

Marina Bay Night Race

Simulation: edtechsims.com/marina-bay-night-race

Name: _____ Class: _____ Date: _____



Scan to open

Data

Useful information (take $g = 10 \text{ m/s}^2$)	
speed = distance $\div$ time	velocity = displacement $\div$ time
acceleration = change in velocity $\div$ time	1 m/s = 3.6 km/h

Part A: The Stewards' Inquiry

On the sim: A car broke the pit-lane speed limit. You are a race steward. Clear stations to collect evidence and unlock the Final Verdict, then name the guilty car. Wrong answers cost +15 s and hints cost +30 s.

A1 Record your progress. For each station you clear, note one misconception it warned you about.

Station	Cleared (✓)	Misconception I learned about
Track Map		
Scalar or Vector?		
Speed Trap		
Pit Lane Limit		
Telemetry: s–t		
Throttle & Brake		
Turbo Boost		
Braking Zone		
Rain Check		

A2 Record your final results.

Final time	Wrong answers	Hints used

Part B: Station Practice

The game's numbers change every time. Use these questions to practise the same skills.

B1 Track Map: distance and displacement

(a) A car drives 300 m east, then turns and drives 400 m north. Calculate its distance travelled and its displacement. [3]

distance = ... m displacement = ... m

(b) The car completes one full lap and stops at the start line. What is its displacement? Explain. [1]

.....

.....

B2 Scalar or Vector?

Classify each quantity as a scalar or a vector.

[4]

Quantity	Scalar / Vector	Quantity	Scalar / Vector
Distance		Displacement	
Speed		Velocity	
Acceleration		Time	
Mass		Weight	

B3 Speed Trap: average speed

(a) Two timing gates are 50 m apart. A car takes 2.5 s to pass between them. Calculate its average speed in m/s and in km/h. [2]

speed = ... m/s = ... km/h

(b) Why is a speed calculated from timing gates more accurate than one from a stopwatch held by a steward? [1]

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B4 Pit Lane Limit: unit conversion

Complete Table 1. [3]

Speed in km/h	Speed in m/s	Above 80 km/h limit?
80		
	25	
72		

Table 1

B5 Telemetry: displacement–time graphs

Fig. 1 shows the displacement–time graph of a car in the pit lane.

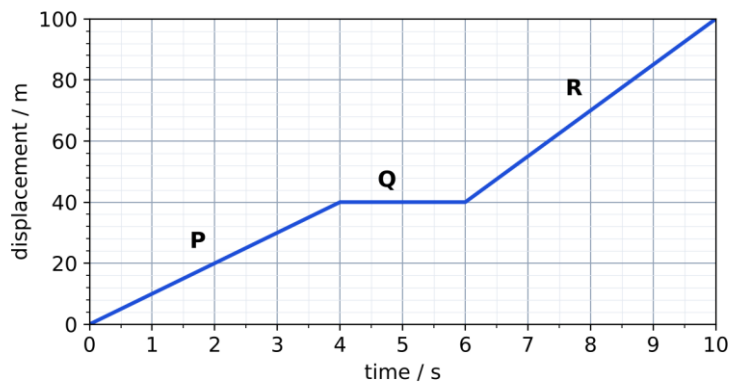


Fig. 1

(a) Calculate the speed of the car in section P and in section R. [2]

P = ... m/s R = ... m/s

(b) Describe the motion in section Q. [1]

.....
.....

(c) Calculate the average speed for the whole 10 s. [1]

average speed = ... m/s

B6 Throttle & Brake: acceleration

- (a) A car accelerates uniformly from rest to 30 m/s in 6.0 s. Calculate its acceleration. [2]

acceleration = ... m/s²

- (b) It then brakes uniformly from 30 m/s to rest in 3.0 s. Calculate its acceleration and explain the sign. [2]

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B7 Turbo Boost: non-uniform acceleration

Fig. 2 shows the velocity–time graph of a car using its turbo boost. A tangent is drawn at point X.

