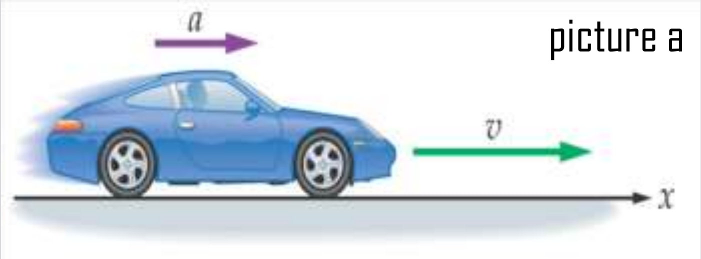
The cheetah has maximum speed of over 30m/s.From the standing start a cheetah can reach 20 m/s in just three or four strides,taking only two seconds.Its acceleration is impressive.A car cannot increase its speed as rapidly but on a long straight road it can easily travel faster then a cheetah.

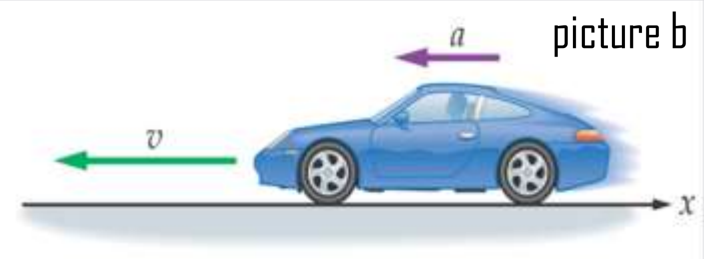
ACCELERATION

In everyday language, the term acceleration means “speeding up”. Anything whose speed is increasing is accelerating. Anything whose speed is decreasing is decelerating. To be more precise in our definition of acceleration, we should think of its as changing velocity. Any object whose velocity is changing magnitude or changing its direction has acceleration. Because acceleration is linked to velocity in this way, it follows that this is a vector quantity. Note that the velocity vector is always directed in the same direction which the object is moving.

When an object’s velocity and acceleration are in the same direction, the object is speeding up. Two cases:

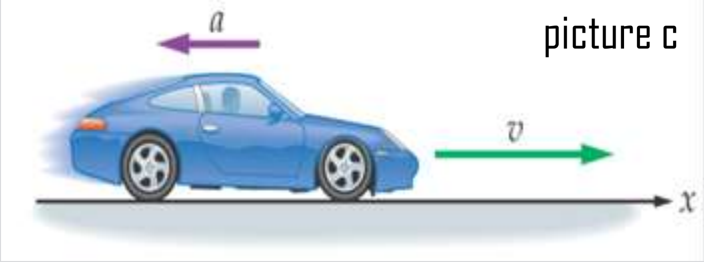
1. Positive velocity with positive acceleration: object speeding up in the positive direction (picture a)
2. Negative velocity with negative acceleration: object speeding up in the negative direction (picture b)

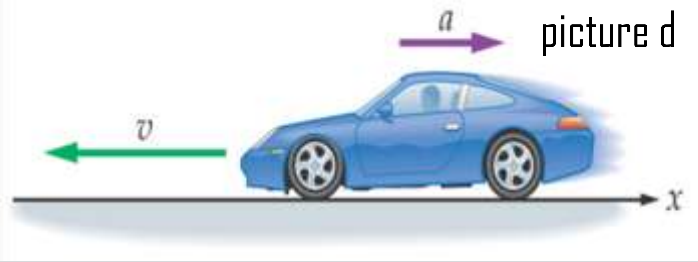


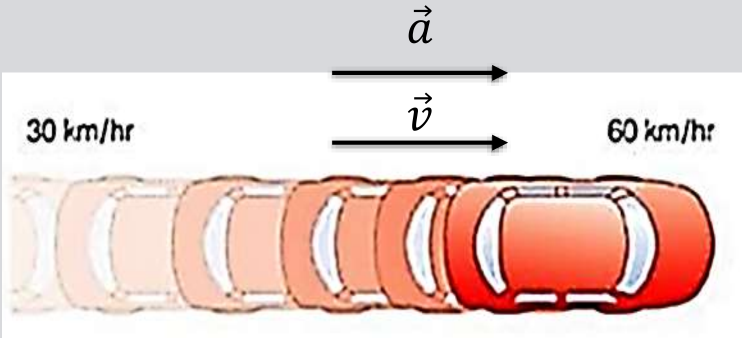


When an object’s velocity and acceleration are in opposite directions, the object is slowing down. Two cases:

1. Positive velocity with negative acceleration: object slowing down in the positive direction (picture c)
2. Negative velocity with positive acceleration: object slowing down in the negative direction (picture d)

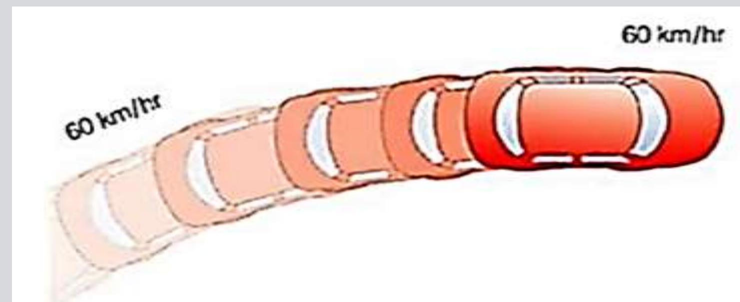


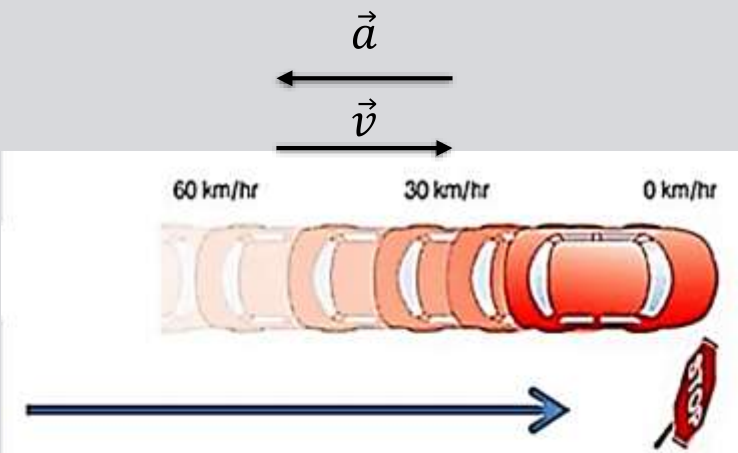




A car is increasing speed along a straight road from $30\ km/h$ to $60\ km/h$. We say that this car is accelerating because its velocity is increasing. (velocity and acceleration are in the same direction).

We say that this car is accelerating because its direction is changing as it turns, which means its velocity is changing even though its speed stays constant.





The brakes on this car are causing it to slow down.. We say that this car is deceleration because its velocity is decreasing (velocity and acceleration are in opposite directions).

AVERAGE ACCELERATION

Much like velocity, there are two kinds of acceleration: average and instantaneous.

Average acceleration is determined over a "long" time interval (the word long in this context means finite – something with a beginning and an end.). The velocity at the beginning of this interval is called the initial velocity, and the velocity at the end is called the final velocity,

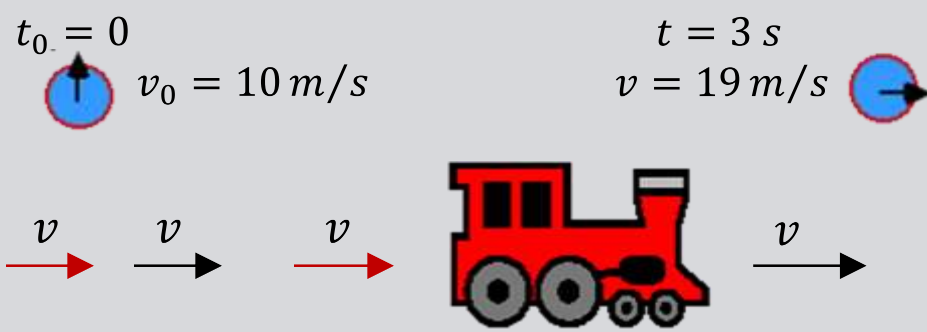
The average acceleration $\vec{a}_{av}$ during the time interval Δt is the change in velocity $\Delta\vec{v}$ (final velocity-initial velocity) divided by Δt:

$$\vec{\boldsymbol{a}}_{\boldsymbol{av}} = \frac{\Delta\vec{\boldsymbol{v}}}{\Delta \boldsymbol{t}}$$

