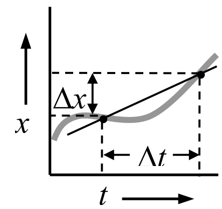
**Discussion sheet 1: Straight-line kinematics**

# Summary

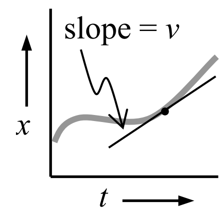



**Average velocity** is the ratio of how far an object moves to the time elapsed.

$$v_{\text{avg}} = \Delta x/\Delta t$$

On a plot of position vs. time, $v_{\text{avg}}$ is the slope of the secant line connecting the starting and ending events.

**Instantaneous velocity** is the limit of average velocity as the time interval becomes infinitesimally brief. It is the velocity at a particular instant of time.




$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

On a position-time plot, $v$ is the slope of the tangent line at that particular instant. Conversely, the area under a velocity-time plot is the change in position.

**Average acceleration** is the rate of the change of an object's velocity.

$$a_{\text{avg}} = \Delta x/\Delta t$$

On a plot of velocity vs. time, $a_{\text{avg}}$ is the slope of the line connecting the starting and ending events.

**Instantaneous acceleration** is the limit of average acceleration as the time interval becomes infinitesimally brief. It is the acceleration at a particular instant of time.

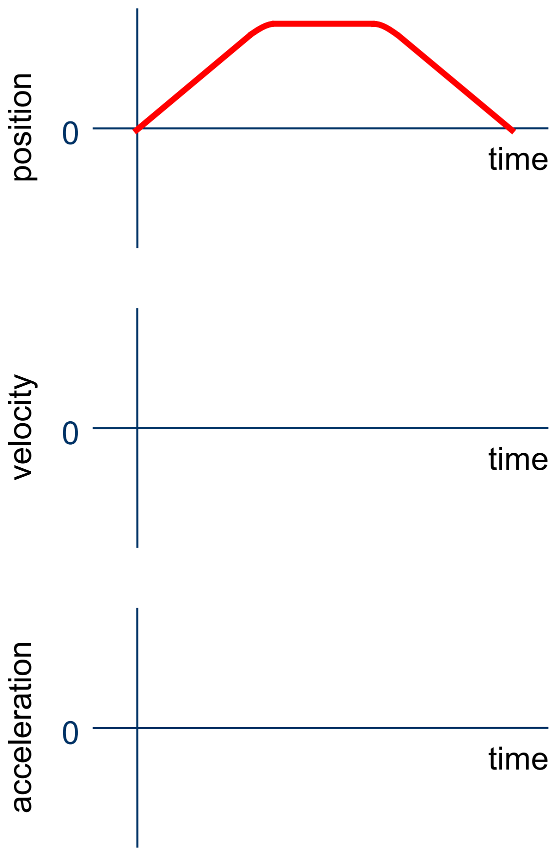
$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$$

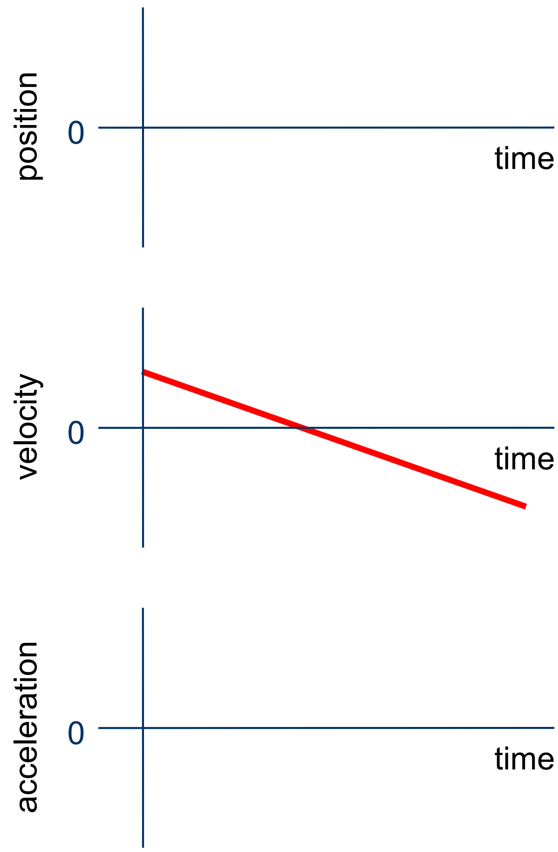
On a velocity-time plot, $a$ is the slope of the tangent line at that particular instant. Conversely, the area under an acceleration-time plot is the change in velocity.

### *Constant-velocity formula*

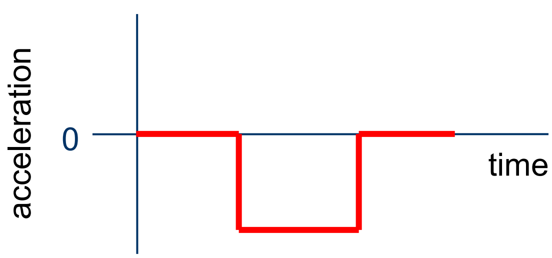
When velocity is constant, $\Delta x/\Delta t$ is the same for any time interval. Then $x = x_0 + vt$.

1. In the following scenarios, the motion of an object is to be described in four ways: (i) in words, (ii) as a position-time graph, (iii) as a velocity-time graph, and (iv) as an acceleration-time graph. In each case, only one description is given. Construct the other three. (You may need to assume some initial conditions.) For additional fun, think of mathematical expressions that would describe the position, velocity, and acceleration.








A coconut hangs motionless from its tree, then drops with increasing downward speed until it lands on the ground, quickly coming to rest.



2. The speed of sound in air is around 343 meters per second. The speed of light is $3.00 \times 10^8$ meters per second.
   a. How much time does it take the sound of a thunderclap sound to travel 1 kilometer (1000 meters)?
   b. If you hear thunder 5.0 seconds after seeing the lightning that caused it, how far away was the lightning bolt? Assume that the light from the lightning flash arrived instantly.
   c. Now, consider the 5.0-second thunderclap again, but this time don't assume that the light from the lightning flash arrived instantly. How much time does it take for light to travel the same distance that sound travels in 5.0 seconds?

3. Tybalt and Mercutio notice each other across the Verona town square, when they are 75 meters apart. They run toward each other, Tybalt at a speed of 3.5 meters per second and Mercutio at a speed of 3.0 meters per second, until they are 3.0 meters apart. Then, they shout insults at each other.
   a. How much time does it take for them to run to 3.0 meters from each other?
   b. How far did Tybalt run?
   c. How far did Mercutio run?

4. A prairie dog pursued by a coyote dashes toward its hole. The prairie dog runs at a speed of 5.4 meters per second, the coyote at a speed of 6.3 meters per second, the prairie dog is 4.2 meters from its hole, and the coyote is 1.8 meters behind the prairie dog.

   a. Does the prairie dog reach its hole before the coyote snatches it?

   b. If all other values are kept the same, what is the longest distance from the hole that would still allow the prairie dog to reach safety?

   c. If all other values are kept the same, what is the minimum speed at which the prairie dog must run to reach safety?

   d. If all other values are kept the same, what is the shortest head start the prairie dog needs to evade the coyote?