Uniform Acceleration

What is acceleration?

- Speeding up
- Slowing down
- Changing direction

Calculating Acceleration

Acceleration = rate of change of velocity

$$= \frac{\text{change in velocity}}{\text{time}}$$

$$a_{average} = \frac{\Delta v}{t} = \frac{v_2 - v_1}{t}$$

$$units: \frac{m}{s^2}$$

Example:
A car starts from rest and undergoes uniform acceleration to reach a velocity of 20.0 m/s (N) in 4.0 s. Calculate its average acceleration.

Example:
A cyclist travelling initially at 14 m/s (S) brakes smoothly and stops in 4.0 s. What is the cyclist's average acceleration?

Example:

Nancy decides to swim in a race. She begins at a velocity of 1.0 m/s (E). She travels for 240 s to end at a speed of 2.5 m/s (E) as she crosses the finish line.

a) What is Nancy's average acceleration during the race?
b) If it takes her 4.0 s to stop after she crosses the finish line, what is her acceleration?

Example:

What is an object's final velocity if it accelerates at 2.0 m/s^2 for 4.1 s from a velocity of 42 km/h?

Acceleration – Graphical Analysis

Consider the data below taken from the free fall segment of a roller coaster ride.

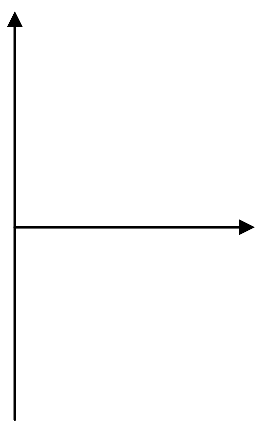
time (s)	0	1.0	2.0	3.0	4.0	5.0
displacement (m)	0	4.4	17.6	39.6	70.4	110.0

a) Graph the data shown.
b) Draw 3 tangent lines to the graph.
c) Find the slope of each tangent line.
d) Construct a velocity time graph.
e) Construct an acceleration time graph.

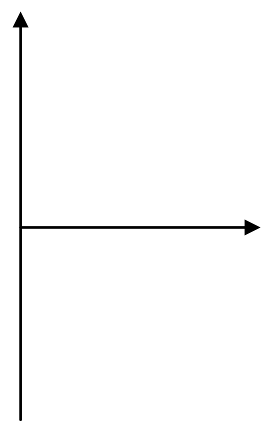
Conclusions:

1. The shape of the displacement time graph is a curve, showing non-equal distances in equal times.
2. The slope of the displacement time graph represents the velocity of the motion. The slope of a tangent line to the curve gives the instantaneous velocity at that time. The slope of a secant line gives the average velocity over that time interval.
3. The velocity time graph is a straight sloping line indicating that the velocity changes at a constant rate.
4. The slope of the velocity time graph represents average acceleration.
5. The acceleration time graph is a straight horizontal line representing uniform acceleration.
6. The area under the velocity time graph represents the displacement for the chosen time interval.
7. The area under the acceleration time graph represents the velocity for the chosen time interval.

Shape of Graphs:

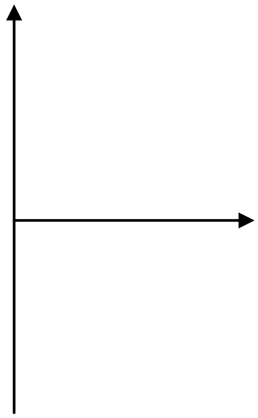


Positive slope initially means the object is moving to the right-it is slowing down (see tangents)
At *x*, slope=0 so object has stopped.
After *x*, the negative slope indicates acceleration to the left, back to the starting point.

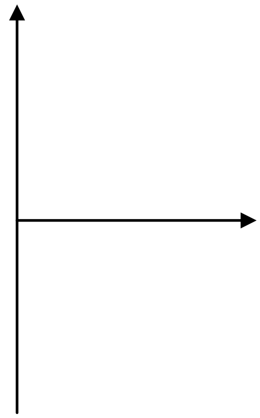


Negative slope up to x indicates movement to the left – it is slowing down.

