Name: _____

Forces & Motion 1

Date:

Time: 1 hour

Total marks available: 60

Total marks achieved: _____

Questions

Q1.

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

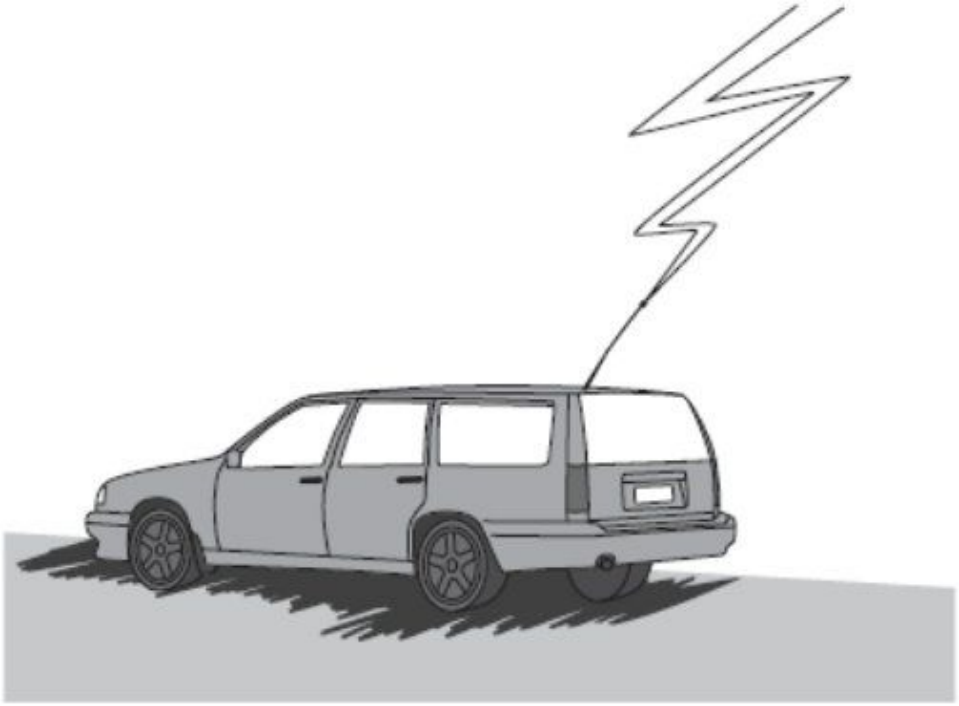

Figure 6

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)

Q2.

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 takes pictures of the athlete every 0.1 s during one throw.

Figure 6 shows the pictures of one throw.

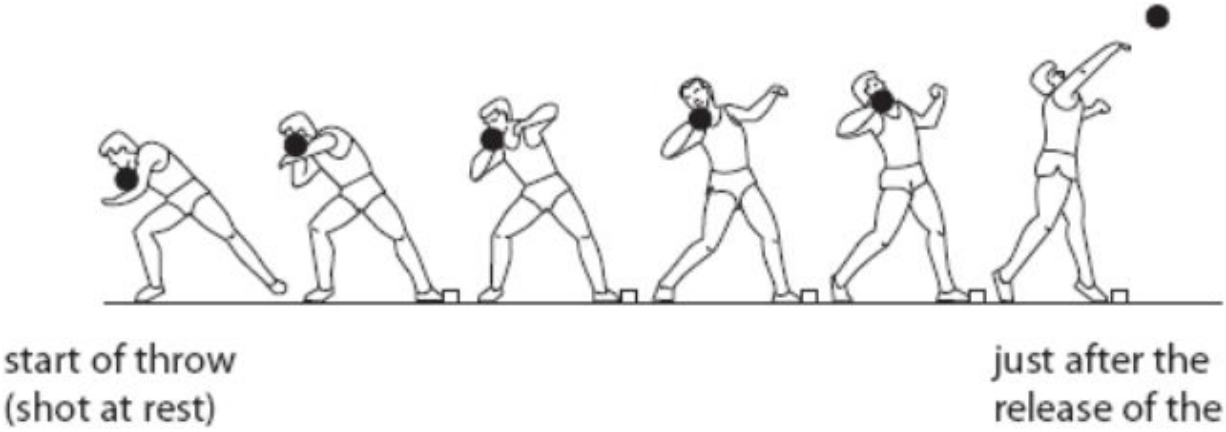

Figure 6

(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

(Total for question = 8 marks)

Q3.

