Feb. 25

Acceleration

How do you know if you are moving?

Even if you are sitting still at your desk, or are sleeping in your bed, you are moving at 30 km/s (earth around the sun). Why don't you feel this?

There are several reasons why we feel "at rest":

- We can't see ourselves moving past something else
- We are moving at a fairly constant speed
- The air is moving with us

Acceleration is the study of increasing and decreasing speed.
You can feel acceleration, and you can also measure it. One of the most important performance indicators for natural and machine motion is acceleration (sprinters, vehicles...)

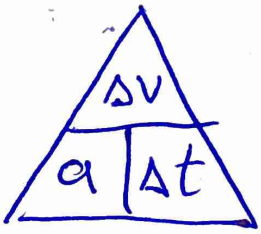
Defining Acceleration

Fraction (dividing)

Acceleration (*a*) is the rate of change of speed or velocity and is calculated by the ratio of change in speed (Δv)(velocity) to the time interval (Δt).

final-initial

f-i



acceleration
(m/s² or km/h/s)

$$\boxed{a = \frac{\Delta v}{\Delta t}}$$

change in speed
or velocity
(m/s or km/h)

change in time
(s)

Units = m/s², km/h/s (with direction included if velocity was used)

Constant acceleration is when the change in speed/velocity is the same for each interval of time. If the acceleration varies over a period of time we refer to the *average acceleration* (a_{av}) of the object. (For all calculations in this unit we assume that acceleration is constant).

Example 1:

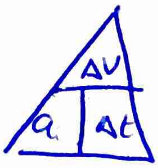
If you speed up on a motorcycle from rest (0 m/s) to 9.0 m/s in a time of 2.0s. What is your acceleration?

$a = ?$

$V_i = 0 m/s$

$V_f = 9 m/s$

$\Delta t = 2s$



$$a = \frac{\Delta V}{\Delta t} = \frac{V_f - V_i}{\Delta t} = \frac{9-0}{2} = \frac{9 m/s}{2s} = \boxed{4.5 m/s^2}$$

What does this mean?

With every second, the speed of the motorcycle increases by 4.5 m/s.

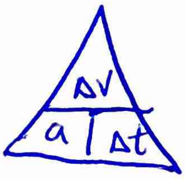
Example 2:

If a car accelerates for 11s at 6.4 m/s², by how much did the velocity of the car change?

$\Delta V = ?$

$\Delta t = 11s$

$a = 6.4 m/s^2$



$$\Delta V = (a)(\Delta t)$$
$$= (6.4 m/s^2)(11s)$$
$$= \boxed{70.4 m/s}$$

Example 3 :

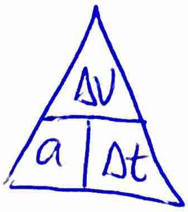
Kerrin is moving at 1.8 m/s near the top of a hill. 4.2 s later she is traveling at 8.3 m/s. What is her average acceleration?

$a = ?$

$\Delta t = 4.2s$

$V_i = 1.8 m/s$

$V_f = 8.3 m/s$



$$a = \frac{V_f - V_i}{\Delta t} = \frac{8.3 - 1.8}{4.2} = \frac{6.5 m/s}{4.2s} = \boxed{1.55 m/s^2}$$

Example 4:

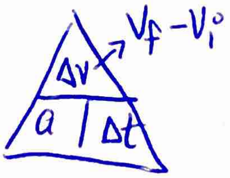
A bus with an initial speed of 12 m/s accelerates at 0.62 m/s² for 15 seconds. What is the final speed of the bus?

$V_i = 12 m/s$

$a = 0.62 m/s^2$

$\Delta t = 15s$

$V_f = ?$



$$\Delta V = (a)(\Delta t)$$
$$V_f \cancel{- V_i} = (a)(\Delta t)$$
$$\cancel{+V_i} \qquad +V_i$$
$$V_f = (a)(\Delta t) + V_i$$
$$= (0.62 m/s^2)(15s) + 12 m/s$$
$$= 9.3 + 12$$
$$\boxed{V_f = 21.3 m/s}$$

Example 1:

If you speed up on a motorcycle from rest (0 m/s) to 9.0 m/s in a time of 2.0s. What is your acceleration?

