Questions

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.
............................................................................................................

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

(iii) The ball bounces back to a height of 1.9 m.
     Continue the line on the graph to show this.
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(iv) Explain why the ball does not bounce back to its original height.
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Q2.

Andrew skis down a hill.

(a) Andrew starts from the top of the hill and his speed increases as he goes downhill. He controls his speed and direction by using his skis. He brings himself to a stop at the bottom of the hill.

Describe the energy changes that happen between starting and stopping.

(b) Andrew returns to the top of the hill and starts again.

(i) His mass is 67 kg.

Show that his momentum is about 2000 kg m/s when his velocity is 31 m/s.

(ii) He falls over when his momentum is 2000 kg m/s.

After he falls over, he slows down by sliding across the snow. It takes 2.3 s for his momentum to reduce to zero. Calculate the average force on Andrew as he slows down.
Q3.

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

Figure 6 shows the apparatus.

![Figure 6](image)

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.
(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.

\[
\text{width} = \text{........................................................... cm}
\]

(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\(^2\).

(Total for question = 6 marks)

Q4.

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.

<table>
<thead>
<tr>
<th>mass</th>
<th>energy</th>
<th>speed</th>
<th>force</th>
</tr>
</thead>
</table>

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

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 (X) in the box next to your answer. The total mass of the rocket including fuel is

- [ ] 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.
Q5.

A truck is towing a car along a level road at a constant velocity.

A tow rope is attached to the truck and the car.

(a) Which of these shows the directions of the forces between the car and the tow rope?
Put a cross (☒) in the box next to your answer.

<table>
<thead>
<tr>
<th>force exerted by car on tow rope</th>
<th>force exerted by tow rope on car</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ A</td>
<td>←→</td>
</tr>
<tr>
<td>□ B</td>
<td>←→</td>
</tr>
<tr>
<td>□ C</td>
<td>←→</td>
</tr>
<tr>
<td>□ D</td>
<td>←→</td>
</tr>
</tbody>
</table>

(b) The truck has to provide a force of 4000 N to the left on the car to keep the car at a constant velocity.

Complete the sentence by putting a cross (☒) in the box next to your answer.
The resultant force on the car is

   | (1) | (1) |
   | A 0 N | 4000 N to the left |
   | 4000 N to the right |
   | 8000 N to the left |

(c) Both vehicles are travelling at 13 m/s.

The driver of the truck then accelerates at 1.2 m/s$^2$ until both vehicles are travelling at 20 m/s.

(i) Calculate the time taken for this acceleration.

\[ \text{time} = \text{........................................................... s} \]

(ii) The mass of the car is 1400 kg.
Calculate the resultant force on the car needed to produce an acceleration of 1.2 m/s$^2$.

\[ \text{force} = \text{........................................................... N} \]

(iii) A rope can withstand a tension of 12 000 N before it breaks. The weight of the car is 14 000 N.
Discuss whether this rope could be strong enough to tow the car with the truck.

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(Total for Question = 10 marks)
Examiner's Report

Q1.

(i) Most candidates successfully read the intercept of the line with the y-axis to give the starting height of 2.5m.

(ii) Most candidates successfully read the intercept on the x-axis to give the time taken for the ball to reach the ground as 0.7s.

(iii) Most responses included a curved line replicating the shape of the original. Several responses showed a vertical line with a peak at 1.9m, for which one mark was awarded ('no time at all') does not fall into the category of taking less time than 0.7s for the third marking point). Some responses showed the ball travelling back in time with a line going back towards the Y axis. Most responses gained at least two marks and the failure to gain three marks was often down to drawing a straight line which was otherwise correct.

Results Plus: Examiner Comments
All three marking points are clear in this answer. The graph line peaks at 1.9m, takes less than 0.7s from the bounce and shows a correct curve.

(iv) Many candidates noted loss of energy 'in the bounce' which clearly meant 'in the collision'. Very few candidates adopted the air resistance route although a number correctly discussed the loss as sound/heat.
A number of responses showed lack of subject understanding by referring to there being more gravity pulling the ball down after the bounce, or implying that the man had thrown the ball to the ground (additional force) rather than just dropping it.

Results Plus: Examiner Comments
This answer has the idea of the ball losing energy when it hits the ground. In addition the energy loss appears as heat and sound. 2 marks were awarded.
Q2.

(a)
In this energy transfer question examiners were looking for three ideas:

- a transfer between GPE and kinetic as Andrew descends
- a transfer between KE and thermal during the decent
- what happens to the energy when he has stopped.

Most candidates failed to score. About a third of candidates scored 1 mark or better with only a very few scoring full marks.

(b)(i)–(ii)
These were straightforward questions involving the use of equations. The vast majority of candidates scored full marks.

