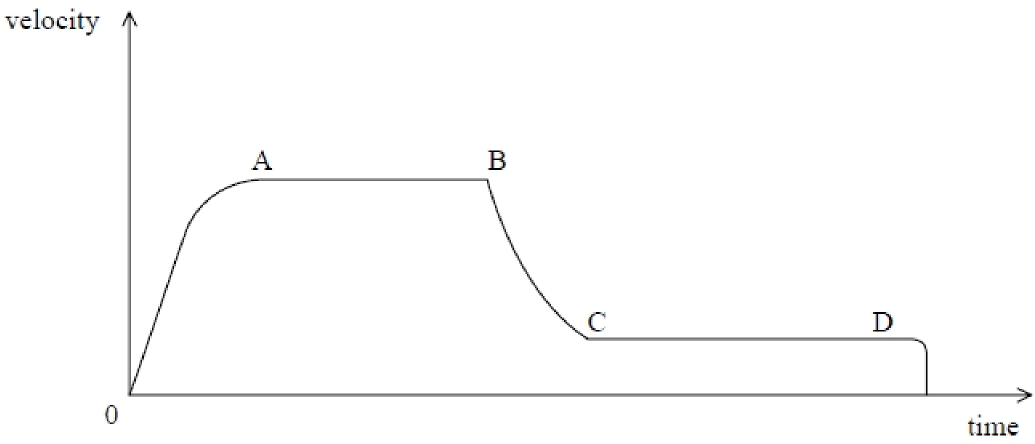
(1)

- ☐ **A** 0
- ☐ **B** 1.0
- ☐ **C** 2.0
- ☐ **D** 3.0

(Total for question = 1 mark)

Q30.

* The graph shows the velocity of a skydiver from the moment that she begins her freefall jump, until she lands on the ground.



Explain, in terms of the force acting, the shape of the graph from the point when the parachute opens until point D.

(6)

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(Total for question = 6 marks)

Q31.

Two ice skaters are gliding across the horizontal ice surface at an ice rink.

(Source: © ITAR-TASS News Agency/Alamy Stock Photo)

Explain why the male skater experiences a change in his velocity when he pushes the female skater forwards.

You should make reference to Newton's laws of motion in your explanation.

(4)

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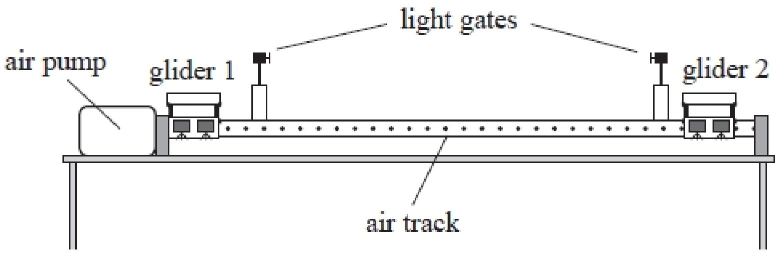
(Total for question = 4 marks)

Q32.

A teacher uses a linear air track to provide a frictionless surface for two gliders, each of mass *m*. She uses this, with a pair of light gates connected to a computer, to investigate a collision between the gliders.

The gliders are each given a small push and travel towards the centre of the track. The gliders collide and move off together.



The computer displays the velocity of the gliders as they pass through the light gates.

Calculate the velocity of the gliders after the collision, using the principle of conservation of linear momentum.

(3)

initial velocity of glider 1 = 0.30 m s^{-1} to the right
initial velocity of glider 2 = 0.70 m s^{-1} to the left

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Magnitude of velocity = ...

Direction of velocity = ...

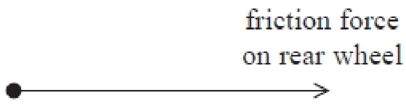
(Total for question = 3 marks)

Q33.

The photograph shows a cyclist cycling at a constant velocity on horizontal ground.

Complete the free-body force diagram to show the four forces acting on the bicycle. Treat the bicycle and cyclist as a single object. One force has been added for you.

(3)



(Total for question = 3 marks)

Q34.

The photograph shows a cyclist cycling at a constant velocity on horizontal ground.

The cyclist stops pedalling and comes to rest in a time of 5.2 s.

(i) Sketch a graph to show how the cyclist's velocity changes during this time.

Assume the deceleration is constant.