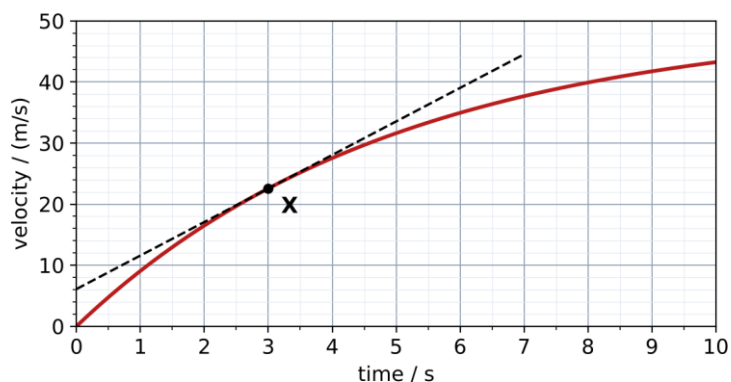


Fig. 2

- (a) Use the tangent to find the acceleration of the car at X ($t = 3$ s). [2]

acceleration = ... m/s²

- (b) Describe how the acceleration of the car changes from 0 s to 10 s. Explain how the graph shows this. [2]

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B8 Braking Zone: area under a v–t graph

A driver travelling at 25 m/s sees a hazard. After a reaction time of 0.80 s, the car decelerates uniformly and stops 5.0 s later. A barrier is 80 m ahead of the point where the driver saw the hazard.

(a) Sketch the v–t graph on Fig. 3.

[2]

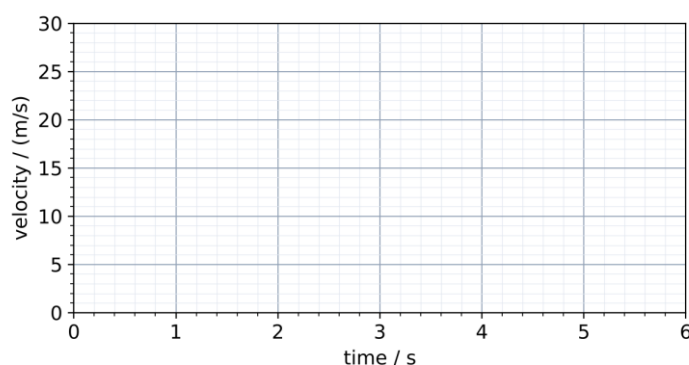


Fig. 3

(b) Calculate the stopping distance. Does the car hit the barrier?

[3]

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B9 Rain Check: free fall and terminal velocity

(a) A raindrop falls from rest. Ignoring air resistance, calculate its velocity after 2.0 s.

[1]

velocity = ... m/s

(b) Number the stages of a falling raindrop with air resistance from 1 to 4.

[2]

Stage	Order
Air resistance equals weight; the drop falls at terminal velocity	
The drop is released; only weight acts, so it accelerates at 10 m/s^2	
Air resistance increases, so the resultant force and acceleration decrease	
As speed increases, air resistance starts to act upwards	

(c) A student says, "A heavy stone falls faster than a light stone in a vacuum." Is the student correct? Explain.

[1]

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Part C: The Final Verdict

Case file: a car's average speed through the 10 s pit-lane timing zone must not be more than 80 km/h. Each car brakes uniformly, then holds a steady speed. The speed gun records Car A's velocity every 2 s:

Time / s	0	2	4	6	8	10
Velocity / (m/s)	30	25	20	20	20	20

Step 1 Plot the v–t graph for Car A on Fig. 4.

[2]

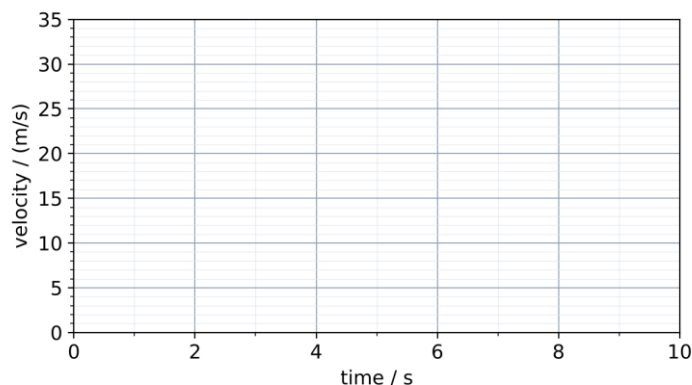


Fig. 4

Step 2 Calculate Car A's acceleration while braking.

[2]

acceleration = ... m/s²

Step 3 Calculate the distance Car A travels in the zone.