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$V_f = 9 m/s$
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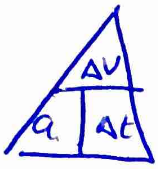


$$a = \frac{\Delta V}{\Delta t} = \frac{V_f - V_i}{\Delta t} = \frac{9-0}{2} = \frac{9 m/s}{2s} = \boxed{4.5 m/s}$$

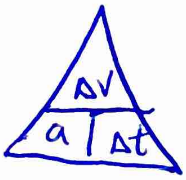
What does this mean?

With every second, the speed of the motorcycle increases by 4.5m/s.

Example 2:

If a car accelerates for 11s at 6.4 m/s^2, by how much did the velocity of the car change?

$\Delta V = ?$
$\Delta t = 11s$
$a = 6.4 m/s^2$



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Kerrin is moving at 1.8 m/s near the top of a hill. 4.2 s later she is traveling at 8.3 m/s. What is her average acceleration?

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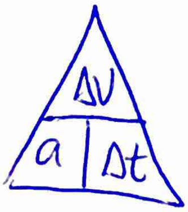
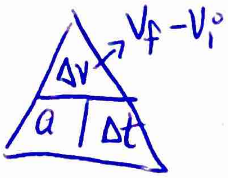


$$a = \frac{V_f - V_i}{\Delta t} = \frac{8.3 - 1.8}{4.2} = \frac{6.5 m/s}{4.2s} = \boxed{1.55 m/s^2}$$

Example 4:

A bus with an initial speed of 12 m/s accelerates at 0.62 m/s^2 for 15 seconds. What is the final speed of the bus?

$V_i = 12 m/s$
$a = 0.62 m/s^2$
$\Delta t = 15s$
$V_f = ?$



$$\Delta V = (a)(\Delta t)$$
$$V_f \cancel{-V_i} = (a)(\Delta t)$$
$$\cancel{+V_i} \qquad +V_i$$
$$V_f = (a)(\Delta t) + V_i$$
$$= (0.62 m/s^2)(15s) + 12 m/s$$
$$= 9.3 + 12$$
$$\boxed{V_f = 21.3 m/s}$$

Deceleration

Slowing Down: To calculate the acceleration while slowing down, you use the same equations, but the answer will have a **negative** sign.

Example:

If a race car traveling at 100 km/h comes to a stop in 5.0 s. What is the average acceleration?

Hint – since the car comes to a stop, the final speed is 0 km/h.

$V_i = 100\ \text{km/h}$

$V_f = 0\ \text{km/h}$

$\Delta t = 5\ \text{s}$

$$a = \frac{\Delta v}{\Delta t} = \frac{V_f - V_i}{\Delta t} = \frac{0 - 100}{5} = \frac{-100\ \text{m/s}}{5\ \text{s}}$$

$$\boxed{= -20\ \text{km/h/s}}$$

Acceleration Practice

1. While traveling along a highway a driver slows from 24 m/s to 15 m/s in 12 seconds. What is the automobile's acceleration? (Remember that a negative value indicates a slowing down or deceleration.)

   $a = -0.75 m/s^2$

2. A parachute on a racing dragster opens and changes the speed of the car from 85 m/s to 45 m/s in a period of 4.5 seconds. What is the acceleration of the dragster?

   $a = -8.9 m/s^2$

3. A car traveling at a speed of 30.0 m/s encounters an emergency and comes to a complete stop. How much time will it take for the car to stop if it decelerates at -4.0 m/s^2?

   $t = 7.5 s$

4. If a car can go from 0 to 60 km/hr in 8.0 seconds, what would be its final speed after 5.0 seconds if its starting speed were 50 km/hr?

   $a = 7.5$ km/h/s

   $V_f = 110$ km/h

5. A cart rolling down an incline for 5.0 seconds has an acceleration of 4.0 m/s^2. If the cart has a beginning speed of 2.0 m/s, what is its final speed?

   $V_f = 22 m/s$

6. A helicopter's speed increases from 25 m/s to 60 m/s in 5 seconds. What is the acceleration of this helicopter?

   $a = 7 m/s^2$

7. As she climbs a hill, a cyclist slows down from 25 km/hr to 6 km/hr in 10 seconds. What is her deceleration?

$a = -1.9$ km/h/s

8. A motorcycle traveling at 25 m/s accelerates at a rate of 7.0 m/s^2 for 6.0 seconds. What is the final speed of the motorcycle?