(2)

(ii) The cyclist travels 7.80 m while coming to rest.

Calculate the average resistive force on the cyclist and bicycle.

mass of cyclist and bicycle = 28.0 kg

(4)

....

....

....

....

....

....

Average resistive force = ...

(Total for question = 6 marks)

Mark Scheme – Newton's Law and Momentum

Q1.

Question Number	Answer	Additional Guidance	Mark
	C is the only correct answer	A is incorrect because the wrong trigonometric function has been used B is incorrect because the wrong trigonometric function has been used D is incorrect because the wrong forces have been used	**1**

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
	C		**1**

Q3.

<table>
<tr><th>Question Number</th><th>Additional guidance</th><th colspan="2">Mark</th></tr>
<tr>
<td>*</td>
<td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5 - 4</td><td>3</td></tr>
<tr><td>3 - 2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
Indicative content

Sphere A applies a force to sphere B (on impact)
According to Newtons third law Sphere B will apply an (equal and) opposite force to Sphere A
This force opposes the motion of Sphere A
Sphere A decelerates, according to N2
The (resultant) force on sphere B accelerates B
The forces/impulse acting (on the spheres) are equal so the change in speeds/momentum are the same for each sphere.

</td>
<td>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
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<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td>
<td>6</td>
</tr>
</table>

Q4.

Question Number	Answer	Additional Guidance	Mark
(i)	• Use of $v^2 = u^2 + 2as$ (1) **Or** Use of $E_k = \frac{1}{2}mv^2$ **and** $\Delta E_{grav} = mg\Delta h$ • Use of $a = \frac{\Delta v}{\Delta t}$ **and** use of $F = ma$ (1) • Force from ground = required Force + weight (1) • 1041 N (1)	Accept use of $F = \frac{\Delta mv}{t}$ Example of calculation $v^2 = 2 \times 9.81\ \text{m s}^{-1} \times 1.6\ \text{m}$ $v = 5.6\ \text{m s}^{-1}$ $a = \frac{5.6\ \text{m s}^{-1}}{0.9} = 6.2\ \text{m s}^{-2}$ $F = 65\ \text{N} \times 6.2\ \text{m s}^{-2} = 403\ \text{N}$ Force from ground = $403\ \text{N} + (65\ \text{kg} \times 9.81\ \text{N kg}^{-1})$ = 1040.65 N	4
(ii)	• bending knees increases the time to come to rest (1) • decreasing rate of change of momentum or reducing the deceleration (1) • and (hence) force (1)	Accept converse argument	3

Q5.

Question Number	Answer	Additional Guidance	Mark
	• Use of $p = mv$ **(1)** • Use of momentum conservation **(1)** • $v = 4.1\ \text{m s}^{-1}$ **(1)**	Example of calculation $p_i = (66 + 52)\ \text{kg} \times 5.6\ \text{m s}^{-1}$ $p_f = (66\ \text{kg})v + (52\ \text{kg} \times 7.5\ \text{m s}^{-1})$ $\therefore v = \frac{(661 - 390)\ \text{kg m s}^{-1}}{66\ \text{kg}} = 4.11\ \text{m s}^{-1}$	3

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
	• use of *mv* • applies momentum conservation • $v = 17\ \text{m s}^{-1}$	(1) (1) (1)	Example of calculation $2700\ \text{kg} \times 9.2\ \text{m s}^{-1} = 0 + 1500\ \text{kg} \times v$ $24840\ \text{kg m s}^{-1} = 1500\ \text{kg} \times v$ $v = 16.6\ \text{m s}^{-1}$	3

Question Number	Acceptable answers		Additional guidance	Mark
	• momentum not conserved as external force acts • friction from the road	(1) (1)		2

Q7.

Question number	Acceptable answers	Additional guidance	Mark
	Either • Calculate acceleration **(1)** • Use of $F = ma$ **(1)** • $F = 38$ N **(1)** **OR** • Calculate change in momentum **(1)** • Use of $F = \frac{\Delta mv}{\Delta t}$ **(1)** • $F = 38$ N **(1)**	Example of calculation: $F = \frac{0.06 \times 25}{0.04} = 37.5\ \text{N}$	3

Q8.