Figure 7 shows a submarine being propelled forward underwater.

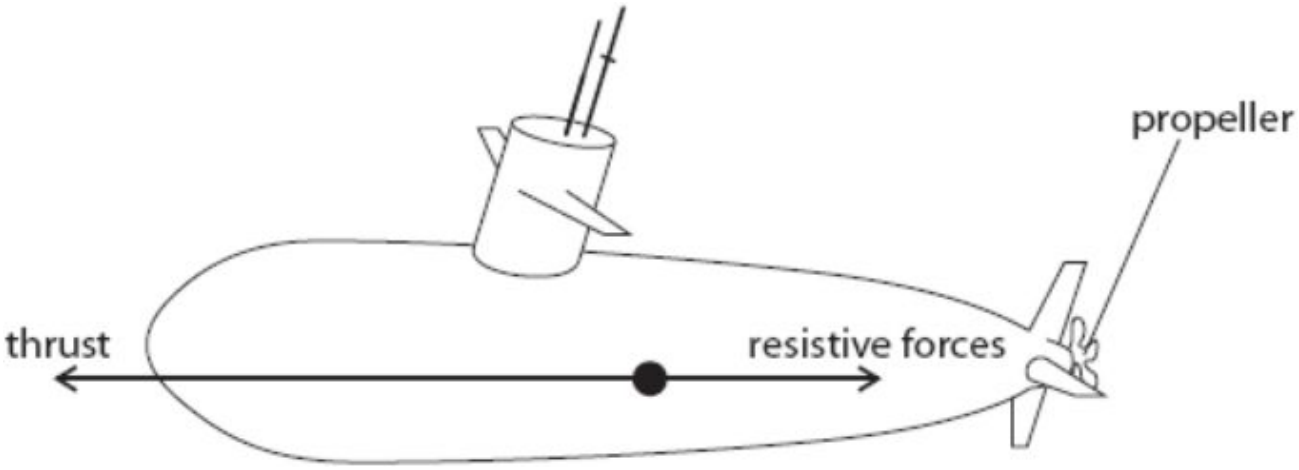

Figure 7

The thrust and the resistive forces are represented in magnitude and direction by the arrows in Figure 7.

* A submerged submarine is stationary.
The engines are put on maximum power.
The submarine moves forward.
The engines maintain maximum power.
The forces resisting the movement of the submarine increase as its speed increases.

The submarine remains horizontal. Explain how the forces acting on the submarine affect its acceleration up to and after it reaches its maximum possible speed.

(6)

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(Total for question = 6 marks)

Q4.

* Figure 14 shows two ice skaters during a sequence in their performance.

Figure 14

The man stays at the same place on the ice throughout the sequence.

At the start of the sequence, the woman is moving at a constant speed around the man while the man holds her arm.

After she has gone round the man several times, the man lets go of the woman's arm.
The sequence ends a few seconds later.

Explain the motion of the woman, in terms of the forces acting and the effects on her motion, for the whole sequence.

(6)

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(Total for question = 6 marks)

Q5.

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)

Q6.

A student investigates the motion of a trolley along a horizontal runway.

Figure 9 shows the apparatus.

