Average Speed vs Average Velocity vs Instantaneous Velocity

Physics with Tiaotiao 跳跳 · Kinematics · High School Physics

Study sheet for the video "Average Speed vs Average Velocity vs Instantaneous Velocity": key ideas, practice questions, answers

Matches: NCERT Class 11 Ch 2 Motion in a Straight Line · FSc Part 1 Ch 3 Motion and Force · AS & A Level 9702 · WAEC/JAMB · HSC · College Physics · AP Physics 1 Unit 1

Key ideas

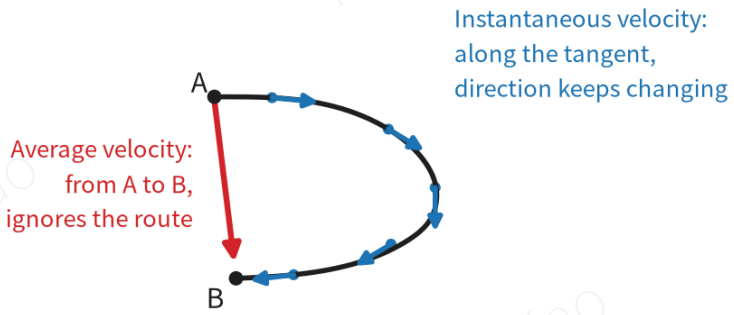
"Fast" has two meanings. Middle school "speed" = how fast you **cover ground** (distance ÷ time). High school adds a second meaning: how fast you **get there** (displacement ÷ time).

Average velocity: displacement ÷ time, v = x / t, unit m/s. It is a **vector**; its direction is the direction of the displacement. Its magnitude is the straight-line distance from start to end, divided by time.
Ignore the process, only the result (start and end) matters. It is about a time interval, not an instant. Always give the direction.

Average speed: distance ÷ time, unit m/s. It is a **scalar** (magnitude only). **Average speed is NOT the magnitude of average velocity!**

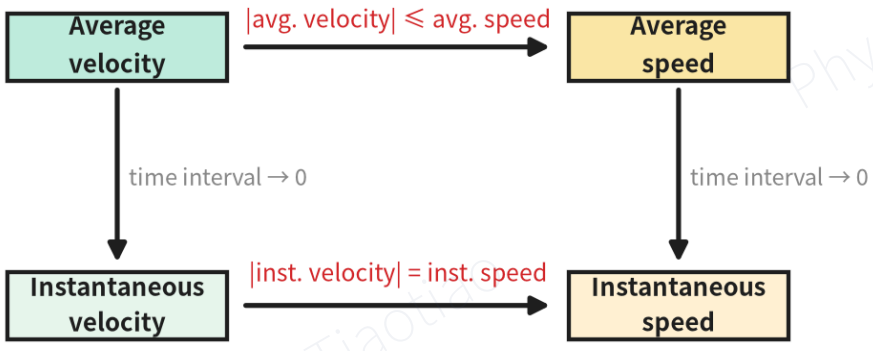
Instantaneous velocity: how fast and in which direction an object moves at one instant (one position). It is the average velocity over an **extremely short time** (e.g. 0.0001 s). A vector; its direction is the **tangent** to the path (a car driving normally: the way it points).

Instantaneous speed = the magnitude of instantaneous velocity. A scalar.



Uniform linear motion = motion with constant instantaneous velocity (constant direction, so a straight line; constant magnitude, so a steady rate). Its average velocity does not depend on which time interval you pick.

Commonly tested



Rule	Notes
Average speed ⩾ magnitude of average velocity	The straight line is the shortest path, so distance ⩾ displacement. Equal only for **one-way straight-line motion**.
Average velocity is 0, average speed is not 0	Back at the start (a full lap): displacement is 0 but distance is not.
Average or instantaneous?	Look at the time. **Extremely short** time (an instant, a position) = instantaneous. A longer time = average. Over a very short time, any motion can be treated as uniform linear motion.
Velocity and speed	They cannot be compared in size (a vector is an arrow, a scalar is a number). The *magnitude* of velocity can be compared with speed.
A problem just says "velocity"	Exam convention: read it as instantaneous velocity. But if the problem gives a time interval or a displacement, still check whether it is average or instantaneous. The textbook also notes that in daily life "velocity" sometimes means speed: judge from context.
Which word to look for	For average velocity, look at **displacement**. For average speed, look at **distance**.

Practice

Try these before checking the answers on the last pages. Goutiao is the dog and Goumao is the cat.

1. Two taxi trips, both from home to Peking University. Trip 1: 7.5 km in 14 min. Trip 2: 10 km in 15 min. (a) Which trip gets there sooner? (b) Work out distance ÷ time for each trip. Which trip covers more ground per minute?

