

Stopping distances and braking

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Paper 2 | Foundation and Higher

Worked solutions and teaching prompts | 24 shared parts + labelled options

Specification points covered

Stopping, thinking and braking distances: 8463 4.5.6.3.1; 8464 6.5.4.3.1
Reaction time and its measurement: 8463 4.5.6.3.2; 8464 6.5.4.3.2
Road/vehicle conditions and braking: 8463 4.5.6.3.3–4; 8464 6.5.4.3.3–4
Related calculations: speed 8463 4.5.6.1.2 / 8464 6.5.4.1.2; kinetic energy 4.1.1.2 / 6.1.1.2
Options: vehicle stopping graphs 8463 only; braking-force estimates Higher only; work $W = Fd$ 4.5.2 / 6.5.2

A cycle-delivery company reviews stopping tests and reaction-time measurements to improve rider training. All data are supplied for this paper exercise, not instructions to carry out emergency stops on a road.

Choose one pupil pathway. Timing is suggested, not classroom-tested. Shared core: 24 parts/ 45 marks; Higher: 24 / 50; Separate Foundation: 24 / 48; Separate Higher: 26 / 54. Accept equivalent wording and consistent follow-through. Original PhysicsUK practice, not an official AQA paper or mark scheme.

1 Thinking distance on delivery routes

During the reaction time the rider has not yet applied the brakes. Assume the speed stays constant in this interval.

1(a) In a delivery stop, define thinking distance. **[1 mark]**

Answer / mark points: The distance travelled from noticing the stop signal to applying the brakes, during the rider's reaction time. [1]

1(b) The rider has now applied the brakes. Define braking distance. **[1 mark]**

Answer / mark points: The distance travelled from applying the brakes until the cycle comes to rest. [1]

Teacher prompt: A distance is measured in metres, not seconds. Do not include the reaction interval.

1(c) The cycle travels at 6.0 m s^{-1} and the reaction time is 0.50 s . Calculate the thinking distance. **[1 mark]**

Answer / mark points: Thinking distance = $6.0 \times 0.50 = 3.0 \text{ m}$. [1]



1 Thinking distance on delivery routes continued

1(d) At 6.0 m s^{-1} , tiredness increases reaction time to 0.80 s . Calculate the new thinking distance. [1 mark]

Answer / mark points: Thinking distance = $6.0 \times 0.80 = 4.8 \text{ m}$. [1]

1(e) On another delivery, speed is 9.0 m s^{-1} and reaction time is 0.50 s . Calculate the thinking distance. [1 mark]

Answer / mark points: Thinking distance = $9.0 \times 0.50 = 4.5 \text{ m}$. [1]

1(f) A rider travels at 4.0 m s^{-1} with reaction time 0.30 s . Calculate the thinking distance. [1 mark]

Answer / mark points: Thinking distance = $4.0 \times 0.30 = 1.2 \text{ m}$. [1]

1(g) A thinking distance of 4.5 m is measured at 6.0 m s^{-1} . Calculate the rider's reaction time. [1 mark]

Answer / mark points: Reaction time = distance / speed = $4.5 / 6.0 = 0.75 \text{ s}$. [1]

1(h) A support van travels at 54 km h^{-1} . Its driver's reaction time is 0.40 s . Calculate its thinking distance. Use $1 \text{ m s}^{-1} = 3.6 \text{ km h}^{-1}$. [2 marks]

Answer / mark points: Speed = $54 / 3.6 = 15 \text{ m s}^{-1}$. [1] Thinking distance = $15 \times 0.40 = 6.0 \text{ m}$. [1]

2 Comparing stopping tests

Table 1 gives braking distances for the same loaded cycle. Reaction time is 0.50 s in every test. The speed shown is the speed when the rider notices the stop signal.

Table 1

Initial speed / m s^{-1}	Dry braking distance / m	Wet braking distance / m
3.0	2.0	4.0
6.0	8.0	16
9.0	18	36

2(a) Use Table 1 to calculate the total stopping distance at 6.0 m s^{-1} on the dry road and on the wet road. [2 marks]

Answer / mark points: Thinking distance = $6.0 \times 0.50 = 3.0 \text{ m}$. Dry stopping distance = $3.0 + 8.0 = 11 \text{ m}$. [1]

Wet stopping distance = $3.0 + 16 = 19 \text{ m}$. [1]



2 Comparing stopping tests continued

2(b) At 6.0 m s^{-1} on the dry road, a distraction increases reaction time from 0.50 s to 0.80 s . Braking distance remains 8.0 m . Calculate the new stopping distance and its increase. **[2 marks]**

Answer / mark points: New thinking distance = $6.0 \times 0.80 = 4.8 \text{ m}$; new stopping distance = $4.8 + 8.0 = 12.8 \text{ m}$. [1]
Increase = $12.8 - 11 = 1.8 \text{ m}$. [1]

Teacher prompt: The distraction increases the reaction time and thinking distance, not the supplied braking distance.