(b)(iii)
This question tested the idea that force is proportional to rate of change of momentum. It proved to be a good discriminator. The idea did not have to be formally stated. The following examples show some ways in which full marks could be scored.

Describe the energy changes that happen between starting and stopping.

When he starts sliding, the potential energy that he had at the top of the hill would be released as kinetic energy as he moved. As his skis rub against the ground, this will cause friction and may release some heat energy, but most of the energy is kinetic. However, when he stops, his kinetic energy will be transferred into heat energy of his skis rubbing against the ground. Also,
(iii) Andrew is not injured by the fall even though he was moving quickly.

Use ideas about force and momentum to explain why he is not injured.

The force was not great enough to injure him because the time it took him to reduce his momentum, increasing the time it takes to reduce his momentum, will decrease the force experienced on him.

(Total for Question 2 = 9 marks)

Results Plus: Examiner Comments
This is a perfectly acceptable way of relating force to the time it takes to reduce the momentum. It scored full marks.

(iii) Andrew is not injured by the fall even though he was moving quickly.

Use ideas about force and momentum to explain why he is not injured.

It took a long time for him to stop. The rate of change of momentum was not that high so the force on him was not that much.

(Total for Question 2 = 9 marks)

Results Plus: Examiner Comments
This is closer to the formal statement of Newton’s second law. It also scored full marks.

(iii) Andrew is not injured by the fall even though he was moving quickly.

Use ideas about force and momentum to explain why he is not injured.

The greater the force is the greater the force is. His momentum changes slowly because he slides across the snow rather than trailing suddenly, this reduces the amount of force exerted upon him so he is not injured.

(Total for Question 2 = 9 marks)

Results Plus: Examiner Comments
This is a very good, well expressed response, which scored full marks.
**Results Plus: Examiner Tip**

In a situation like this, write down the relevant equation:

\[ \text{force} = \frac{\text{change in momentum}}{\text{time}} \]

then use it to construct your written answer.

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Q3.

No Examiner's Report available for this question

Q4.

(i)

A large majority correctly identified force as a vector quantity.

(iii)

Most candidates drew an upward-pointing arrow to correctly represent the thrust for 1 mark.

The second mark was frequently missed by either incorrectly calculating the size (answers of 1.3 were often seen) or by mistaking the thrust for the resultant force of 0.5N.

Q5.

(c) (i)

This was another question where candidates had to transpose an equation. Similar comments apply regarding the showing of working. This time, however, the units were straightforward and fully correct answers were more frequent.

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(c) Both vehicles are travelling at 13 m/s.

The driver of the truck then accelerates at 1.2 m/s\(^2\) until both vehicles are travelling at 20 m/s.

(i) Calculate the time taken for this acceleration.

\[
S = \frac{D}{t} \quad \text{and} \quad v = u + at
\]

\[
20 - 13 \quad 1.2
\]

time = \(5.8\) s
This is a correct answer, gaining 3 marks.

One mark was awarded for method.

(c) (ii)

Calculation of force was generally correctly done but there were many candidates who squared the given value of acceleration during their evaluation.

(c) (iii)

Up to this point, the question had been about the horizontal forces involved in towing the car. It was therefore a pity that so many of even the better candidates, focused on the (vertical) force of weight. It would seem that the difference between gravitational effect of mass and inertia was poorly understood. A few responses did consider how the tension might depend upon the acceleration of the truck and/or whether the truck and car were going up a hill, but the large majority of candidates simply wrote that the weight of the car is greater than 12 00N and so the rope would snap. A few seemed to intuitively know that tow ropes do not need to be strong enough to support the entire weight of a car but struggled to express themselves. It was common to read that the truck would ‘take all of the weight’ and so relieve the tension in the rope.
A rope can withstand a tension of 12000 N before it breaks. The weight of the car is 14000 N.

Discuss whether this rope could be strong enough to tow the car with the truck.

Yes. This is because the rope is not holding the entire weight of the car and so the force on the rope would be much less than 12000 N and most likely less than 12000 N.

Results Plus: Examiner Comments
The candidate has clearly understood the direction of the forces involved. This type of response was quite rare. It scored 2 marks.

It all depends on how the driver of the truck drives, but if it's towing the car and not lifting it, the rope should be strong enough to tow the car with as the force on the car would be the mass x acceleration as long as the acceleration stays low, it should be safe.

Results Plus: Examiner Comments
This answer also makes the point that the rope would be strong enough if the acceleration was kept small.

Mark Scheme

Q1.

<table>
<thead>
<tr>
<th></th>
<th>Answer</th>
<th>Acceptable answers</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
<td>2.5 (m)</td>
<td>Allow answers between (and including) 2.45 &amp; 2.55</td>
<td>(1)</td>
</tr>
<tr>
<td>(ii)</td>
<td>0.7 (s)</td>
<td>Allow answers</td>
<td>(1)</td>
</tr>
</tbody>
</table>
### Question 2

<table>
<thead>
<tr>
<th>Answer</th>
<th>Acceptable answers</th>
<th>Mark</th>
</tr>
</thead>
</table>
| (a)    | Description including 3 of the following:  
- (Gravitational) potential energy (transferred) to KE(1)  
- Idea of energy transfer to heat/sound whilst descending (1)  
- Chemical energy is transferred to heat energy in Andrew (1)  
- Idea of energy dissipated on stopping (1)  

(G)PE (transferred) to KE Allow gravitational energy for GPE  
Energy transferred to heat because of air resistance/ friction  
The energy goes to heat as he stops. Energy is transferred to the surroundings | (3) |
| (b)(i) | substitution (1)  
$67 \times 31$ evaluation (1)  
$2077 \text{ (kg m/s)}$ | 2080, 2100 working backwards using 2000  
$v= 29.85, 30$  
$m= 64.52, 65$  
$67 \times 31=2000$ scores only one mark | (2) |
| (b)(ii) | substitution (1)  
$2000 \div 2.3$ evaluation (1)  
$870 \text{ (N)}$ | answer to (b)(i)) $\div 2.3 = 903$, $869.6$, $869.5$ | (2) |
| (b)(iii) | an explanation linking two of the following  
- Force on Andrew is quite small (1)  
- Force is reduced/ less /not as strong slows down/changes momentum gradually  
acceleration $= 1.35 ^{\circ} \text{g}$ or $13.5 \text{ m/s}^2$ slows | (2) |
Because impact time is long (1)  
The acceleration/deceleration is quite small (1)  
Because impact distance is far (1)  
down (rate of) change of momentum scores 2 marks

<table>
<thead>
<tr>
<th>Question number</th>
<th>Answer</th>
<th>Additional guidance</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I)</td>
<td>An explanation that combines identification - knowledge (1 mark) and reasoning/justification - understanding (1 mark):</td>
<td></td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>• unbalanced / resultant force (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• (provided by) tension in the string / (weight of) metal disc (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ii)</td>
<td>substitution into speed = d/t (1)</td>
<td>full marks will be awarded for correct numerical answer without working</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>1.15 = d / 0.04 (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>evaluation (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>d = 0.046m</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>= 4.6 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(iii)</td>
<td>using $V^2 - u^2 = 2ax$</td>
<td>allow 1.3225 allow solving $V^2 - u^2 = 2ax$ for a</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>$V^2 = 1.15^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>= 1.3225 (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$2 \times a \times x = 2 \times 1.2 \times 0.55$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>= 1.32 (1)</td>
<td></td>
<td></td>
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</tbody>
</table>

Total question = 8 marks
### Q4.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Answer</th>
<th>Acceptable answers</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
<td>force (1)</td>
<td>If than one word given then 0 marks.</td>
<td>(1)</td>
</tr>
<tr>
<td>(ii)</td>
<td>B 0.07kg</td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>(iii)</td>
<td>Arrow pointing (vertically) upwards (1)</td>
<td>Marks are independent of each other</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>Value of 1.2 (N) (written near to arrow) (1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Q5.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Answer</th>
<th>Acceptable answers</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>B ← , B →</td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>(b)</td>
<td>A − 0 N</td>
<td></td>
<td>(1)</td>
</tr>
</tbody>
</table>
| (c)(i)          | Substitution (1)  
1.2 = (20 − 13) / t  
Transposition (1)  
t = (20-13)/1.2  
Evaluation  
5.8 (s) (1)  
substitution and transposition can be in either order | 1.2 = 7 / t  
t = 7/1.2  
5.833 (etc)  
Give full marks for correct answer, no working | (3)  |
| (c)(ii)         | Substitution  
1400 × 1.2 (1)  
Evaluation  
1700 (N) (1)     | 1680  
Allow full marks for correct answer with no working shown | (2)  |
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Answer</th>
<th>Acceptable answers</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c) (iii)</td>
<td>An discussion to include three of the following points</td>
<td>forces are horizontal not vertical / only needs to overcome friction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The tow rope does not have to support the weight of the car (1)</td>
<td>Force is needed to accelerate / resultant force is 0 at constant velocity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tension is caused by accelerating force (plus frictional forces) (1)</td>
<td>Force to accelerate is 1700N</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tension is 5700 N (in this situation) (1)</td>
<td>Forces could be kept small</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forces could be kept below 12,000N (1)</td>
<td>If truck is driven gently/slowly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If acceleration is kept small (1)</td>
<td></td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td>Numerical justification using ( f = m \times a ) (1)</td>
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</tbody>
</table>

(Total for Question = 10 marks)