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 and practice questions (answers are in a separate answer key)

Key ideas

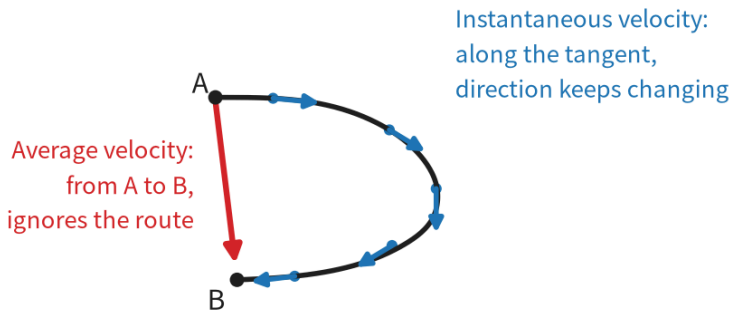
"Fast" has two meanings. Middle school "speed" = how fast you **cover ground** (distance ÷ time). High school adds a second meaning: how fast you **get there** (displacement ÷ time).

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!**

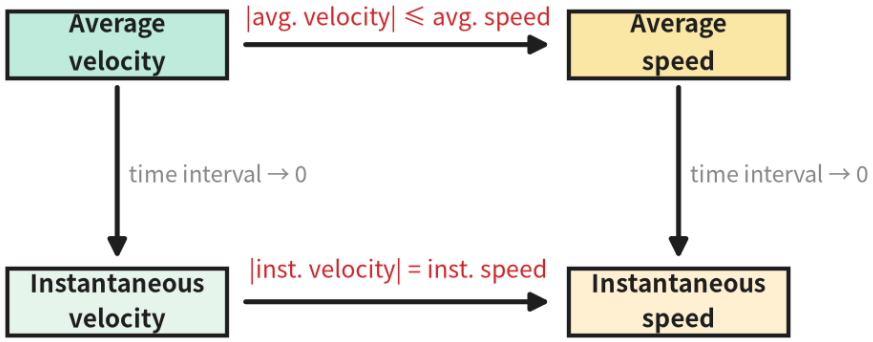
Instantaneous velocity: how fast and in which direction an object moves at one instant (one position). It is the average velocity over an **extremely short time** (e.g. 0.0001 s). A vector; its direction is the **tangent** to the path (a car driving normally: the way it points).

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 first. The answers are in a separate answer key. 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?

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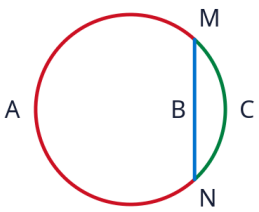
8. True or false? Uniform linear motion is exactly motion with constant instantaneous velocity. _____

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.

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