2(c) A rider claims that doubling speed from 3.0 to 6.0 m s^{-1} doubles stopping distance on the dry road. Use Table 1 and thinking distances to explain why the claim is wrong. **[2 marks]**

Answer / mark points: Thinking distance doubles from 1.5 to 3.0 m . [1] Braking distance increases fourfold from 2.0 to 8.0 m , so total stopping distance increases from 3.5 to 11 m , not to 7.0 m . [1]

Teacher prompt: Only thinking distance is proportional to speed when reaction time is fixed. The table supports the stated braking comparison.

2(d) In the 6.0 m s^{-1} tests, explain why the wet road increases braking distance but does not increase thinking distance. **[2 marks]**

Answer / mark points: Wet conditions reduce tyre–road grip, reducing the available braking force and increasing braking distance. [1] Speed and reaction time are unchanged, so thinking distance is unchanged. [1]

2(e) At 6.0 m s^{-1} the stop signal is noticed 15 m before a barrier. Using the 0.50 s reaction time, decide whether the cycle stops before the barrier in each road condition. Give a distance margin or shortfall. **[2 marks]**

Answer / mark points: Dry: 11 m is less than 15 m , so it stops 4.0 m before the barrier. [1] Wet: 19 m exceeds 15 m , so it cannot stop before it; the stopping-distance shortfall is 4.0 m . [1]

Teacher prompt: Do not claim it travels 4 m beyond an actual solid barrier. The calculation identifies insufficient clear distance.

2(f) To investigate only the effect of road surface, state two other variables the company must keep the same between tests. **[2 marks]**

Answer / mark points: Any two: initial speed; total load/mass; tyre condition/type/pressure; brake condition and application; rider and reaction time if comparing total stopping distances. [1 each, max 2]



3 Energy and braking

For this section, the cycle, rider and cargo have total mass 100 kg unless otherwise stated. Each stop begins on level ground.

3(a) Calculate the kinetic energy of the 100 kg cycle and rider at 3.0 m s^{-1} and at 6.0 m s^{-1} . **[2 marks]**

Answer / mark points: At 3.0 m s^{-1} : $E = 0.5 \times 100 \times 3.0^2 = 450 \text{ J}$. [1]
At 6.0 m s^{-1} : $E = 0.5 \times 100 \times 6.0^2 = 1800 \text{ J}$. [1]

3(b) Extra cargo increases total mass from 100 to 140 kg. Speed remains 6.0 m s^{-1} . Calculate the new kinetic energy and the percentage increase from the 1800 J value for the lighter load. **[2 marks]**

Answer / mark points: $E = 0.5 \times 140 \times 6.0^2 = 2520 \text{ J}$. [1] Percentage increase = $(2520 - 1800) / 1800 \times 100 = 40\%$. [1]

Teacher prompt: This is an energy comparison, not proof of a specific braking-distance change without information about braking force.

3(c) The company's brake discs become warmer during a stop. Explain this in terms of frictional work and energy stores. **[2 marks]**

Answer / mark points: The friction force in the brakes does work as the wheel turns, reducing the vehicle's kinetic energy. [1] Energy is transferred to the internal/thermal energy store of the brakes, increasing their temperature. [1]

Teacher prompt: "Friction" alone is not a full explanation. Energy is transferred, not destroyed or created.

3(d) A rider squeezes the brakes extremely hard, producing a large deceleration. Explain two possible dangers. **[2 marks]**

Answer / mark points: Greater frictional work rate can make the brakes overheat during demanding braking. [1] The tyres may lose grip/lock or the cycle may become unstable, causing loss of control. [1]

Teacher prompt: Accept a clear linked danger such as a rider being thrown forward during abrupt deceleration. Do not award two marks for repeats of loss of control.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk



4 Investigating reaction time

A desktop timer switches on a lamp after an unpredictable delay, starts timing at lamp onset, and stops when the rider presses a button. Table 2 gives one rider's results with and without a spoken mental-arithmetic task. The distraction is tested while seated, never while cycling.

