

Stopping Distances

Mark Scheme



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1. Whether it is a skydiver in freefall or a car braking at a junction, acceleration is the fundamental measure of how an object's velocity changes.

- a) A driver is travelling along a road when they suddenly see a hazard. They hit the brake pedal, and the car comes to a stop.

Which factor below will **only** increase the thinking distance of the driver?

A – is the only correct answer.	1 mark
	Total: 1 mark

- b) When a car brakes sharply, kinetic energy is transferred into another store of energy, causing the temperature of the brakes to increase. Which energy store is the kinetic energy transferred into?

D – is the only correct answer.	1 mark
	Total: 1 mark

- c) A car is travelling at 20 m/s. Its braking distance is 24 m.

If the car doubles its speed to 40 m/s, what will its new braking distance be?

D – is the only correct answer.	1 mark
	Total: 1 mark

- d) A student drops a ruler between another student's fingers to test their reaction time. The figure below shows the drop. Why is a ruler drop test a valid way to measure reaction time?

B – is the only correct answer.	1 mark
	Total: 1 mark

- e) A train driver receives an automated signal to stop at the next station.

Which statement about the shaded areas under the graph is correct?

C – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 5 marks)

2. A car manufacturer is testing the brakes on a new vehicle.

The car has a mass of 1400 kg.

During the test, the car is travelling at a steady velocity of 20 m/s. The driver presses the brake pedal, and the car comes to a complete stop over a braking distance of 35 m.

- a) Calculate the kinetic energy of the car just before the driver presses the brakes.

$E = \frac{1}{2} (\text{mass}) \times \text{velocity squared}$	1 mark
$E = \frac{1}{2} (1400) \times 20^2$	1 mark
$E = 280,000 \text{ J}$	1 mark
	Total: 3 marks

- b) State the amount of work done by the brakes to bring the car to a stop.

$E = 280,000 \text{ J}$	1 mark
	Total: 1 mark

- c) Use your answer to part (b) to calculate the average braking force exerted by the brakes.

Work done = force $\times$ distance	1 mark
$280,000 = \text{force} \times 35$	1 mark
$\text{force} = 280,000 \div 35$ $\text{force} = 8000 \text{ N}$	1 mark
	Total: 3 marks

- d) State the equation that links acceleration, mass and resultant force.

$\text{force} = \text{mass} \times \text{acceleration}$ Allow any correct version of this equation.	1 mark
	Total: 1 mark

- e) Calculate the deceleration of the car as it brakes.

$8000 = 1400 \times a$	1 mark
$a = 8000 \div 1400$	
$a = 5.71 \text{ m/s}^2$	1 mark
	Total: 2 marks

- f) Explain, using calculations if you wish, why doubling the speed of the car to 40 m/s would cause the braking distance to increase by a factor of four.

An explanation to include the following:	
Kinetic energy is proportional to velocity squared (v^2). Therefore, doubling the velocity quadruples (2^2) the kinetic energy.	1 mark
Because work done = force $\times$ distance, four times as much energy requires four times as much work, which takes four times the braking distance (if the braking force is constant). Allow 1 mark for linking the quadrupled the kinetic energy to needing four times the work done/distance to stop. Marking note: allow both marks for the correct calculation showing the braking distance increasing by a factor of 4.	1 mark
	Total: 2 marks

(Total for Question 2 is 12 marks)

3. A passenger jet touches down on a runway.



At the exact moment it touches down, the jet has 196,000 kJ of kinetic energy.
The jet has a mass of 80,000 kg.

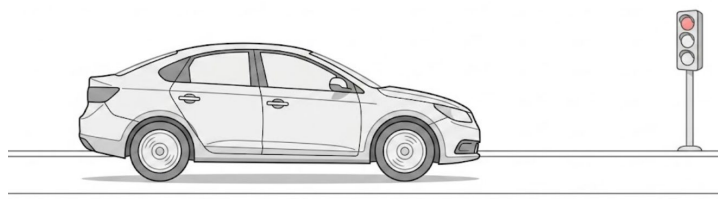
The thrust reversers and the wheel brakes apply a combined braking force of 250,000 N until the jet comes to a complete stop.

Calculate the total distance the jet travels along the runway before it stops.
You must show all of your working.