$V_f = 67$ m/s

9. A car starting from rest accelerates at a rate of 8.0 m/s/s. What is its final speed at the end of 4.0 seconds?

$V_f = 32$ m/s

10. After traveling for 6.0 seconds, a runner reaches a speed of 10 m/s. What is the runner's acceleration? *assume the runner started from a rest.

$a = 1.\overline{6}$ m/s^2 or 1.7 m/s^2

11. A cyclist accelerates at a rate of 7.0 m/s^2. How long will it take the cyclist to reach a speed of 18 m/s? assume they started at 0 m/s

$\Delta t = 2.57$ s

12. A skateboarder traveling at 7.0 meters per second rolls to a stop at the top of a ramp in 3.0 seconds. What is the skateboarder's acceleration?

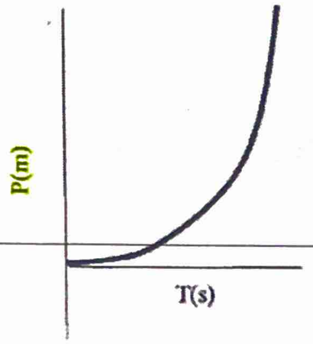
$a = -2.33$ m/s^2

Acceleration on a Graph

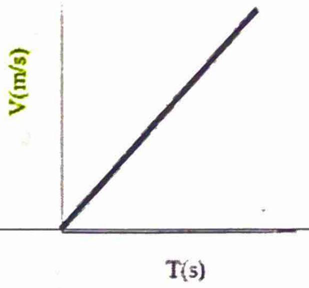
Acceleration can be plotted on a position-time graph, or a velocity-time graph. Again, a line sloping upwards is a positive motion, and a line sloping downwards is a negative motion.

Positive Slopes (Acceleration)

- On a position-time graph (left) acceleration is plotted with a line curving upwards, since the velocity (or slope) is increasing as time goes on.
- On a velocity-time graph (right) acceleration is plotted with an upwards sloping straight line, since the velocity is increasing at a steady rate as time goes on.

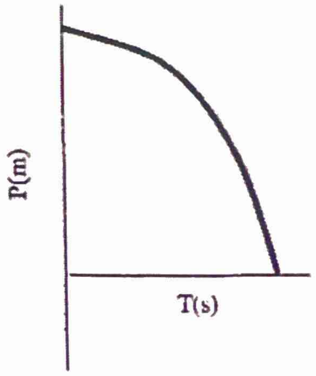


The slope at 0 seconds is 0 m/s. The slope of the graph is becoming more positive, larger in the positive direction. The velocity is increasing in the positive direction (speeding up in the positive direction). This is accelerated motion.

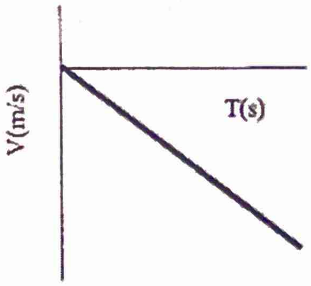


Negative Slopes (Deceleration)

- On a position-time graph (left) acceleration is plotted with a line curving downwards, since the velocity (or slope) is decreasing as time goes on.
- On a velocity-time graph (right) acceleration is plotted with a downwards sloping straight line, since the velocity is decreasing at a steady rate as time goes on.



The object starts at rest to the right of the origin and moves towards the origin. The slope becomes more negative. The velocity becomes more negative (speeding up in the negative direction). The object's last position is at the origin.



In Summary…

has direction ↗

Quantity	Symbol of the Quantity	Unit	Vector or Scalar? → no direction
time instant	t	s, min, h.	Scalar
time interval	Δt	s, min, h.	Scalar
distance	d	m, km, cm, mm	Scalar
displacement	Δd	m, km, cm, mm	Vector
Speed	v	m/s, km/h	Scalar
velocity	$\vec{v}$	m/s, km/h	Vector
acceleration	a	m/s^2, km/h/s	Both