Table 2

Trial	Focused reaction time / s	Distracted reaction time / s
1	0.30	0.48
2	0.32	0.50
3	0.28	0.52

4(a) Calculate the mean reaction time for each condition in Table 2. **[2 marks]**

Answer / mark points: Focused mean = $(0.30 + 0.32 + 0.28) / 3 = 0.30$ s. [1]

Distracted mean = $(0.48 + 0.50 + 0.52) / 3 = 0.50$ s. [1]

4(b) Use the two means to calculate the extra thinking distance at 6.0 m s^{-1} during the distraction. You may use 0.30 s and 0.50 s if you did not obtain the means. **[2 marks]**

Answer / mark points: Focused distance = $6.0 \times 0.30 = 1.8$ m; distracted distance = $6.0 \times 0.50 = 3.0$ m. [1]

Extra thinking distance = $3.0 - 1.8 = 1.2$ m. [1]

4(c) State a typical range of human reaction times. Explain whether the 0.50 s distracted mean is an unusual result by itself. **[2 marks]**

Answer / mark points: Typical reaction times are about 0.2–0.9 s. [1] 0.50 s lies in this range, so it is not unusual on this evidence alone. [1]

4(d) Explain why the lamp should switch on after an unpredictable delay, and why the same lamp and button position should be used in both conditions. **[2 marks]**

Answer / mark points: An unpredictable delay prevents the rider anticipating the signal and pressing before reacting to it. [1] Keeping signal and button arrangements the same controls the stimulus/movement required, so distraction is the intended change. [1]

4(e) A manager concludes that every rider's reaction time increases by exactly 0.20 s when distracted. Explain why Table 2 does not establish this conclusion, and suggest an improvement. **[2 marks]**

Answer / mark points: The results are for only one rider and one distraction; people and distractions differ, so this cannot establish an exact universal increase. [1] Test many riders in both conditions, using repeats for each, and compare the paired mean changes/spread. [1]



4 Investigating reaction time continued

4(f) Describe how to use the seated lamp-and-button timer to investigate the effect of distraction on reaction time. Include controlled conditions, reliable measurements and how to analyse the results. Structure your answer: measurement sequence → change one factor → repeats and controls → comparison and safety. **[6 marks]**

Answer / mark points: Model method: Seat a volunteer comfortably with a finger beside the button and the lamp clearly visible. After an unpredictable delay, the apparatus lights the lamp and starts timing automatically; the volunteer presses the button as soon as they see it, stopping the timer. Record the time. Obtain several trials without distraction and several while the volunteer performs the same spoken mental-arithmetic task. Keep the lamp, brightness, button/finger position, instructions and apparatus unchanged. Use the same person for a paired comparison. Vary the waiting delay, give rests and vary the order of conditions to reduce anticipation, fatigue and practice/order effects. Repeat for several volunteers. For each person calculate a mean in each condition and its change; compare the changes and spread before drawing a conclusion. Repeat a trial if the volunteer pressed before the lamp or the apparatus failed, recording the reason; do not discard results just because they are inconvenient. Keep all testing seated and away from roads; never use alcohol or drugs to create an impairment.

Holistic levels: 5–6 marks — coherent, usable paired investigation with correct automatic timing, controlled distraction, repeats and meaningful analysis; 3–4 — mostly workable measurement and comparison with important omissions in control, reliability or analysis; 1–2 — isolated relevant actions without a usable investigation; 0 — no relevant method. Judge overall quality, not six automatic checklist marks.

Teacher prompt: This is a reaction-time investigation, not an AQA required practical. An observer manually starting a stopwatch adds the observer's reaction time. Accept another safe valid arrangement if measurement, control and analysis are explained.



5 Separate Physics only comparing vehicles

Separate Physics only, Foundation and Higher. Figure 1 shows supplied test results for a cycle and a van on a closed test track. Points are joined by straight segments. Read total stopping distance, not braking distance. These particular results are not universal safe stopping distances.