[2]

distance = ... m

Step 4 Calculate Car A's average speed in km/h.

[2]

average speed = ... km/h

Step 5 The stewards have found that Car B's average speed was 23.0 m/s and Car C's was 21.5 m/s. Which car is guilty? Show your working.

[2]

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Part D: Practice Questions

D1 A car travels 1.2 km along Raffles Avenue in 1.5 minutes. Calculate its average speed in m/s and km/h. [2]

speed = ... m/s = ... km/h

D2 Explain why a car moving at a constant speed around a bend is accelerating. [2]

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D3 A skydiver jumps from a plane and later opens a parachute. Describe and explain how the skydiver's velocity changes from the moment of jumping until landing. [4]

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.....

.....

Answer Key: Marina Bay Night Race

Data

Useful information (take $g = 10 \text{ m/s}^2$)		
speed = distance $\div$ time	velocity = displacement $\div$ time	acceleration = change in velocity $\div$ time
	1 m/s = 3.6 km/h	

Part A: The Stewards' Inquiry

On the sim: A car broke the pit-lane speed limit. You are a race steward. Clear stations to collect evidence and unlock the Final Verdict, then name the guilty car. Wrong answers cost +15 s and hints cost +30 s.

A1 Record your progress. For each station you clear, note one misconception it warned you about.

Station	Cleared (✓)	Misconception I learned about
Track Map		
Scalar or Vector?		
Speed Trap		
Pit Lane Limit		
Telemetry: s–t		
Throttle & Brake		
Turbo Boost		
Braking Zone		
Rain Check		

Student's own records. Examples: displacement = distance after a full lap; speed is a vector; forgetting to convert km/h to m/s ($\times 3.6$ / $\div 3.6$ mix-up); a flat s–t line means constant speed; deceleration given as a positive value; using a rectangle instead of a trapezium for the area under a v–t graph; heavier objects fall faster.

A2 Record your final results.

Final time	Wrong answers	Hints used

Part B: Station Practice

The game's numbers change every time. Use these questions to practise the same skills.

B1 Track Map: distance and displacement

(a) A car drives 300 m east, then turns and drives 400 m north. Calculate its distance travelled and its displacement. [3]

Distance = $300 + 400 = 700 \text{ m}$. Displacement = $\sqrt{(300^2 + 400^2)} = 500 \text{ m}$, in a north-easterly direction.

- (b) The car completes one full lap and stops at the start line. What is its displacement? Explain. [1]
Zero. It finishes where it started, so its change in position is zero.

B2 Scalar or Vector?

Classify each quantity as a scalar or a vector. [4]

Quantity	Scalar / Vector	Quantity	Scalar / Vector
Distance	Scalar	Displacement	Vector
Speed	Scalar	Velocity	Vector
Acceleration	Vector	Time	Scalar
Mass	Scalar	Weight	Vector

B3 Speed Trap: average speed

- (a) Two timing gates are 50 m apart. A car takes 2.5 s to pass between them. Calculate its average speed in m/s and in km/h. [2]

$$50 \div 2.5 = 20 \text{ m/s}; 20 \times 3.6 = 72 \text{ km/h}$$

- (b) Why is a speed calculated from timing gates more accurate than one from a stopwatch held by a steward? [1]

Timing gates have no human reaction time.

B4 Pit Lane Limit: unit conversion

Complete Table 1. [3]

Speed in km/h	Speed in m/s	Above 80 km/h limit?
80	22.2	— (the limit)
90	25	Yes
72	20	No

Table 1

B5 Telemetry: displacement–time graphs

Fig. 1 shows the displacement–time graph of a car in the pit lane.

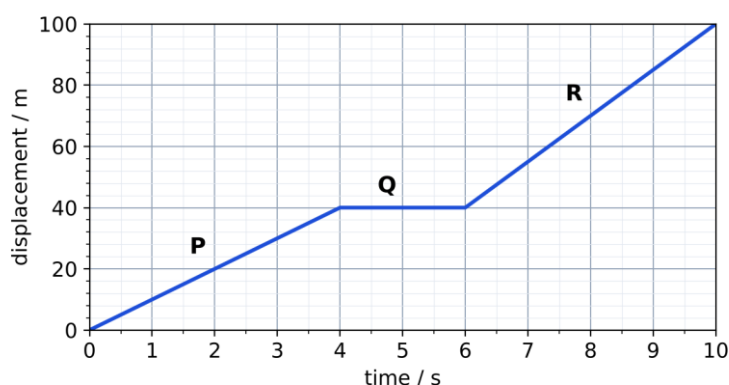


Fig. 1

- (a) Calculate the speed of the car in section P and in section R. [2]
P: $40 \div 4 = 10 \text{ m/s}$. R: $60 \div 4 = 15 \text{ m/s}$.