(a) _____ (b) Trip 1: _____ km/min Trip 2: _____ km/min

2. Goutiao, our pet dog, ran 10 laps around the neighborhood, 200 m per lap, in 20 min. What is the average velocity?

Answer: _____

3. Goumao, our pet cat, dashed around the house: first 2 m to the right, then 6 m to the left, 20 s in total. What is the average velocity?

Answer: _____ m/s, direction: _____

4. Which statement about average velocity has the correct physical meaning? ( )

A. A car's average velocity at the end of 10 s after setting off is 5 m/s

B. A car's average velocity over some time interval is 5 m/s, meaning its displacement in every 1 s of that interval is 5 m

C. Average velocity only roughly reflects how fast an object moves

D. To find average velocity, you must take into account how the velocity changes during that interval

Answer: _____

5. Goumao (the cat) runs around at home: 2 m to the right, then 6 m to the left, 20 s in total. What are its average velocity and average speed?

Average velocity: _____ Average speed: _____

6. Goutiao (the dog) chases Goumao from behind, running 10 m to the right in 5 s. What are its average velocity and average speed?

Average velocity: _____ Average speed: _____

7. After an earthquake, roads and bridges were wrecked and vehicles could not get through. To reach the disaster area quickly, a rescue team crossed obstacle after obstacle on foot, covering 60 km of rugged mountain road in 5 h. Which statement about the rescuers' velocity and speed is correct? ( )

A. The average velocity is 3.3 m/s

B. The velocity at every instant is 3.3 m/s

C. The average speed is 3.3 m/s

D. The speed at every instant is 3.3 m/s

Answer: _____ Why?

_____

8. True or false? Uniform linear motion is exactly motion with constant instantaneous velocity. _____

9. Which of the velocities below are average velocities, and which are instantaneous velocities? Write "average" or "instantaneous".

_____ (1) A sprinter in the 100 m race crosses the finish line at 9.5 m/s;

_____ (2) After the speed-up, the train reaches 150 km/h;

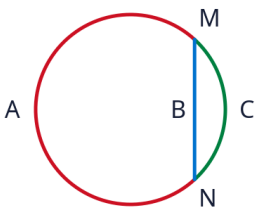
_____ (3) Because of a traffic jam, the car moves through the tunnel at only 1.2 m/s;

_____ (4) A space capsule returning to Earth lands in the Pacific Ocean at 8 m/s;

_____ (5) A bullet hits a wall at 800 m/s.

10. At a school sports meet, Teacher Liu runs one lap around a 400 m circular track and returns to the start in 80 s. Over this time, his average velocity is _____ m/s and his average speed is _____ m/s. As he crosses the finish line, the magnitude of his velocity is _____ his speed at that instant (fill in >, < or =).

11. The figure shows the paths of three particles A, B and C. All three start from N at the same time and reach M at the same time. Which of the following statements is correct? ( )



A. From N to M, A has the greatest average velocity.

B. From N to M, the three particles have the same average speed.

C. From N to M, A has the greatest average speed.

D. On reaching M, A has the greatest instantaneous speed.

Answer: _____

12. Decide whether each statement is true (T) or false (F).

_____ (1) Instantaneous velocity is just the average velocity of a moving object over a short time interval.

_____ (2) For uniform linear motion, the average velocity does not depend on which time interval (or which displacement) you pick.

_____ (3) Instantaneous speed is the magnitude of instantaneous velocity.

_____ (4) Average speed is the magnitude of average velocity.

_____ (5) If the average velocity of a motion is zero, its average speed is also zero.

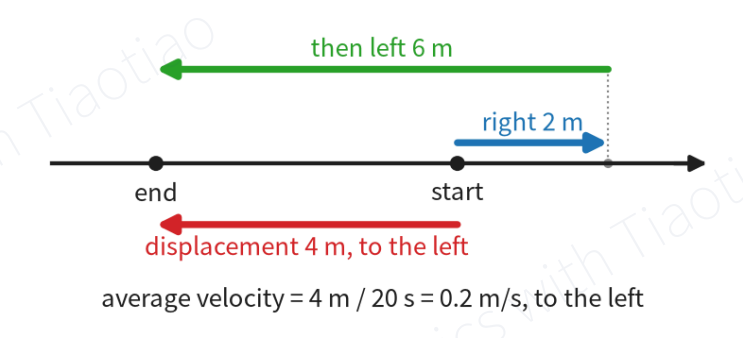
Answers and explanations

Tap a blue time to jump to the part of the video that explains the question.