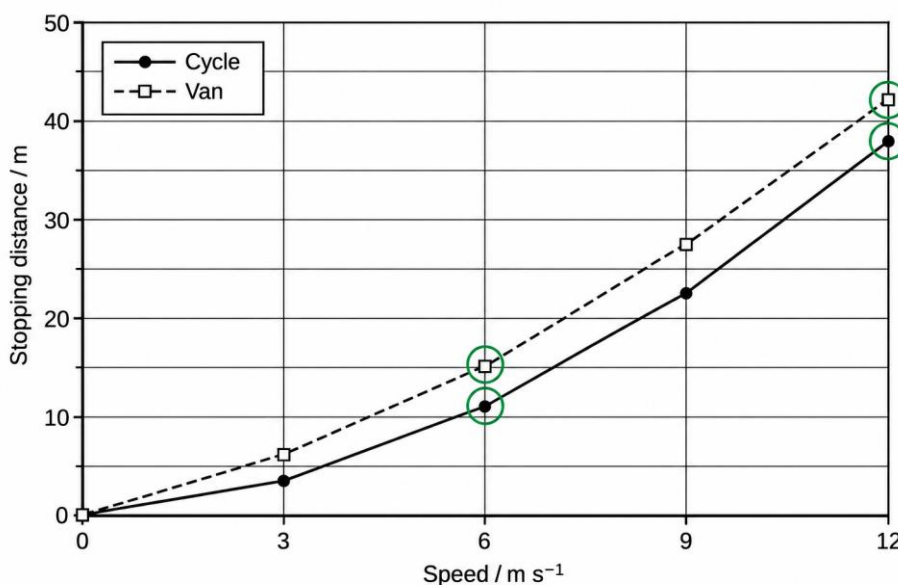


Figure 1

5(a) Separate Physics only. Use Figure 1 to read the stopping distance of the cycle and of the van at 6.0 m s^{-1} . **[2 marks]**

Answer / mark points: Cycle: about 11 m. [1] Van: about 15 m. [1] Accept $\pm 0.5 \text{ m}$ for each graph reading.

5(b) Separate Physics only. At 12 m s^{-1} , read the van's stopping distance and calculate how much greater it is than the cycle's stopping distance. **[2 marks]**

Answer / mark points: Van: about 42 m. [1] Cycle: about 38 m; difference = $42 - 38 = 4.0 \text{ m}$. [1] Accept consistent readings with $\pm 0.5 \text{ m}$ reading tolerance and follow-through.

5(c) Separate Physics only. A rider says the cycle's stopping distance is proportional to speed. Use its 6.0 and 12 m s^{-1} readings to assess this claim. **[2 marks]**

Answer / mark points: Doubling speed from 6.0 to 12 m s^{-1} changes stopping distance from about 11 to 38 m. [1] 38 m is not twice 11 m, so the supplied data do not show proportionality. [1]

5(d) Separate Physics only. Can Figure 1 alone tell you whether the van driver has a longer reaction time than the cyclist? Explain. **[1 mark]**

Answer / mark points: No. Total stopping distance combines thinking and braking distance; the graph does not separate the reaction-time contribution. [1]



6 Higher tier only estimating braking forces

Higher tier only, both routes. A loaded cycle of total mass 100 kg brakes from 6.0 m s^{-1} to rest on level ground over 8.0 m. Ignore air resistance and other energy losses. Use $W = Fd$ and assume the braking work equals the decrease in kinetic energy; F is the average braking-force magnitude.

6(a) Higher tier only. Calculate the average braking-force magnitude for the 8.0 m stop described above. **[2 marks]**

Answer / mark points: Kinetic energy lost = $0.5 \times 100 \times 6.0^2 = 1800 \text{ J}$. [1] $F = W / d = 1800 / 8.0 = 225 \text{ N}$. [1]

Teacher prompt: Use the braking distance 8.0 m, not a thinking distance or total stopping distance.

6(b) Higher tier only. On a wet surface, the same mass stops from 6.0 m s^{-1} over 16 m. Estimate the average braking-force magnitude using the same energy assumptions. **[2 marks]**

Answer / mark points: Energy lost remains 1800 J. $F = W / d$. [1] $F = 1800 / 16 = 112.5 \text{ N}$, about 113 N. [1]

6(c) Higher tier only. The loaded mass is now 140 kg at 6.0 m s^{-1} . Assume the average braking force remains 225 N. Calculate the braking distance and then the total stopping distance for reaction time 0.50 s. **[3 marks]**

Answer / mark points: Energy lost = $0.5 \times 140 \times 6.0^2 = 2520 \text{ J}$. [1] Braking distance = $2520 / 225 = 11.2 \text{ m}$. [1]
Thinking distance = $6.0 \times 0.50 = 3.0 \text{ m}$; total stopping distance = $11.2 + 3.0 = 14.2 \text{ m}$. [1]

Teacher prompt: The fixed average braking force is a stated modelling condition, not a universal rule for heavier vehicles.

6(d) Higher tier only. At 9.0 m s^{-1} , the 100 kg cycle must still brake to rest in 8.0 m. Estimate the required average braking force and compare it with the 225 N value at 6.0 m s^{-1} . **[2 marks]**

Answer / mark points: Energy lost = $0.5 \times 100 \times 9.0^2 = 4050 \text{ J}$; $F = 4050 / 8.0 = 506.25 \text{ N}$, about 506 N. [1]
Force ratio = $506.25 / 225 = 2.25$, so 2.25 times the force is needed at the same braking distance. [1]

Teacher prompt: Do not assume the tyres/brakes can supply this force safely; this is the force required by the model.

Review and improve

Keep reaction time separate from braking time. Thinking distance depends on speed and reaction time; braking distance depends on speed, road/tyre grip and brakes. Friction does work and increases internal energy. Higher force calculations use braking distance only, not total stopping distance.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk

