The stopping distance of a car is the sum of the thinking distance and the braking distance.

The table below shows how the thinking distance and braking distance vary with speed.

<table>
<thead>
<tr>
<th>Speed in m/s</th>
<th>Thinking distance in m</th>
<th>Braking distance in m</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>6</td>
<td>6.0</td>
</tr>
<tr>
<td>15</td>
<td>9</td>
<td>13.5</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
<td>24.0</td>
</tr>
<tr>
<td>25</td>
<td>15</td>
<td>37.5</td>
</tr>
<tr>
<td>30</td>
<td>18</td>
<td>54.0</td>
</tr>
</tbody>
</table>

(a) What is meant by the braking distance of a vehicle?

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(c) A student looks at the data in the table above and writes the following:

\[
\text{thinking distance } \propto \text{ speed}
\]

\[
\text{thinking distance } \propto \text{ speed}
\]

Explain whether the student is correct.

............................................................................................................................
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(2)

(d) Applying the brakes with too much force can cause a car to skid.

The distance a car skids before stopping depends on the friction between the road surface and the car tyres and also the speed of the car.

Friction can be investigated by pulling a device called a 'sled' across a surface at constant speed.

The figure below shows a sled being pulled correctly and incorrectly across a surface.

The constant of friction for the surface is calculated from the value of the force pulling the sled and the weight of the sled.

![Diagram of sleds being pulled correctly and incorrectly]

Why is it important that the sled is pulled at a constant speed?

Tick one box.

If the sled accelerates it will be difficult to control.  

If the sled accelerates the value for the constant of friction will be wrong.  

If the sled accelerates the normal contact force will change.  

(1)
(e) If the sled is pulled at an angle to the surface the value calculated for the constant of friction would not be appropriate.

Explain why.

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(2)

(f) By measuring the length of the skid marks, an accident investigator determines that the distance a car travelled between the brakes being applied and stopping was 22 m.

The investigator used a sled to determine the friction. The investigator then calculated that the car decelerated at 7.2 m / s$^2$.

Calculate the speed of the car just before the brakes were applied.

Give your answer to two significant figures.

Use the correct equation from the Physics Equation Sheet.

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Speed = ................................................... m / s

(3)

(Total 11 marks)
Figure 1 shows a golfer using a runway for testing how far a golf ball travels on grass. One end of the runway is placed on the grass surface. The other end of the runway is lifted up and a golf ball is put at the top. The golf ball goes down the runway and along the grass surface.

Figure 1

(a) A test was done three times with the same golf ball. The results are shown in Figure 2.

Figure 2

(i) Make measurements on Figure 2 to complete Table 1.

Table 1

<table>
<thead>
<tr>
<th>Test</th>
<th>Distance measured in centimetres</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.5</td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
(ii) Calculate the mean distance, in centimetres, between the ball and the edge of the runway in Figure 2.

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

Mean distance = ........................................ cm

(1)

(iii) Figure 2 is drawn to scale.
Scale: 1 cm = 20 cm on the grass.

Calculate the mean distance, in centimetres, the golf ball travels on the grass surface.

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

Mean distance on the grass surface = ......................... cm

(1)

(iv) The distance the ball travels along the grass surface is used to estimate the ‘speed’ of the grass surface.

The words used to describe the ‘speed’ of a grass surface are given in Table 2.

Table 2

<table>
<thead>
<tr>
<th>‘Speed’ of grass surface</th>
<th>Mean distance the golf ball travels in centimetres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast</td>
<td>250</td>
</tr>
<tr>
<td>Medium fast</td>
<td>220</td>
</tr>
<tr>
<td>Medium</td>
<td>190</td>
</tr>
<tr>
<td>Medium Slow</td>
<td>160</td>
</tr>
<tr>
<td>Slow</td>
<td>130</td>
</tr>
</tbody>
</table>

Use Table 2 and your answer in part (iii) to describe the ‘speed’ of the grass surface.

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(1)
(b) The shorter the grass, the greater the distance the golf ball will travel. A student uses the runway on the grass in her local park to measure the distance the golf ball travels.

(i) Suggest two variables the student should control.

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(ii) She carried out the test five times. Her measurements, in centimetres, are shown below.

| 75 | 95 | 84 | 74 | 79 |

What can she conclude about the length of the grass in the park?

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

(c) Another student suggests that the ‘speed’ of a grass surface depends on factors other than grass length.

She wants to test the hypothesis that ‘speed’ depends on relative humidity.

Relative humidity is the percentage of water in the air compared to the maximum amount of water the air can hold. Relative humidity can have values between 1% and 100%.

The student obtains the data in Table 3 from the Internet.

Table 3

<table>
<thead>
<tr>
<th>Relative humidity expressed as a percentage</th>
<th>Mean distance the golf ball travels in centimetres</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td>180</td>
</tr>
<tr>
<td>79</td>
<td>162</td>
</tr>
<tr>
<td>87</td>
<td>147</td>
</tr>
</tbody>
</table>

(i) Describe the pattern shown in Table 3.