1. (a) **Trip 1** gets there sooner: same start and end, less time. (b) Trip 1: 7.5 ÷ 14 ≈ **0.54 km/min**. Trip 2: 10 ÷ 15 ≈ **0.67 km/min**. Trip 2 covers more ground per minute, so Trip 2 "runs faster".
"Gets there fast" = average velocity (displacement ÷ time). "Runs fast" = average speed (distance ÷ time).
▶ **Watch 1:46, Example 1**

2. **0**. After ten full laps the dog is back at the start, so its position has not changed: displacement = 0, and average velocity = 0 ÷ 20 min = 0. The 2000 m is distance, so it is not used.
▶ **Watch 5:45, Example 2**

3. **0.2 m/s, to the left**. Taking right as positive, the cat ends 6 − 2 = 4 m to the left of the start, so the displacement is 4 m to the left. Average velocity = 4 m ÷ 20 s = 0.2 m/s, in the direction of the displacement: to the left.



▶ **Watch 5:45, Example 3**

4. **C**. Average velocity only records the result, so it only roughly reflects how fast an object moves.
A 10 s after setting off is an instant. An average velocity needs a time interval. **B** The same 25 m in 5 s can be 5 m every second, or standing still for 4 s and then 25 m in the 5th second. The average velocity is 5 m/s both times, so it cannot show the process. **D** Average velocity = displacement ÷ time. You do not need to know how the velocity changes.
▶ **Watch 7:41, Example 4**

5. **Average velocity 0.2 m/s to the left; average speed 0.4 m/s.** Average speed = distance ÷ time = (2 + 6) m ÷ 20 s = 8 m ÷ 20 s = 0.4 m/s. The two are not equal.
▶ **Watch 10:59, Example 5**

6. **Average velocity 2 m/s to the right; average speed 2 m/s.** Displacement = 10 m to the right, so v = 10 m ÷ 5 s = 2 m/s, to the right. Distance is also 10 m, so average speed = 10 m ÷ 5 s = 2 m/s.
In one-way straight-line motion, the magnitude of average velocity = average speed.
▶ **Watch 11:48, Example 6**

7. **C**. The 60 km follows a winding mountain road, so it is distance, not displacement. Distance ÷ time is average speed: 60 000 m ÷ (5 × 3600 s) ≈ 3.3 m/s. **A, B** use "velocity", which needs displacement. **D** The problem gives only the total distance and total time, so we cannot say the speed is 3.3 m/s at every instant.
▶ **Watch 12:57, Example 7**

8. **True**. Constant direction means it can only move in a straight line. Constant magnitude means it moves at a steady rate. Together, that is uniform linear motion.
▶ **Watch 18:43, Example 8**

9. (1) **instantaneous**; (2) **average**; (3) **average**; (4) **instantaneous**; (5) **instantaneous**.
Look at the time: an extremely short time (a moment, a position, e.g. 0.0001 s) means instantaneous.
For (2), this is the standard answer for this problem, not a general rule: one instant says nothing about arriving sooner. What counts is the overall speed after the speed-up.
▶ **Watch 18:54, Example 9**

10. **0 m/s; 5 m/s; =**. He ends where he started, so the displacement is 0 and the average velocity is 0. The distance is 400 m, so the average speed is 400 m ÷ 80 s = 5 m/s. At the finish line the time is extremely short, so we mean instantaneous: the magnitude of instantaneous velocity equals instantaneous speed.
▶ **Watch 24:28, Example 10**

11. **C**. All three have the same displacement (N to M) and the same time, so they have the same average velocity: **A** is wrong. A has the longest path, so the largest distance, so the greatest average speed: **B** is wrong and C is right. The problem gives no information about speed at the moment of arrival, so **D** cannot be concluded.
For average velocity, look at displacement. For average speed, look at distance.
▶ **Watch 25:47, Example 11**

12. **(1) F (2) T (3) T (4) F (5) F**
(1) "Instantaneous" means an *extremely* short time, not just a short one. (2) For uniform linear motion, the velocity is the same all the time. (3) That is the definition. (4) Average speed is not the magnitude of average velocity: the two mean different things. (5) One full lap: average velocity is 0 but average speed is not.
▶ **Watch 28:34, Example 12**

One-line summary

Average velocity: displacement ÷ time (vector). Average speed: distance ÷ time (scalar). Over an extremely short time, average becomes instantaneous.

Key terms

Term	Meaning	Chinese
average velocity	displacement ÷ time; a vector	平均速度 píngjūn sùdù
average speed	distance ÷ time; a scalar	平均速率 píngjūn sùlǜ
instantaneous velocity	velocity at one instant; along the tangent	瞬时速度 shùnshí sùdù
instantaneous speed	magnitude of instantaneous velocity	瞬时速率 shùnshí sùlǜ
displacement	change of position, start to end; a vector	位移 wèiyí
distance (path length)	length of the path travelled; a scalar	路程 lùchéng
uniform linear motion	constant instantaneous velocity	匀速直线运动 yúnsù zhíxiàn yùndòng
tangent	line touching the path at one point	切线 qiēxiàn