- (b) Describe the motion in section Q. [1]
Stationary (at rest); the displacement does not change.

- (c) Calculate the average speed for the whole 10 s. [1]

$$100 \div 10 = 10 \text{ m/s}$$

B6 Throttle & Brake: acceleration

- (a) A car accelerates uniformly from rest to 30 m/s in 6.0 s. Calculate its acceleration. [2]

$$(30 - 0) \div 6.0 = 5.0 \text{ m/s}^2$$

- (b) It then brakes uniformly from 30 m/s to rest in 3.0 s. Calculate its acceleration and explain the sign. [2]

$$(0 - 30) \div 3.0 = -10 \text{ m/s}^2. \text{ Negative because the velocity is decreasing (deceleration).}$$

B7 Turbo Boost: non-uniform acceleration

Fig. 2 shows the velocity–time graph of a car using its turbo boost. A tangent is drawn at point X.

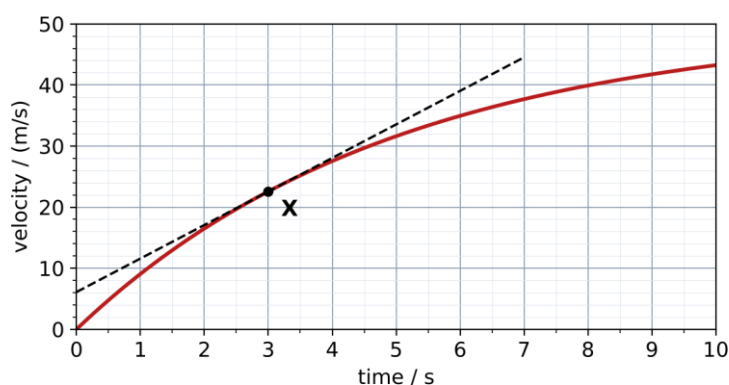


Fig. 2

- (a) Use the tangent to find the acceleration of the car at X ($t = 3 \text{ s}$). [2]

$$\text{Gradient of tangent} \approx (44.5 - 6.1) \div 7 \approx 5.5 \text{ m/s}^2 \text{ (accept } 5.0\text{--}6.0\text{).}$$

- (b) Describe how the acceleration of the car changes from 0 s to 10 s. Explain how the graph shows this. [2]

The acceleration decreases. The gradient of the v – t graph becomes less steep with time.

B8 Braking Zone: area under a v – t graph

A driver travelling at 25 m/s sees a hazard. After a reaction time of 0.80 s, the car decelerates uniformly and stops 5.0 s later. A barrier is 80 m ahead of the point where the driver saw the hazard.

- (a) Sketch the v – t graph on Fig. 3. [2]

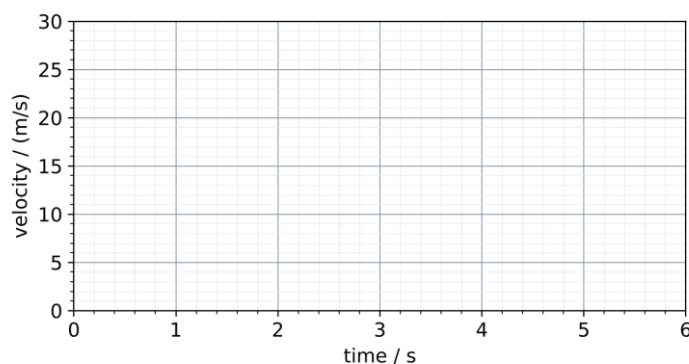


Fig. 3

Horizontal line at 25 m/s from 0 to 0.8 s, then a straight line down to 0 m/s at 5.8 s.

(b) Calculate the stopping distance. Does the car hit the barrier? [3]

Thinking distance = $25 \times 0.8 = 20$ m; braking distance = $\frac{1}{2} \times 25 \times 5.0 = 62.5$ m; stopping distance = 82.5 m. 82.5 m $>$ 80 m, so the car hits the barrier.