Sometimes this equation is written differently. We use v_0 for the initial velocity and v for final velocity. Then the acceleration is given by equation: $\boldsymbol{a}_{\boldsymbol{av}} = \frac{\boldsymbol{v}-\boldsymbol{v}_0}{\Delta \boldsymbol{t}}$

Example:

Consider a train that starts at rest with initial velocity $10\, m/s$, after 3 seconds the train reaches a speed of $19\, m/s$. What is the average acceleration of the train?



$$a_{av} = \frac{\Delta v}{\Delta t} = \frac{19\, m/s - 10\, m/s}{3s - 0s} = 3\, m/s^2$$

INSTANTANEOUS ACCELERATION

In contrast, **instantaneous acceleration** is measured over a "short" time interval. The word short in this context means infinitely small or infinitesimal — having no duration or extent whatsoever. It's a mathematical ideal that can can only be realized as a limit. The limit of a rate as the denominator approaches zero is called a derivative. Instantaneous acceleration is then the limit of average acceleration as the time interval approaches zero — or alternatively, acceleration is the derivative of velocity.

$$\vec{\boldsymbol{a}} = \frac{\Delta\vec{\boldsymbol{v}}}{\Delta\boldsymbol{t}} \quad \Delta t \to 0$$

We will be mostly interested in situations where the acceleration is constant, in which case the instantaneous acceleration and the average acceleration are the same thing.

UNITS OF ACCELERATION

The unit of acceleration is $\frac{m}{s^2}$ (metres per secund squared). The sprinter might have an acceleration of 5 $\frac{m}{s^2}$ his velocity increases by 5 $\frac{m}{s}$ every second. We could express acceleration in other units. For example, an advertisement might claim that the car accelerates from 0 to 60 miles per hour (mph) in 10s. Its acceleration would then be 6mph /s. However, mixing together hours and seconds is not a good idea, so acceleration is always given in the standard SI unit.

UNIFORMLY ACCELERATED LINEAR MOTION

The acceleration of an object is constant when the velocity of an object change by an equal amount in every equal time period.
If the velocity of an object increase during the motion, this kind of motion is called uniformly accelerated linear motion (picture 1).
If the velocity of an object decrease during the motion, this kind of motion is called uniformly decelerated linear motion (picture 2).

Picture 1

Picture 2

EQUATIONS OF UNIFORMLY ACCELERATED LINEAR MOTION

This equations can be used when the acceleration is constant. There are five variables in the four kinematics equations. These variables are:
v_0- initial velocity, s- distance travelled, a- acceleration (const), v- final velocity, t- time taken
If the values of the three variables are known, then the value of the fourth variable can be calculated. In this manner, the equations provide a useful means of predicting information about an object's motion if other information is known.
For example, if the acceleration value and the initial and final velocity values of a car is known, then the distance travelled of the car and the time taken can be predicted using the equations.

▶ Equation 1 (The velocity as a function of time)

Acceleration is defined as: $a = (v - v_0)/t$

(We use v_0 for the initial velocity, v for final velocity and t for time taken)

Rearranging this gives the **equation 1** of motion:

$$v = v_0 + a \cdot t$$

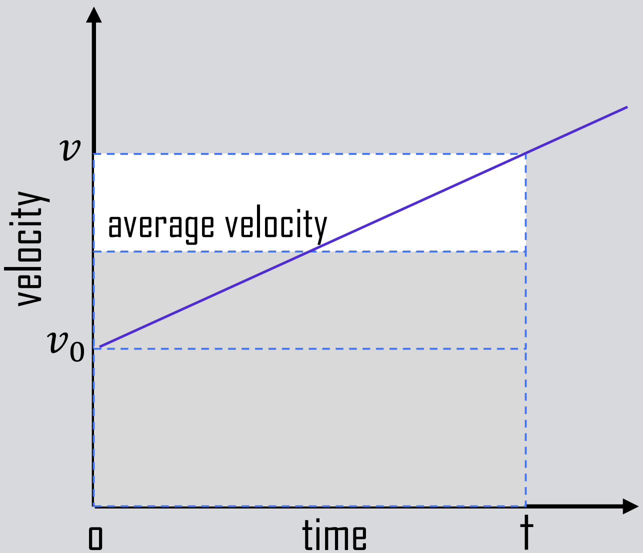
Final velocity = initial velocity + change in velocity