Convert kJ to J: $E_k = 196,000 \times 1000 = 196,000,000 \text{ J}$	1 mark
Realising that this kinetic energy is equal to the work done. Calculate distance (s)	1 mark
$\text{Work done} = \text{force} \times \text{distance}$ $W = F \times s$	1 mark
$\text{Distance} = 196,000,000 \div 250,000$	1 mark
$\text{Distance} = 784 \text{ m}$	2 marks
Marking note: allow full marks for an alternative method that gets the correct answer. Award no marks if working is not shown as the question stated working must be shown.	
	Total: 6 marks

(Total for Question 3 is 6 marks)

4. A driver is travelling along a straight road. They see a traffic light turn red ahead of them.



The car has a mass of 1200 kg and is travelling at a velocity of 15 m/s.

- a) Calculate the kinetic energy of the car before the driver presses the brakes.

$E = \frac{1}{2} (\text{mass}) \times \text{velocity squared}$	1 mark
$E = \frac{1}{2} (1200) \times 15^2$	1 mark
$E = 135,000 \text{ J}$	1 mark
	Total: 3 marks

- b) The driver presses the brake pedal. The brakes apply a force of 6000 N to stop the car.
Assuming that all of the kinetic energy is transferred to the brakes, calculate the braking distance of the car.

Work done = force $\times$ distance	1 mark
$135,000 = 6000 \times \text{distance}$	1 mark
distance = $135,000 \div 6000$ distance = 22.5 m	1 mark
	Total: 3 marks

- c) State the energy transfer that takes place as the brakes are applied.

Kinetic energy (of the car) is transferred to thermal / internal / heat energy (in the brakes). Accept "kinetic energy to heat/thermal energy".	1 mark
	Total: 1 mark

d) Explain the factors that can cause the **thinking distance** of a driver to **increase**.

An explanation to include the following:	
Thinking distance increases if reaction time increases: • The driver is tired / fatigued. • The driver is under the influence of alcohol or drugs. • The driver is distracted (for example by a mobile phone etc). Allow other valid biological factors that increase reaction time, such as: • The driver is elderly/older. • The driver is unwell / has a medical condition.	3 marks
Thinking distance increases if speed increases: • Travelling at a higher speed (means the car covers more distance during the same reaction time). Marking note: Do NOT accept factors relating to braking distance, e.g., wet roads, worn tyres, mass of car, or poor brakes. These score zero).	1 mark
	Total: 4 marks

(Total for Question 4 is 11 marks)

5. The total stopping distance of a vehicle is made up of the thinking distance and the braking distance.

Explain the factors that can cause the **braking distance** of a car to **increase**.

You should explain how each factor physically affects the braking of the car.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	The student correctly identifies at least one or two factors affecting braking distance (for example "wet roads", "bald tyres"), but offers no explanation as to why.
Level 2	3 - 4	The student identifies several correct factors but explanations may be lacking in detail or physical terminology (for example just saying "it takes longer to stop"). May include minor irrelevant points (mentioning one reaction time factor).
Level 3	5 - 6	The student identifies multiple correct factors affecting braking distance and provides a clear physical explanation for how each factor increases the distance (referencing friction, kinetic energy, or mass).

Indicative content:	
Factor: <u>road conditions – wet or icy roads</u>. Explanation: Water or ice reduces the friction between the tyres and the road surface, meaning less braking force can be applied before the car skids, increasing the distance required to stop. Factor: <u>vehicle condition</u> – this includes worn (bald) tyres or worn brake pads. Explanation: Worn tyres provide less grip, and worn brakes apply less clamping force. Both reduce the total friction force that can be generated by the car to remove kinetic energy. Factor: <u>mass of the vehicle</u> ($F = ma$) Explanation: A larger mass means the car has more kinetic energy at a given speed. Alternatively, because $a = F \div m$, for a maximum constant braking force, a larger mass results in a smaller deceleration. Factor: <u>speed – its kinetic energy</u>, the car is travelling at a higher speed before braking. Explanation: A higher speed means the car has much more kinetic energy. Therefore, the brakes must do more work ($W = Fs$) over a longer distance to bring that energy down to zero.	
	Total: 6 marks

(Total for Question 5 is 6 marks)