Question Number	Acceptable Answer		Additional guidance	Mark
	• recognises minimum upward force is *mg* • resolve force parallel to string • minimum force = 0.22 N	(1) (1) (1)	Example of calculation: $F = \frac{11 \times 10^{-3}\ \text{kg} \times 9.81\ \text{N kg}^{-1}}{\sin 30^\circ} = 0.22\ \text{N}$	**(3)**

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	• change in velocity $=(-49)-(40)=-89$ m s^{-1} (1) • use of $v = u + at$ to determine acceleration (1) • use of $F = ma$ to get F $=(-)19\,000$ N (1) • a sensible comparison of 19 000 N with (2 000 kg × 9.81 N kg^{-1}) (1)	Example of calculation Taking the initial direction of the ball as positive $\Delta v=(-49)-(40)=-89$ m s^{-1} $a = \frac{-89\text{ m s}^{-1}}{0.70\times10^{-3}\text{ s}} = -1.27\times10^{5}$ m s^{-2} $F = 0.15$ kg $\times -1.27\times10^{5}$ m s^{-2} $F = -19\,100$ N Magnitude of force using the given value $= 2\,000$ kg $\times 9.81$ N kg^{-1} $= 19\,620$ N	**(4)**

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• the point through which the weight (of a body) acts (1) **Or** The point around which the mass is equally distributed **Or** if supported at/below this point the body would be in equilibrium	alt. the point at which the entire mass can be assumed to be located.	1

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	D -0.60 kg m s^{-1}		**1**

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	• Glider 1 exerts this force on glider 2, so according to N3 (1) • Glider 2 will exert an (equal and) opposite force on glider 1 (1) • There is now a resultant force on glider 1 (1) • Glider 1 accelerates according to N1 **Or** glider 1 now moves to the left according to N1 (1)		**4**

Q13.

Question Number	Acceptable Answer	Additional Guidance	
	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The table shows how the marks should be awarded for indicative content and lines of reasoning.		

IC points	IC mark	Max linkage mark available	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

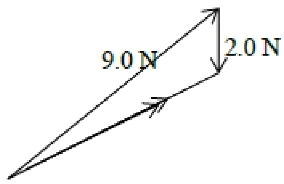
	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between its points and is unstructured	0

	Indicative content: • (Collision takes place on an ice surface so) there is minimal friction **Or** External forces are negligible • Momentum is conserved in the collision • The momentum of stone A before the collision equals the momentum of (A and) B after the collision • Stone A must be at rest after the collision • All of the kinetic energy of stone A must have been transferred to stone B • Kinetic energy is conserved in an elastic collision		**6**

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative points seen in answer → Number of marks awarded for indicative points: 6 → 4 5-4 → 3 3-2 → 2 1 → 1 0 → 0 Indicative content: • Newton's 3rd law pair of forces must be of the same type **Or** Newton's 3rd law pair of forces must act on different bodies • The two forces mentioned are not a 3rd Law pair **Or** gravity is not a good description of force • The lift on the plane should be paired with the push of the plane on the air **Or** the gravitational force of Earth on plane should be paired with the gravitational force of plane on Earth. • If the vertical resultant force is zero the plane will not accelerate vertically • So the plane could be 'at rest' or moving with uniform velocity in the vertical direction • There must be some horizontal motion so plane can't be in same place	The following table shows how the marks should be awarded for structure and lines of reasoning Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout → 2 Answer is partially structured with some linkages and lines of reasoning → 1 Answer has no linkage between points and is unstructured → 0 **Linkage Marks** IC points 1 – 3 **Two** of these points could score one linkage mark IC points 4 – 6 **Two** of these points could score one linkage mark	6

Q15.

Question Number	Acceptable answers		Additional guidance	Mark
	• Construction of vector diagram with 2 N/weight and 9N / catapult force labelled and all three directions shown • Correct scaling of 9 N and 2 N forces • Magnitude = 7.6 N to 8.0 N • Direction = 27° to 31°	(1) (1) (1) (1)	 MP2: Award if MP3 awarded. Otherwise, the ratio of the lengths should lie between 4.3 and 4.8 (if no diagram, only MP3/4 can be awarded if answers obtained by calculation)	**4**

Q16.