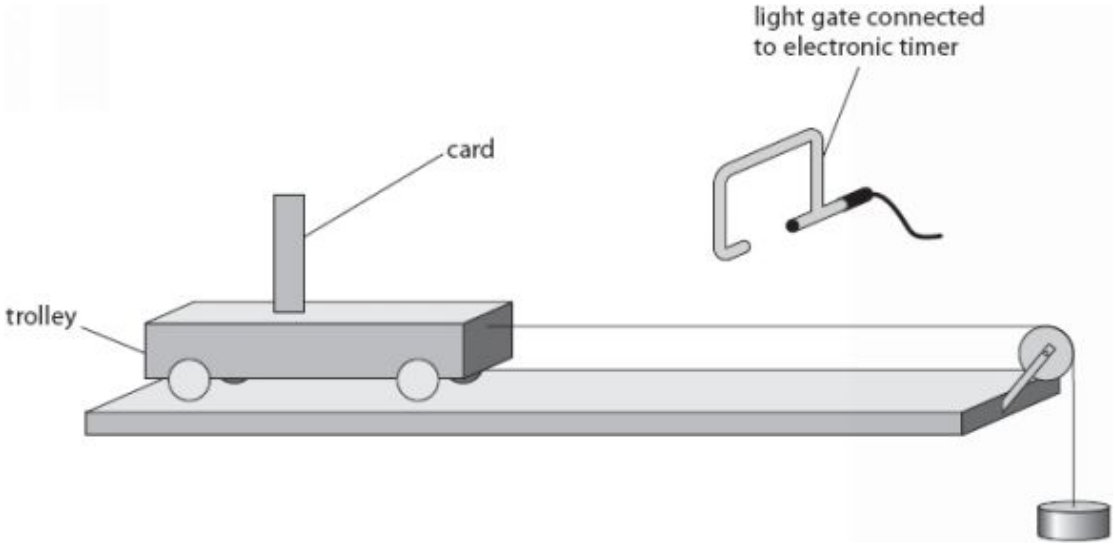

Figure 9

The trolley is attached to a string passing over a pulley.

A 100 g metal disc hangs on the end of the string.

The light gate measures the time it takes for the card to pass through it.

When the trolley is released, it accelerates along the track.

(i) Explain why the trolley accelerates along the track.

(2)

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(ii) The card takes 0.040 s to travel through the light gate.

The student calculates that the average speed of the trolley through the light gate is 1.15 m/s.
Calculate the width of the card.

(2)

width = ... cm

(iii) The trolley travels 1.2 m along the track from the start before the card reaches the light gate.

Show that acceleration of the trolley along this distance is approximately 0.55 m/s^2.

(2)

(Total for question = 6 marks)

Q7.

Which row of the table is correct for both force and velocity?

(1)

	force	velocity
☐ A	scalar	scalar
☐ B	scalar	vector
☐ C	vector	scalar
☐ D	vector	vector

(Total for question = 1 mark

Q8.

Another rocket has a total mass of 90 g when it takes off. The acceleration of the rocket when it takes off is 3.3 m/s^2.

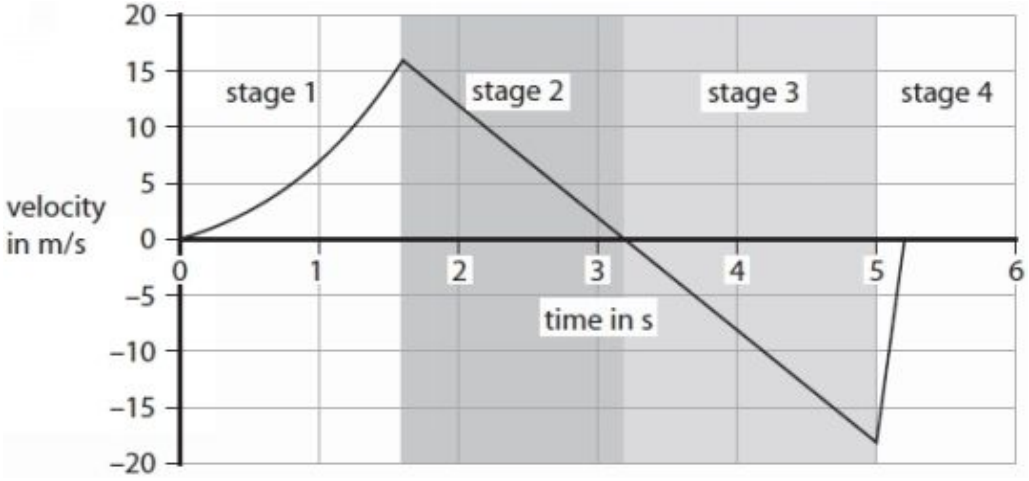
(i) Calculate the resultant force on the rocket when it takes off.