................................................................................................................
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(1)
(ii) The student writes the following hypothesis:
'The mean distance the golf ball travels is inversely proportional to relative humidity.'

Use calculations to test this hypothesis and state your conclusion.

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(3)

(iii) The data in Table 3 does not allow a conclusion to be made with confidence.

Give a reason why.

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(1)

(d) In a test, a golf ball hits a flag pole on the golf course and travels back towards the edge of the runway as shown in Figure 3.

Figure 3

The distance the ball travels and the displacement of the ball are not the same.

What is the difference between distance and displacement?

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(2)

(Total 15 marks)
The diagram shows a car at position X.

The handbrake is released and the car rolls down the slope to Y. The car continues to roll along a horizontal surface before stopping at Z. The brakes have not been used during this time.

(i) What type of energy does the car have at X?

................................................................................................................
(1)

(ii) What type of energy does the car have at Y?

................................................................................................................
(1)

(b) The graph shows how the velocity of the car changes with time between Y and Z.

(i) Which feature of the graph represents the negative acceleration between Y and Z?

................................................................................................................
(1)

(ii) Which feature of the graph represents the distance travelled between Y and Z?

................................................................................................................
(1)
(iii) The car starts again at position X and rolls down the slope as before. This time the brakes are applied lightly at Y until the car stops.

Draw on the graph another straight line to show the motion of the car between Y and Z.

(c) Three students carry out an investigation. The students put trolley D at position P on a slope. They release the trolley. The trolley rolls down the slope and along the floor as shown in the diagram.

The students measure the distance from R at the bottom of the slope to S where the trolley stops. They also measure the time taken for the trolley to travel the distance RS. They repeat the investigation with another trolley, E.

Their results are shown in the table.

<table>
<thead>
<tr>
<th>Trolley</th>
<th>Distance RS in centimetres</th>
<th>Time taken in seconds</th>
<th>Average velocity in centimetres per second</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>65</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>80</td>
<td>2.6</td>
<td></td>
</tr>
</tbody>
</table>

(i) Calculate the average velocity, in centimetres per second, between R and S for trolleys D and E. Write your answers in the table.

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(3)
(ii) Before the investigation, each student made a prediction.

- Student 1 predicted that the two trolleys would travel the same distance.
- Student 2 predicted that the average velocity of the two trolleys would be the same.
- Student 3 predicted that the negative acceleration of the two trolleys would be the same.

Is each prediction correct?

Justify your answers.

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(3) (Total 12 marks)

(a) The diagram shows two forces acting on an object.

![Diagram showing two forces: 2N to the left and 6N to the right]

What is the resultant force acting on the object?

Tick (✓) one box.

- 8 N to the right
- 8 N to the left
- 4 N to the right
- 4 N to the left

(1)
(b) BASE jumpers jump from very high buildings and mountains for sport.

The diagram shows the forces acting on a BASE jumper in flight. The BASE jumper is wearing a wingsuit.

(i) Draw a ring around the correct answer in the box to complete each sentence.

The BASE jumper accelerates forwards when force A is ________ to force B.

The BASE jumper falls with a constant speed when force C is ________ to force D.
(ii) To land safely the BASE jumper opens a parachute.

What effect does opening the parachute have on the speed of the falling BASE jumper?

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

Give a reason for your answer.

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

(2)
(Total 5 marks)
(a) The diagrams, A, B and C, show the horizontal forces acting on a moving car.

Draw a line to link each diagram to the description of the car’s motion at the moment when the forces act.

Draw only three lines.

- **A** (500 N to 500 N)
  - Link to stationary

- **B** (200 N to 500 N)
  - Link to constant speed

- **C** (500 N to 200 N)
  - Link to slowing down

(b) The front crumple zone of a car is tested at a road traffic laboratory. This is done by using a remote control device to drive the car into a strong barrier. Electronic sensors are attached to a dummy inside the car.

(i) Draw an arrow in **Box 1** to show the direction of the force that the car exerts on the barrier.

(ii) Draw an arrow in **Box 2** to show the direction of the force that the barrier exerts on the car.
(iii) Complete the following by drawing a ring around the correct line in the box.

The car exerts a force of 5000 N on the barrier. The barrier does not move. The force exerted by the barrier on the car will be

- more than
- equal to
- less than 5000 N.

(iv) Which one of the following gives the most likely reason for attaching electronic sensors to the dummy?

Put a tick (✓) in the box next to your answer.

- To measure the speed of the car just before the impact.  
- To measure the forces exerted on the dummy during the impact.  
- To measure the distance the car travels during the impact.

(Total 7 marks)

The diagram shows the horizontal forces acting on a car travelling along a straight road.

(a) Complete the following sentences by drawing a ring around the correct word in each box.