Question Number	Answer	Mark
	C	**1**
	Incorrect Answers: **A** – incorrect normal force direction **B** – incorrect normal force direction and frictional force direction **D** – incorrect frictional force direction	

Q17.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• distance between at least two pairs of images (1) • distances between images are the same in x direction (1) • distance between images varies in y direction showing a changing velocity (1) • velocity in the x direction is constant so x direction is independent of y direction (1)	MP1 and 2 could come from marks on the diagram	4
(ii)	• use of $v^2 = u^2 + 2as$ or $s = ut + \frac{1}{2}at^2$ (1) • initial vertical component velocity = 0.47 m s^{-1} (1) • use of $v_H = d/t$ in the horizontal (1) • Use of Pythagorus with v_H and u_V (1) • Resultant velocity = 1.1 m s^{-1} (1)	alt to MP2 : 0.5 m s^{-1} (allow 0.4 to 0.6) if using distance taken from first two images and $v_H = d/t$ Example of calculation: $0 = u^2 - 2 \times 9.81$ m s^{-2} $\times 0.011$ m $u_V = 0.465$ m s^{-1} $v_H = \frac{0.08 \text{ m}}{0.08 \text{ s}}$ $v_H = 1.0$ m s^{-1} $v = \sqrt{(0.47^2 + 1.0^2)}$ Resultant velocity = 1.1 m s^{-1}	5
(iii)	• Use of $\Delta W = F \Delta s$ (1) • Use of $E_k = ½ mv^2$ (1) • $F = 0.015$ N (1) Alternative • Use of $v^2 = u^2 + 2as$ (1) • Use of $F = ma$ (dependent on MP1) (1) • $F = 0.015$ N (1)	Allow ECF from (a)(ii) Example of calculation: $2 \times F \times 0.003$m $= \frac{1}{2} \times 150 \times 10^{-6}kg\times 1.1^2$ (m s^{-1})^2 $F = 0.015$ N "show that" value gives $F = 0.013$ N Alternative 1.1^2 (ms^{-1})$^2 = 2 \times a \times 0.003$ m $a = 202$ m s^{-2} $2 \times F = 150 \times 10^{-6}$ kg$\times 202$ ms^{-2} $F = 0.015$ N	3

Q18.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q19.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B is not correct as these forces are not in equilibrium C is not correct as these forces are not in equilibrium D is not correct as these forces are not in equilibrium		**1**

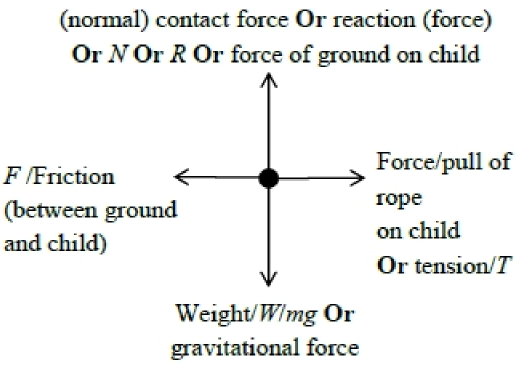
Q20.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• 26 - 28 s	(1)	Unit required	**1**
(ii)	• Use of gradient of the graph between 28 and 46 s • Acceleration = 16 - 17 m s^{-2}	(1) (1)	<u>Example of calculation</u> Gradient of tangent = $\frac{490\ m\ s^{-1} - 0\ m\ s^{-1}}{52\ s - 22\ s}$ Acceleration = 16.3 m s^{-2}	**2**
(iii)	• Use of $\Sigma F = ma$ using a from (ii) • $\Sigma F = (89 + 120) \times 10^3$ N – frictional force • Frictional force = 80 kN to 84 kN (full ecf for acceleration)	(1) (1) (1)	<u>Example of calculation</u> $(89 + 120) \times 10^3$ N - F = 7790 kg × 16.3 m s^{-2} $F = 82.0 \times 10^3$ N	**3**

Q21.