(2)

resultant force = ... N

*(ii) The rocket contains 50 g of fuel when it takes off.
The fuel burns and the rocket rises vertically.
After a while, there is no fuel left.
Eventually the empty rocket falls back to the ground.

The graph is a velocity–time graph for the rocket.
Four stages are labelled on the graph.



Explain why the velocity of the rocket changes as shown in the graph.

(6)

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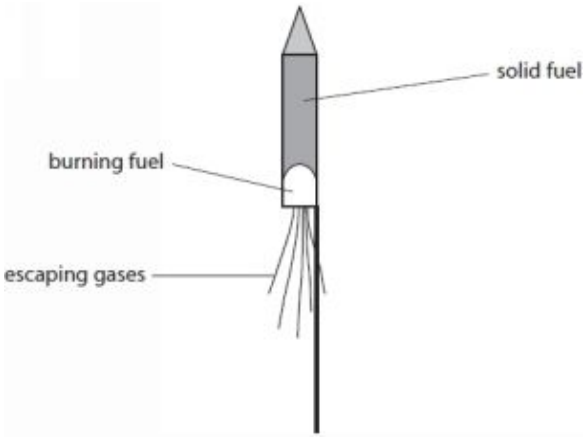
Q9.

A firework rocket contains a solid fuel inside a cardboard tube.

The burning of the fuel creates a thrust to propel the rocket upwards.



(i) Scientists can refer to several different quantities when describing the motion of the rocket.

mass	energy	speed	force

Only one of these quantities is a vector.
Complete this sentence using **one** of the words from the box.

(1)

The vector quantity is .....

(ii) Before the fuse is lit, the total weight of a rocket including fuel is 0.7N.

The gravitational field strength is 10 N/kg.

Complete the sentence by putting a cross (☒) in the box next to your answer.
The total mass of the rocket including fuel is

(1)

☒ **A** 0.007 kg

☒ **B** 0.07 kg

☒ **C** 0.7 kg

☒ **D** 7 kg

(iii) There is a resultant force on the rocket of 0.5 N upwards when it takes off.

The arrow on the diagram shows the size and direction of the force of gravity acting on the rocket when it takes off.

Add another arrow to the diagram to show the thrust produced by the burning fuel at the time the rocket takes off.
You should label the arrow with the size of the thrust.

(2)

Q10.

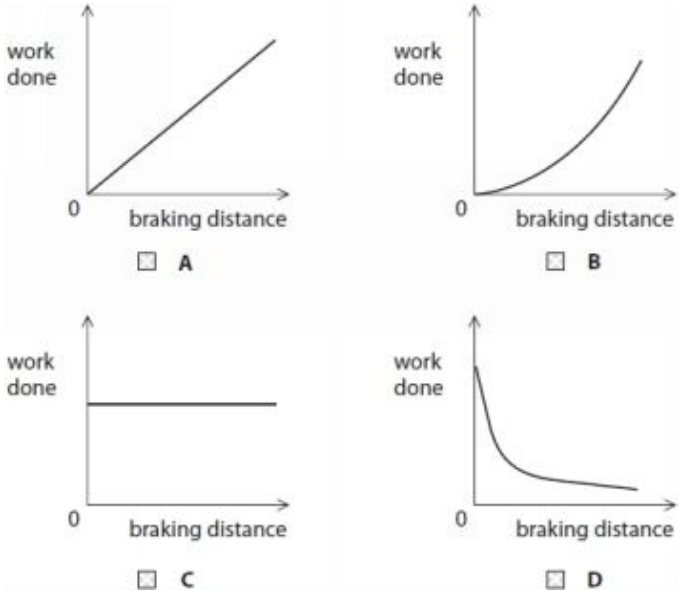
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The work done to bring a car to rest is given by the equation

work done = braking force × braking distance

Which of these graphs is correct for the car if a constant braking force is applied?