B9 Rain Check: free fall and terminal velocity

(a) A raindrop falls from rest. Ignoring air resistance, calculate its velocity after 2.0 s. [1]

$$v = 10 \times 2.0 = 20 \text{ m/s}$$

(b) Number the stages of a falling raindrop with air resistance from 1 to 4. [2]

Stage	Order
Air resistance equals weight; the drop falls at terminal velocity	4
The drop is released; only weight acts, so it accelerates at 10 m/s^2	1
Air resistance increases, so the resultant force and acceleration decrease	3
As speed increases, air resistance starts to act upwards	2

(c) A student says, "A heavy stone falls faster than a light stone in a vacuum." Is the student correct? Explain. [1]

No. In a vacuum all objects fall with the same acceleration, $g = 10 \text{ m/s}^2$.

Part C: The Final Verdict

Case file: a car's average speed through the 10 s pit-lane timing zone must not be more than 80 km/h. Each car brakes uniformly, then holds a steady speed. The speed gun records Car A's velocity every 2 s:

Time / s	0	2	4	6	8	10
Velocity / (m/s)	30	25	20	20	20	20

Step 1 Plot the v–t graph for Car A on Fig. 4. [2]

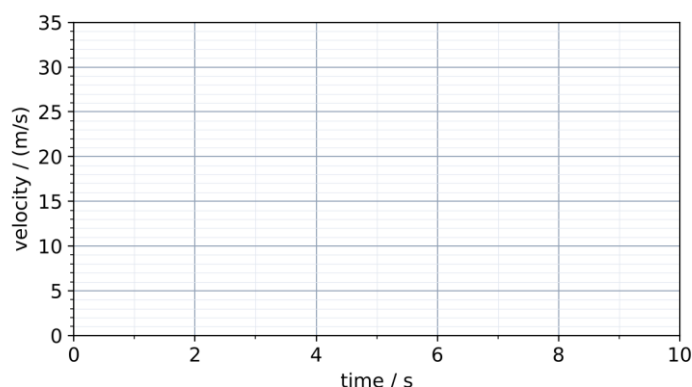


Fig. 4

Straight line from (0, 30) to (4, 20), then horizontal at 20 m/s to 10 s.

Step 2 Calculate Car A's acceleration while braking. [2]

$$(20 - 30) \div 4 = -2.5 \text{ m/s}^2$$

Step 3 Calculate the distance Car A travels in the zone. [2]

$$\text{Trapezium } \frac{1}{2} \times (30 + 20) \times 4 = 100 \text{ m; rectangle } 20 \times 6 = 120 \text{ m; total} = 220 \text{ m}$$

Step 4 Calculate Car A's average speed in km/h. [2]

$$220 \div 10 = 22 \text{ m/s} = 22 \times 3.6 = 79.2 \text{ km/h}$$

Step 5 The stewards have found that Car B's average speed was 23.0 m/s and Car C's was 21.5 m/s. Which car is guilty? Show your working. [2]

Car B: $23.0 \times 3.6 = 82.8 \text{ km/h} > 80 \text{ km/h}$, so Car B is guilty. Car A (79.2 km/h) and Car C ($21.5 \times 3.6 = 77.4 \text{ km/h}$) are within the limit.

Part D: Practice Questions

D1 A car travels 1.2 km along Raffles Avenue in 1.5 minutes. Calculate its average speed in m/s and km/h. [2]

$$1200 \div 90 = 13.3 \text{ m/s}; \times 3.6 = 48 \text{ km/h}$$

D2 Explain why a car moving at a constant speed around a bend is accelerating. [2]

Acceleration is the rate of change of velocity. Velocity is a vector; its direction changes around the bend, so the velocity changes even though the speed is constant.

D3 A skydiver jumps from a plane and later opens a parachute. Describe and explain how the skydiver's velocity changes from the moment of jumping until landing. [4]

At first, velocity increases (acceleration 10 m/s^2) as weight $>$ air resistance. Air resistance increases with speed until it equals weight: terminal velocity. When the parachute opens, air resistance $>$ weight, so the skydiver decelerates. Air resistance falls as speed falls until it again equals weight: a new, lower terminal velocity until landing.