(i) When the driving force equals the drag force, the speed of the car is

- decreasing
- constant
- increasing

(1)
(ii) Putting the brakes on transforms the car’s kinetic energy mainly into

- heat
- light
- sound

(1)

(b) The charts, A, B and C give the thinking distance and the braking distance for a car driven under different conditions.

(i) Draw straight lines to match each chart to the correct conditions.

Draw only three lines.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Charts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed = 22 m/s, driver wide awake</td>
<td>A</td>
</tr>
<tr>
<td>Speed = 13 m/s, driver wide awake</td>
<td>B</td>
</tr>
<tr>
<td>Speed = 13 m/s, driver very tired</td>
<td>C</td>
</tr>
</tbody>
</table>

Key

- Thinking distance
- Braking distance

(2)

(ii) The three charts above all apply to dry road conditions.

How would the braking distances be different if the road were wet?

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

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(1) (Total 5 marks)
Mark schemes

(a) the distance travelled under the braking force 
1

(b) the reaction time will increase
1
increasing the thinking distance (and so increasing stopping distance)
(increases stopping distance is insufficient)
1

(c) No, because although when the speed increases the thinking distance increases by the same factor the braking distance does not.
1

e.g.
increasing from 10 m / s to 20 m / s increases thinking distance from 6 m to 12 m but the braking distance increases from 6 m to 24 m
1

(d) If the sled accelerates the value for the constant of friction will be wrong.
1

(e) only a (the horizontal) component of the force would be pulling the sled forward
1
the vertical component of the force (effectively) lifts the sled reducing the force of the surface on the sled
1

(f) $- u^2 = 2 \times -7.2 \times 22$
award this mark even with $0^2$ and / or the negative sign missing
1

u = 17.7(99)
1

18
allow 18 with no working shown for 3 marks
allow 17.7(99) then incorrectly rounded to 17 for 2 marks

(a) (i) 9.5
accept ±1 mm
1

(ii) 9.5
ee cf from (a)(i)
1
(iii) 190
\[ 20 \times \text{(a)(ii) ecf} \]

(iv) medium
\[ \text{ecf from (a)(iii)} \]

(b) (i) any two from:

- position of ball before release
- same angle or height of runway
- same ball
- same strip of grass

(ii) long
or
longer than in part (a)
or
uneven

do not allow reference to speed

(c) (i) as humidity increases mean distance decreases

accept speed for distance

(ii) \[ 71 \times 180 = 12780 \]
\[ 79 \times 162 = 12798 \]
\[ 87 \times 147 = 12789 \]

all three calculations correct with a valid conclusion gains 3 marks

or

find k from \( R = \frac{k}{d} \)

all three calculations correct gains 2 marks

or

\[ 87 / 71 \times 147 = 180.1 \sim 180 \]
\[ 87 / 79 \times 147 = 161.9 \sim 162 \]

two calculations correct with a valid conclusion gains 2 marks

conclusion based on calculation

one correct calculation of k gains 1 mark

(iii) only three readings or small range for humidity

accept not enough readings

accept data from Internet could be unreliable

ignore reference to repeats
(d) distance is a scalar or has no direction or has magnitude only

*allow measurements from diagram of distance and displacement*

displacement is a vector or has direction

---

(a) (i) gravitational potential (energy)

(ii) kinetic (energy)

(b) (i) slope or gradient

(ii) area (under graph)

*do not accept region*

(iii) starts at same y−intercept

steeper slope than original and cuts time axis before original

*the entire line must be below the given line*

*allow curve*

---

(c) (i) and

31

*correct answers to 2 significant figures gains 3 marks even if no working shown*

*both values to more than 2 significant figures gains 2 marks:*

30.952……

30.769….

65 / 2.1 and / or

80 / 2.6 gains 1 mark

*if incorrect answers given but if both are to 2 significant figures allow 1 mark*

(ii) student 1 incorrect because 80 ≠ 65

student 2 correct because average velocities similar

*ecf from (c)(i)*

student 3 incorrect because times are different

---
(a) 4 N to the right

(b) (i) bigger than
equal to
(ii) reduces it

increases air resistance / drag / force C
accept parachute has large(r) (surface) area

(b) (i) horizontal arrow to the right
judge by eye
accept an arrow drawn outside the box if it is labelled correctly

5 (a) 3 lines drawn
all correct
allow 1 mark for each correct line
if two or more lines are drawn from any diagram then all these lines are incorrect

stationary
constant speed
slowing down
accelerating forwards
(ii) horizontal arrow to the left

judge by eye

accept an arrow drawn outside the box if it is labelled correctly

(iii) equal to

(iv) to measure the forces exerted on the dummy during the impact

(a) (i) constant

1

(ii) heat

1

(b) (i) 3 links correct

allow 1 mark for 1 correct link
if more than one line is drawn from a condition mark all lines from that condition incorrect

2

(ii) increased

1