(1)



(Total for question = 1 mark)

Q11.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Figure 7 shows a submarine being propelled forward underwater.

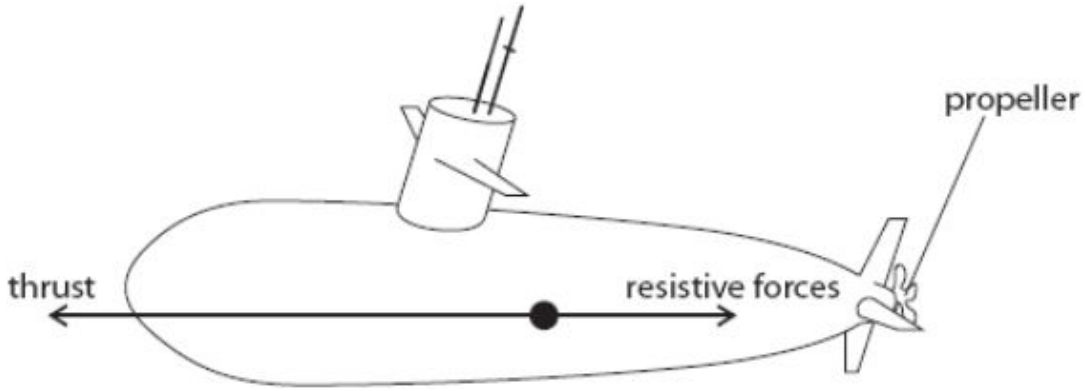


Figure 7

The thrust and the resistive forces are represented in magnitude and direction by the arrows in Figure 7.

(i) Which one of the following is correct?

(1)

☒ **A** The submarine is speeding up.

☒ **B** The submarine is slowing down.

☒ **C** The submarine is moving at a constant speed.

☒ **D** The submarine is moving at a constant velocity.

(ii) The propeller forces water away from the back of the submarine.

Explain why this produces a thrust in the forward direction.

(2)

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(iii) For a submarine to come to a standstill, its engines are put in reverse.

The propeller then runs in a reverse direction, producing a force causing the submarine to decelerate. It takes many minutes to come to rest.
Explain, using Newton's second law, why it takes many minutes for the submarine to slow down and come to a standstill.

(2)

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(Total for question = 5 marks)

Q12.

Explain **one** way the students could improve their procedure to obtain a more accurate value for *g*.

(2)

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(Total for question = 2 marks)

Q13.

Two students try to determine a value for *g*, the acceleration due to gravity.

(i) They measure the time, *t*, for a small steel ball to fall through a height, *h*, from rest.

They measure *t* to be 0.74 s, using a stopwatch.
They measure *h* to be 2.50 m, using a metre rule.
Calculate a value for *g* from the students' measurements.
Use the equation

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

(2)

g = ... m/s^2

(ii) They record the time *t* for two more drops from the same height.

The three values for time *t* are

0.74 s, 0.69 s, 0.81 s.

Calculate the average value of time *t* to an appropriate number of significant figures.

(2)

average value of time *t* = ... s

(Total for question = 4 marks)

Mark Scheme

Q1.

Question number	Answer	Additional guidance	Marks
(i)	recall K.E.= ½ m v^2(1) rearrangement (1) (m =) 2 x K.E. ÷ v^2 substitution (1) (m =) 2 x 960 000 ÷ 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)

Q2.

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

Question number	Answer	Additional guidance	Mark
(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
(iii)	Substitution (1) F = 7.26 x 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
(iv)	Rearrangement (1) v = a x t Substitution (1) v = 23 x 0.48 Evaluation (1) 11 m/s	 Accept 11.04(m/s) full marks will be awarded for correct numerical answer without working	(3)

Q3.