Question Marks	Acceptable Answers	Additional guidance	Mark
	• Magnet accelerates ball Or magnet increases ball's KE (1) • Momentum is conserved in the collision(s) (1) • (Since collisions are elastic) KE conserved so third ball moves off with the same velocity/KE as incoming ball hit magnet with (1)	Marks can be gained by discussing either set of balls	3

Q22.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	Four forces correctly labelled (1 force correctly labelled scores one mark 2 or 3 forces correctly labelled scores two marks 4 forces correctly labelled scores three marks)		3

(b)*

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5-4	3
3-2	2
1	1
0	0

The following table shows how the marks should be awarded for structure and lines of reasoning

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Indicative content

Indicative content	Additional guidance	Mark
• The idea that the rope is under tension	Accept tension for 'force of rope on team'	
• Team A exerts a force on the rope and due to N3 the rope exerts a force on Team A		
• Force of rope on team A > frictional force for Team A		
• Team A now has a resultant force (to the right)	MP4: accept 'unbalanced' for 'resultant'	6
• Team A accelerates (to the right) due to N1/2		
• (This is because) the frictional force between Team B and the ground is larger **Or** Team B applies a greater • force (on the rope) than team A	Accept converse for MP6 but a reference to both Team A and Team B is required for MP6	

Q23.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	total kinetic energy is mv^2	**(1)**

Q24.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Equate $E = mg\Delta h$ and $E = \frac{1}{2}mv^2$ (1) • Use of $p = mv$ (1) • p = 50 kg m s^{-1} (1)	Do not accept $v^2 = u^2 + 2as$ (because the hammer does not move in a straight line with constant acceleration) <u>Example of calculation</u> $mg\Delta h = \frac{1}{2}mv^2$ 31 kg × 9.81 ms^{-2} × 0.13 m = $\frac{1}{2}$ × 31 kg × v^2 $v = \sqrt{(2 \times 9.81 \text{ ms}^{-1} \times 0.13 \text{ m})}$ = 1.6 m s^{-1} p = 31 kg × 1.6 m s^{-1} = 49.6 kg m s^{-1}	3

Q25.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• use of $v^2 = u^2 + 2as$ **(1)** **OR** use of ½ mv^2 =mgh **(1)** • initial speed = 7.0 m s^{-1} **(1)**	Example of calculation: v = 0 a = −9.81 m s^{-1} s = 2.5 m $u^2 = -2as$ u^2 = − (2 × −9.81 m s^{-1} × 2.5 m) = 49 m^2 s^{-2} u = 7.0 m s^{-1} Alternative calculation: ½ v^2 = gh v = √(2gh) = √(2 x 9.81 x 2.5) = = 7.0 m s^{-1}	2
(b)	• use of trig function to find v vertical **(1)** • use of trig function to find v horizontal **(1)** • use of equation of motion to find time of flight **(1)** • use of equation of motion to find distance **(1)** • horizontal distance = 2.7 m **(1)**	Example of calculation vertical velocity = 6.5 m s^{-1} sin 20 = 2.22 m s^{-1} time of flight using $v = u + at$ -2.22 m s^{-1} = 2.22 m s^{-1} + (-9.81 m s^{-1}× t) t = 0.45 s horizontal velocity = 6.5 m s^{-1} cos 20 = 6.11 m s^{-1} horizontal distance using $s = ut$ s = 6.11 m s^{-1} × 0.45 s s = 2.7 m	5
(c)(i)	• use of p=mv **(1)** • correctly applies conservation of momentum **(1)** • v = 14.8 m s^{-1} **(1)**	Example of calculation: momentum of lid = − momentum of canister 1.6 g × v = 4.3 g × 5.5 m s^{-1} v = 14.8 m s^{-1}	3
(c)(ii)	An explanation that makes reference to: • no unbalanced force on dry ice **(1)** • so no acceleration according to Newton's First Law **(1)**	MP2 is dependent on MP1 Allow suitable reference to Newton's Second Law for MP2	2

Q26.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td></td>
<td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

Indicative content
IC1 The student applies a force to the skateboard
IC2 By Newtons 3rd Law the skateboard also applies a force to the student
IC3 The two forces are equal in size but opposite in direction
IC4 The student accelerates according to Newtons 2nd Law
IC5 The skateboard decelerates according to Newton's 2nd Law.
IC6 The skateboard has a higher (magnitude of) acceleration than the student as it has a smaller mass</td>
<td>The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
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<tr><td>Answer has no linkage between points and is unstructured</td><td>0</td></tr>
</table>
Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
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<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
</td>
<td>6</td>
</tr>
</table>

Q27.

Question number	Acceptable answers	Additional guidance	Mark
	• The forces are different types **(1)** • The forces act on the same object **(1)**		**2**

Q28.