$$v = v_0 + a \cdot t$$

$$v_0 = 0$$

$$v = a \cdot t$$

Final velocity = change in velocity



▶ Equation 2

Distance is given by the area under the velocity-time graph. Graph shows that the object`s average-velocity is half-way between $v_0$ and $v$. So the object`s average velocity, calculated by averaging its initial and final velocities, is given by: $\frac{v+v_0}{2}$

The object distance is the shadow area in graph (this is rectangle), and so we have:

Distance = average velocity × time taken

$$s = \frac{v + v_0}{2} \cdot t$$

▶ Equation 3 (The distance as a function of time)

From **equations 1** and **equation 2**, we can derivate **equation 3** :

$v = v_0 + a \cdot t$ **equation 1** $s = \frac{v_0 + v}{2} \cdot t$ **equation 2**

Substituting v from **equation 1** gives:

$$s = \frac{(v_0 + v_0 + a \cdot t)}{2} \cdot t \Rightarrow s = v_0 \cdot t + \frac{a \cdot t^2}{2}$$

$$s = v_0 \cdot t + \frac{a \cdot t^2}{2}$$

$$v_0 = 0$$

$$s = \frac{a \cdot t^2}{2}$$

▶ Equation 4 (The velocity as a function of distance)

From **equations 1** and **equation 2**, we can derivate **equation 4** :

$v = v_0 + a \cdot t$ **equation 1** $s = \frac{v_0 + v}{2} \cdot t$ **equation 2**

Substituting for time t from **equation 1** gives:

$$s = \frac{v + v_0}{2} \cdot \frac{v - v_0}{a}$$

Rearranging this gives:

$$2as = (v + v_0) \cdot (v - v_0) = v^2 - v_0^2 \Rightarrow v^2 = v_0^2 + 2as$$

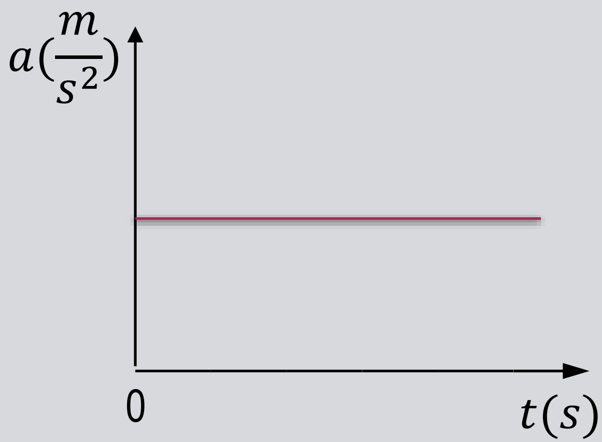
$$v = \sqrt{v_0^2 + 2as}$$

$$v^2 = v_0^2 + 2as$$

$$v_0 = 0$$

$$v = \sqrt{2as}$$

MOTION GRAPHS

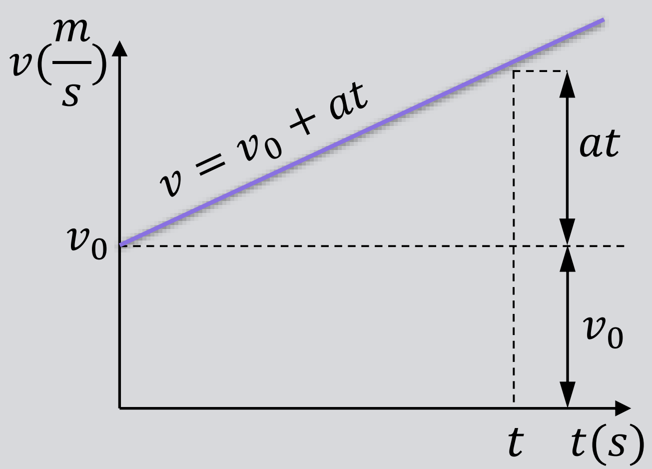


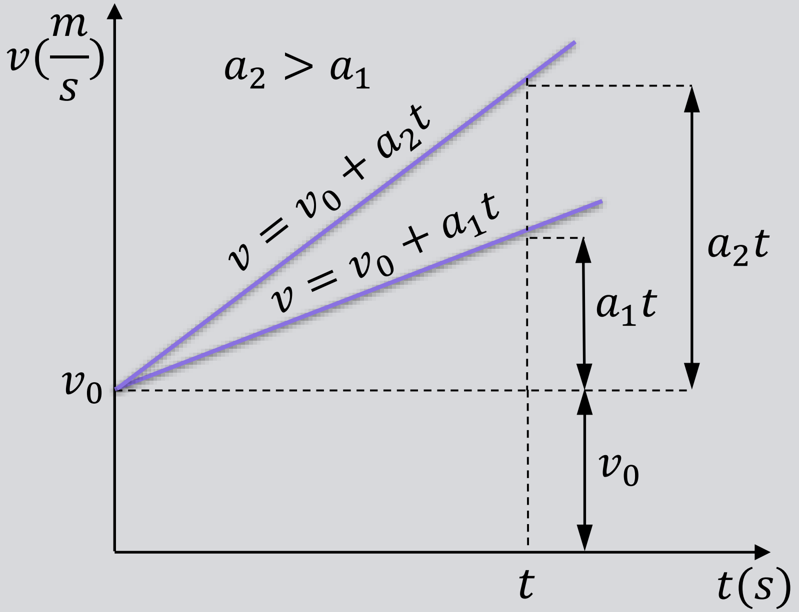
Graph of acceleration versus time

Time is on the x-axis and acceleration is on the y-axis.
The straight horizontal line in the graph shows that the body acceleration does not change as time goes by, so the body is moving at a constant acceleration. Acceleration is positive and body is moving to the right (velocity is positive).

Graph of velocity versus time

Time is on the x-axis and velocity is on the y-axis.
A graph of velocity versus time for uniformly accelerated linear motion gives a diagonal line. In the initial moment $t_0 = 0$ the velocity is equal initial velocity ($v = v_0$) and then the velocity increases so that in a specific moment t velocity has the value $v = v_0 + at$.

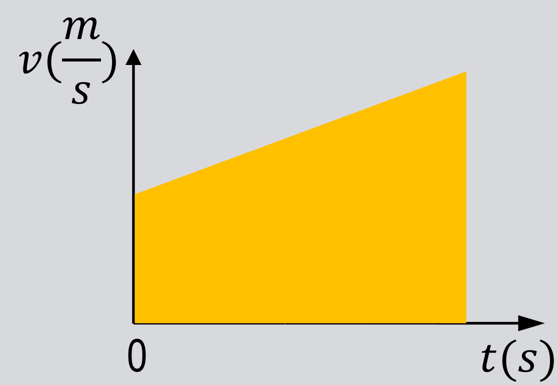




The slope of the velocity graphs depends on the value of the acceleration.

The picture shows two graphs for two different values of acceleration . For the same time (t) the velocity of a body with acceleration a_2 is larger than the velocity of a body with acceleration a_1. So the graph with the larger acceleration a_2 is steeper than the graph with a smaller acceleration a_1. So if the value of acceleration is higher, than the graph of velocity versus time is steeper.

Even in case of accelerated motion, the distance is equal to the area under velocity / time graph, just as in uniform motion. .



PROBLEMS

1. How long does it take for a car to increase its velocity in a uniformly accelerated motion from 36 km/h to 72 km/h over a distance of 150 m? What is its acceleration?