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)** **Stage 1** • (At the beginning) maximum force is applied • With zero resistive force(s) • And maximum acceleration **Stage 2** • As the speed increases the increasing resistive force results in a decreasing resultant forward force • And a decreasing acceleration • So velocity increases at a decreasing rate **Stage 3** • Eventually thrust = resistive force(s) • Then no resultant force forward and no acceleration • Submarine continues forward at a constant speed	(6)

Level	Mark	Descriptor
	0	No rewardable material.
Level 1	1–2	• 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	• 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	• 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)

Q4.

Question number	Indicative content	Mark
*	The indicative content below is not prescriptive and candidates are not required to include all of the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **A01 (6 marks)** • force needed to keep an object moving in a circle • when moving in a circle, direction of velocity changes • must be an acceleration • moving in a straight line with no resultant force at constant velocity **A02 (6 marks)** • the woman changing direction while circling the man • she is changing velocity (but not changing speed) • therefore she is accelerating • this requires a force towards the centre of her orbit • this is a centripetal force • when the man releases the woman, the centripetal force ceases • there is no resultant force on the woman (if friction from the ice can be ignored) • the woman therefore continue in a straight line • she is now travelling at a constant velocity	**(6)**

Level	Mark	Descriptor
	0	No awardable content
Level 1	1-2	• Demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) • The explanation attempts to link and apply knowledge and understanding of scientific ideas, flawed or simplistic connections made between elements in the context of the question. (AO2)
Level 2	3-4	• Demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) • The explanation is mostly supported through linkage and application of knowledge and understanding of scientific ideas, some logical connections made between elements in the context of the question. (AO2)
Level 3	5-6	• Demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) • The explanation is supported throughout by linkage and application of knowledge and understanding of scientific ideas, logical connections made between elements in the context of the question. (AO2)

Q5.

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 $v^2-u^2 = 2xaxd$	**(3)**

Q6.

Question number	Answer	Additional guidance	Mark
(i)	An explanation that combines identification - knowledge (1 mark) and reasoning/justification - understanding (1 mark): • unbalanced / resultant force (1) • (provided by) tension in the string / (weight of) metal disc (1)		(2)

Question number	Answer	Additional guidance	Mark
(ii)	substitution into speed = d/t (1) 1.15 = d / 0.04 (1) evaluation (1) d = 0.046m = 4.6 cm (1)	full marks will be awarded for correct numerical answer without working	(2)

Question number	Answer	Additional guidance	Mark
(iii)	using $V^2 - u^2 = 2ax$ $V^2 = 1.15^2$ $= 1.3225$ (1) $2 \times a \times x = 2 \times 1.2 \times 0.55$ $= 1.32$ (1)	allow 1.3225	(2)

Q7.

Question Number	Answer	Mark
	D | vector | vector **is the only correct answer** ***A*** *'scalar scalar' is incorrect, both force and velocity are vectors* ***B*** *'scalar vector' is incorrect, with force being described incorrectly as a scalar* ***C*** *'vector scalar' is incorrect, with velocity being described incorrectly as a scalar*	**(1)** AO 1 1

Q8.

Question Number	Answer	Acceptable answers	Mark
(i)	Substitution $\frac{90}{1000} \times 3.3$ (1) evaluation 0.30 (N) (1)	A value which rounds to 0.30 eg 0.297 Give full marks for correct answer with no working Ignore power of ten error until evaluation Allow 1 mark for 297 even with no working shown	**(2)**