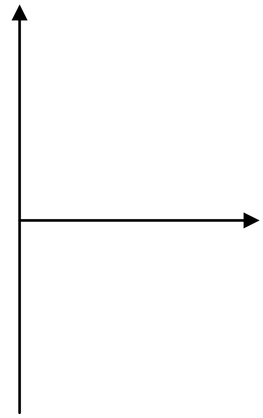
At *x*, slope=0 so object has stopped.
After *x*, the positive slope indicates acceleration to the right back to the starting point.



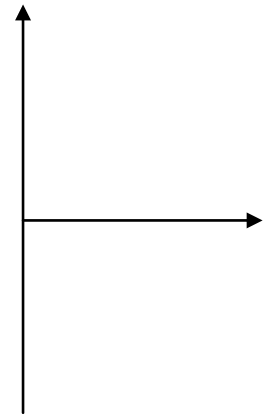
Object is moving to the right and is picking up speed.



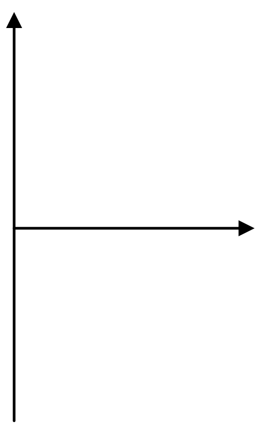
Object is moving to the left and picking up speed.



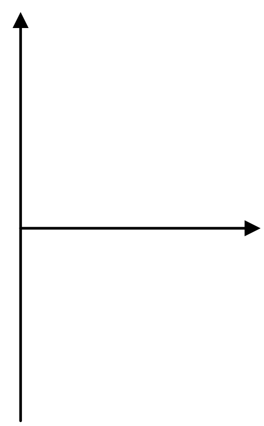
Object is moving to the left, but it is losing speed and stops at time *x*.



Object is moving to the right. It is losing speed and stops at time *x*.