Question Number	Additional guidance			Mark
	• Measurement of change in height of Sphere A • actual height = $\frac{\text{image height} \times 11}{4.8}$ • Use of E_k gained = E_{grav} lost to determine v • Use of $p = mv$ • $p_A = 0.025 \text{ kg m s}^{-1}$	(1) (1) (1) (1) (1)	Initial decrease in height from photo = 2.9 ± 0.1 cm Height of frame in photo = 4.8 ± 0.1 cm MP2-4 award even if measurement for the height is out of range MP3 use of equation of motion scores 0 <u>Example of calculation</u> $h_A = \frac{2.9 \text{ cm} \times 11 \text{ cm}}{4.8 \text{ cm}} = 6.6 \text{ cm}$ $\frac{1}{2} \times 0.022 \text{ kg} \times v_A^2 = 0.022 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 6.6 \times 10^{-2} \text{ m}$ $v_A = 1.14 \text{ m s}^{-1}$ $p_A = 0.022 \text{ kg} \times 1.14 \text{ m s}^{-1} = 0.025 \text{ kg m s}^{-1}$ Accept p_A in range 0.024 – 0.026 kg m s^{-1}	**5**

Q29.

Question Number	Acceptable answers	Additional guidance	Mark
	B as equal to total momentum before = 1×2−0.5×2	1.0	**1**
	A is the answer if each trolley had the same momentum C is the momentum of the second trolley only D is the answer if the two trolleys were travelling in the same direction		

Q30.

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
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<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>**6**</td></tr>
</table>

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<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
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</table>
</td><td></td><td></td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • As parachute opens (at B) the upwards force increases • Along BC the velocity is decreasing at a non-constant rate • The drag is greater than weight (negative gradient) • The drag is decreasing (curved line) • Eventually the drag force balances the weight • No acceleration so line is horizontal		

Q31.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • (Male skater exerts a force on female skater), so according to N3 **(1)** • Female skater will exert an (equal and) opposite force on male skater **(1)** • There is now a resultant force on male skater **(1)** • Male skater decelerates according to N1/N2 **(1)** **Or** male skater's velocity decreases according to N1/N2		**4**

Q32.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $p = mv$ (1) • Use of principle of conservation of momentum (1) • Magnitude of velocity = 0.2 m s^{-1} with direction to the left (1)	MP1: see 0.3 m, 0.7 m or $2mv$ MP3: accept 'in the initial direction of glider 2' for 'to the left' <u>Example of calculation</u> (taking the initial direction of glider 1 as positive) $0.3\,m - 0.7\,m = 2mv$ $v = -0.2\ \text{m s}^{-1}$	3

Q33.

Question Number	Acceptable answers		Additional guidance	Mark
	• Opposite horizontal force, labelled friction/resistance/drag • Vertically downward force labelled *W*/weight/*mg* • Vertically upwards force labelled *R*/Reaction/*N*/Normal (contact force)	(1) (1) (1)	ignore extra words such as ..of bicycle	3

Q34.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• straight line starting on *v* axis with negative gradient • intercept on *t* axis marked 5.2 with unit s	(1) (1)		2
(ii)	• Use of $s = \frac{(u+v)t}{2}$ with $v = 0$ • Use of another SUVAT equation to determine *a* • Use of $F = ma$ • Resistance = 16 N **Or** • Use of area = base × height / 2 • Use of acceleration is gradient of line • Use of $F = ma$ • Resistance = 16 N **Or** • Use of $s = (u + v)t/2$ with $v = 0$	(1) (1) (1) (1) (1) (1) (1) (1)	Example of calculation Using SUVAT eg $7.8\text{ m} = (u + 0)5.2\text{ s}/2$ $u = 3.0\text{ m s}^{-1}$ $7.8\text{ m} = 3.0\text{m s}^{-1} \times 5.2\text{ s} + \frac{1}{2}a\,5.2^2\text{ s}^2$ $a = (-)0.58\text{ m s}^{-2}$ Using area under graph $\text{Area} = 7.8\text{ m} = v \times \frac{5.2\text{ s}}{2}$ $v = 3.0\text{ m s}^{-1}$ $a = \text{gradient} = \frac{3.0\text{ m s}^{-1}}{5.2\text{ s}}$ $a = (-)0.58\text{ m s}^{-2}$ $F = 28\text{ kg} \times 0.58\text{ m s}^{-2}$ $F = 16.2\text{ N}$	4
	• Use $E_k = ½ mv^2$ • Use of $W = F\Delta s$ • Resistance = 16 N			