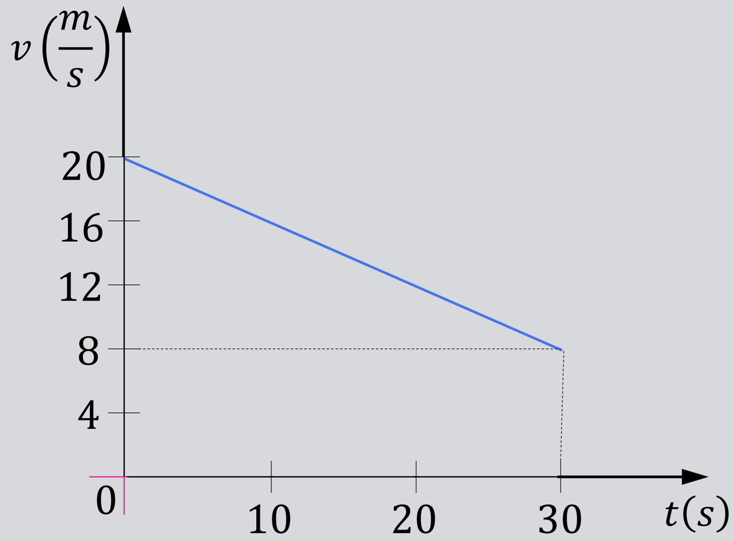
2. A car started from rest and moved with constant acceleration. After 1 s its velocity is 3m/s.
a) Find the velocity of a car after 5 s?
b) Find the distance covered by the car after 10 s?

3. A body starts from rest and cover a distance Δs = 27m during the fifth second of its motion. Find the acceleration of the body. ?

4. A world's land speed record was set by Colonel John P. Stapp when in March 1954 he rode a rocket-propelled sled that moved along a track at 1020 km/h. He and the sled were brought to a stop in 1.4 s. In terms of *g*, what acceleration did he experience while stopping?

5. A bus is moving with a velocity of $36\frac{km}{h}$. Before the traffic light the driver starts to break and bus will stop after 10 s. What is the deceleration of the bus? How far was bus from the traffic light when it began to break?

6. The velocity-time graph represents the motion of a car along a straight road for a period of 30 s.



a) Describe the motion of the car

b) From the graph, determinate the car's initial and final velocities over the time of 30 s

c) Derminate the acceleration of the car

d) By calculating the area under the graph, determinate the distance of the car

7. A train started from rest and moved with constant acceleration. At one time it was travelling $30\,\frac{m}{s}$, and 160 m further it was travelling $50\,\frac{m}{s}$. Calculate:

a) the acceleration

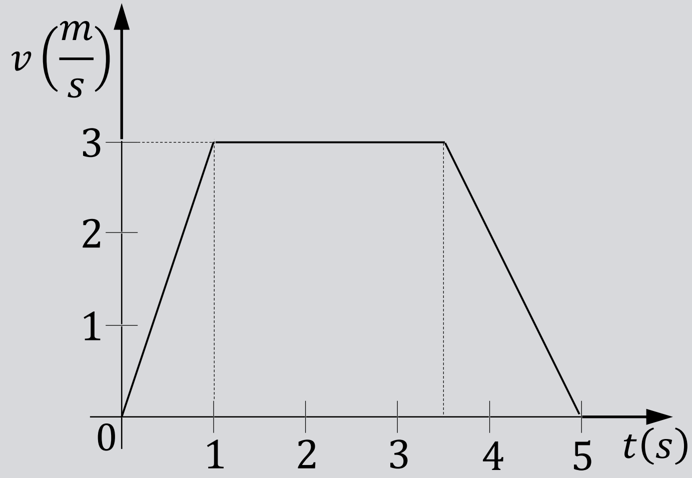
b) the time required to trevel 160m mentioned

c) the time required to attain the speed of $30\,\frac{m}{s}$

d) the distance moved from rest to the time the train had a speed of $30\,\frac{m}{s}$

8. Two bodies set off from point A and B towards each other. The one leaving point A drives with a uniform acceleration $1\frac{m}{s^2}$ and initial velocity $15\frac{m}{s}$, while the other goes with a uniform deceleration $1\frac{m}{s^2}$ and initial velocity $10\frac{m}{s}$. Determinate the time of motion and the distance covered by the first body before they meet, if the distance between A and B is 30 m.

9. Graph showes the variation of the velocity of a moving object with time.



a) Draw the graph showing the variation of the acceleration with time

b) Calculate average speed for all 5 s

10. Graph showes the variation of the acceleraation of a moving object with time. Draw the graph showing the variation of the velocity with time. Initial velocity of the object is $2\frac{m}{s}$.