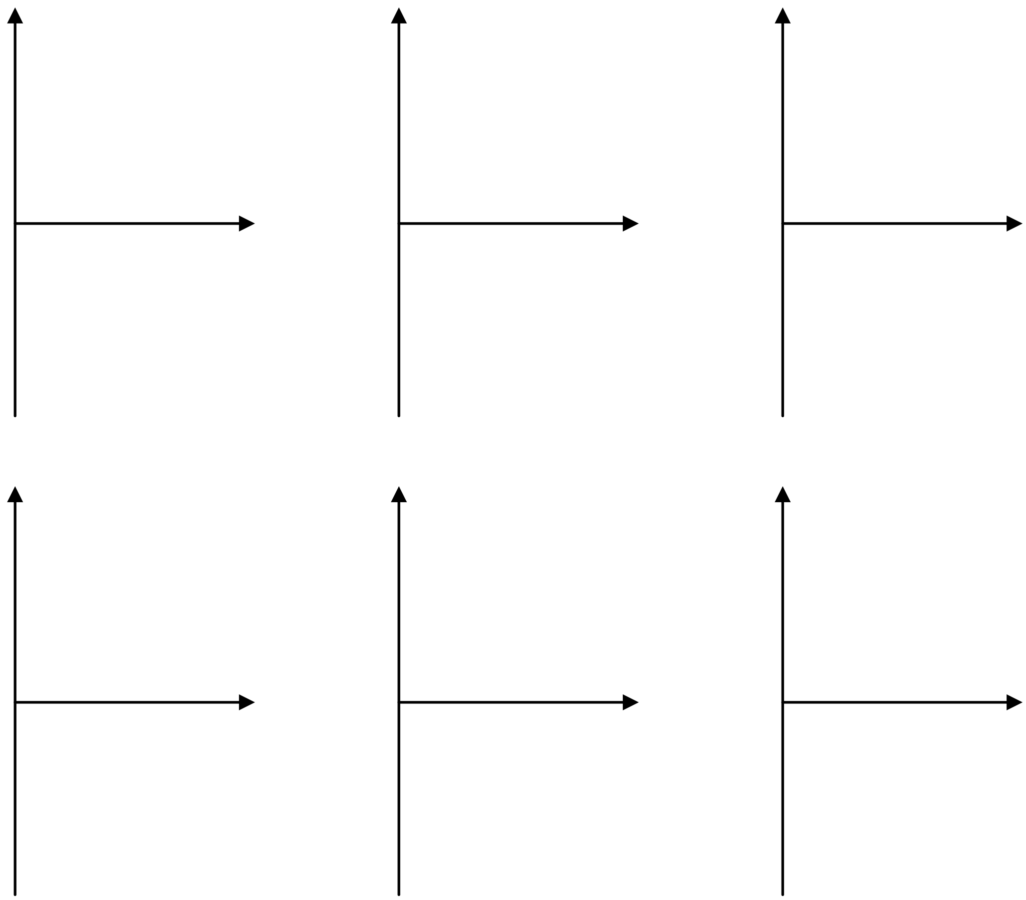


Represents a positive acceleration.



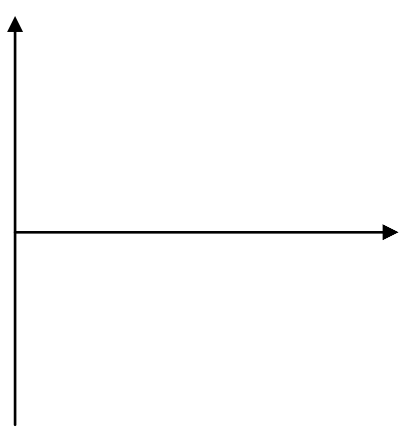
Represents a negative acceleration.

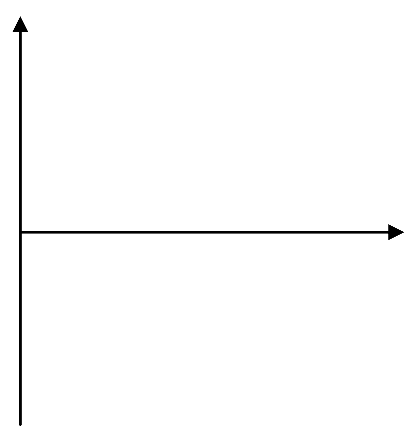
Practice graphs:



Example:

Convert the velocity time graph shown to a displacement time graph.

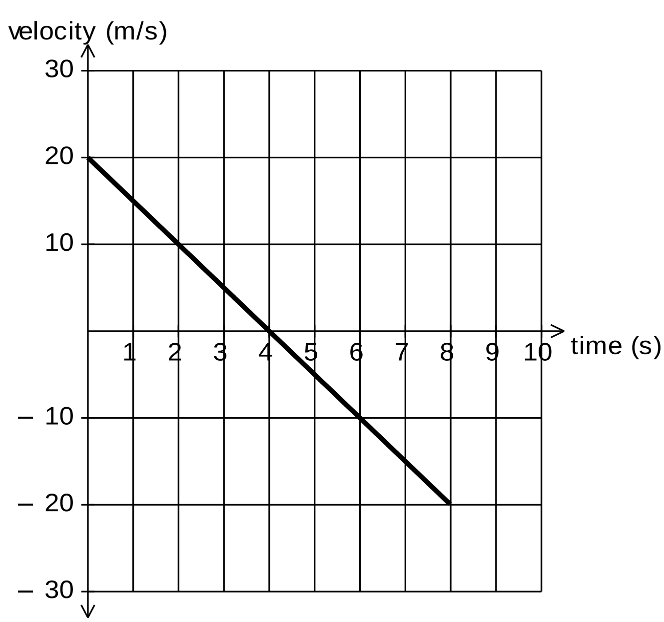




Sketch d-t and v-t graphs for the following situation:

A: slowing down to the left
B: speeding up to the right
C: constant speed
D: slowing down quickly to the right
E: constant speed of 0 m/s
F: speeding up to the left

Example:
The graph below shows a cyclist's motion. The cyclist, travelling at 20 m/s, arrives at the bottom of a hill, climbs up the hill to a stop, then coasts back down again. Find the total distance, displacement and acceleration.



What is the average velocity over the first 6.0 s?

Graphical Summary:

- Know general shapes of graphs
- Convert from one graph to another
- Find slopes and areas and know what they represent
- Useful summary charts in text on pages 19, 23, 24, 25, 39, 42, 45, 47, 48, 50.

Kinematics Derivations:

Jigsaw derivations activity.

Kinematics Formulae:

$$a = \frac{v_2 - v_1}{t}$$

$$d = \frac{1}{2}(v_1 + v_2)t$$

$$d = v_1 t + \frac{1}{2}at^2$$

$$d = v_2 t - \frac{1}{2}at^2$$

$$v_2^{\,2} = v_1^{\,2} + 2ad$$

Example:
Consider a car travelling to the left at 16.0 m/s. When the brakes are applied, the car accelerates at −2.0 m/s^2.

a) Assuming a smooth application of the brakes, how many seconds does it take for the car to come to a complete stop?
b) If the car skidded all the way, how long would the skid marks be?
c) If the driver only braked for 2.5 s, what would the velocity of the car be when her foot went back to the gas pedal.

Example:
A car accelerates uniformly from rest to 2.0 m/s^2. How far does the car travel between 2.0 s and 4.0 s?

Example:
Calculate the acceleration of an airbag that deploys in 30.0 milliseconds and moves out a distance of 40.0 cm.

Example: (a quadratic solution)
A person accelerates uniformly at a rate of 0.20 m/s^2 from an initial velocity of 3.0 m/s. How long will it take to travel a distance of 12 m?

Example:

Example:

Fred and Barney are at opposite ends of a 1.0 km long drag strip in their racecars. Fred accelerates from rest toward Barney at a constant 2.0 m/s^2. Barney travels toward Fred at a constant speed of 10.0 m/s. How much time elapses before they collide?

Example:

A car travelling at 41 km/h accelerates at −2.3 m/s^2 for 2.7 s. How far has the car travelled in that time? What is its final velocity?

Acceleration Due to Gravity:

Acceleration of falling objects near the surface of Earth does not depend on mass.
Acceleration does depend on air resistance. Galileo first proved that, ignoring the effects of air resistance, the acceleration of falling objects is constant.

Objects can only pick up so much speed before they attain terminal velocity (i.e. the speed at which no more acceleration occurs). Terminal velocity is dependent on the mass and size of the falling object as well as the amount of air resistance.

Acceleration due to gravity is $g = 9.80\ m/s^2$. This value changes slightly depending on elevation and also on whether you are closer to the equator or the poles. Earth is slightly flattened at the poles. The N pole is closer to the center of Earth than the equator, so g is slightly higher (see p. 164).

Example:
A rock dropped from a bridge falls into the water below. What is its velocity after 0.80 s?

Example:
A baseball is popped up (straight up) leaving the bat at 29 m/s.
a) How high will it rise?
b) How long will the ball be in the air?
c) What will be the position of the ball 5.0 s after it leaves the bat?
d) How fast will the ball be moving and in what direction at the 5.0 s mark?

Example:
A hot air balloon is rising upward with a constant velocity of 4.0 m/s. As the balloon reaches a height of 4.0 m above the ground, the balloonist accidentally drops a can of pop over the edge of the basket. How long does it take the pop can to reach the ground?