Question Number		Indicative Content	Mark
QWC	*(ii)	An explanation demonstrating some of the following: Descriptions of the graph • Accelerates upwards during stage1 • Maximum velocity is reached at the end of stage 1 • Accelerates downwards / decelerates during stage 2 • Accelerates during stage 3 • Comes to rest during stage 4. Interpretations of the shape of the graph • Fuel is burnt creating thrust in stage • Thrust is upwards in stage 1/ • Gravity/weight (is always) a downward force • Fuel runs out at end of stage 1/ has ran out by stage 2 • Still going up during/ max height at end of stage 2 • Starts to fall at start of stage 3 • Negative velocity during stage 3 because it is falling. • Rapid deceleration / collision with the ground during stage 4/end of stage 3 Explanations for changes in velocity • Resultant force upwards/ thrust greater than gravity force during stage 1 • Acceleration non-linear because mass is decreasing / resultant force is increasing • Linear deceleration in stage 2/3 because force of gravity is constant • Resultant downward force/only gravity/ weight is acting during stage 2 and 3 • Large resultant force of impact during stage 4	(6)

Level	0	No rewardable content
1	1 - 2	• A limited explanation involving descriptions of the graph. • E.g. The rocket gets faster as it goes up during stage 1. The rocket slows down during stage 2 • 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 explanation involving interpretations of the shape of the graph e.g. The rocket's velocity increases during stage 1 because the burning fuel provides a force. The rocket accelerates downwards during stage 3 • 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 explanation which includes descriptions and interpretations for the shape of the graph including an explanation. E.g. The rocket's acceleration during stage 1 is increasing because it is losing mass as the fuel is burnt. It then slows down until it reaches maximum height at the end of stage 2 • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors

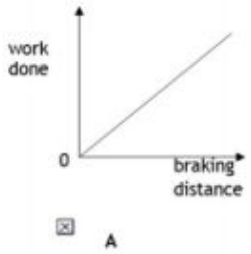
Q9.

Question Number	Answer	Acceptable answers	Mark
(i)	force (1)	If than one word given then 0 marks.	**(1)**

Question Number	Answer	Acceptable answers	Mark
(ii)	B 0.07kg		**(1)**

Question Number	Answer	Acceptable answers	Mark
(iii)	Arrow pointing (vertically) upwards (1) Value of 1.2 (N) (written near to arrow) (1)	 Marks are independent of each other	**(2)**

Q10.

Question Number	Answer	Mark
	 ☒ A **The only correct answer is A (showing direct proportionality)** **B** is not correct – curve (not showing direct proportionality) **C** is not correct – constant value shown (not showing direct proportionality) **D** is not correct – curve (not showing direct proportionality)	**(1)**

Q11.

Question Number	Answer	Additional guidance	Mark
(i)	A The submarine is speeding up.		**(1)**

Question Number	Answer	Additional guidance	Mark
(ii)	An explanation that combines identification (1 mark) and reasoning (1 mark) • identify the two forces which are (force of the submarine on the water) and <u>force/push of water on the submarine/propeller</u> (1) • these forces are equal and opposite (1)	states N's 3rd law mentions action and reaction **ignore** balanced forces	**(2)**

Question Number	Answer	Additional guidance	Mark
(iii)	An explanation that combines identification (1 mark) and reasoning (1 mark) • states N's 2nd law (1) $F = \frac{(mv - mu)}{t}$ • The reason that a long time is needed is because of a big change in momentum (1)	large momentum if no other marks scored F = ma scores 1 mark **OR** large mass scores 1 mark	(2)

Q12.

Question Number	Answer	Additional guidance	Mark
	an explanation linking: use an electronic timer / (1) to eliminate reaction time (1)	 light gate/ data logger there are other options which should be judged to this pattern (e.g. increase distance to reduce effect of reaction time)	**(2)** AO 3 3b

Q13.

Question Number	Answer	Additional guidance	Mark
(i)	substitution (1) $\frac{2x2.5}{0.74^2}$ evaluation (1) 9.1(3) (m/s^2)	 $\frac{5}{0.5476}$ award full marks for the correct answer with no working	**(2)** AO 2 1

Question Number	Answer	Additional guidance	Mark
(ii)	(0.74 + 0.69 + 0.81) ÷ 3 (1) 0.7(5) (1)	accept 0.7 or 0.75 award full marks for the correct answer with no working 0.746 or 0.747 or 0.750 scores 1 mark	**(2)** AO 3 2a AO 3 2b