Acceleration formula Notes

Acceleration Formula

Acceleration is the rate of change of velocity with time. It is a measure of the change in the velocity of an object per unit time and mathematically acceleration formula is given as

$$Acceleration = \frac{change\ in\ velocity}{time\ taken}$$

For describing average acceleration, we first consider the motion of an object along straight line.
Suppose at time t_1 object is at point P moving with velocity v_1 and at time t_2 it is at point Q and has velocity v_2. Now average acceleration of object in moving from P to Q is

$$a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

which is the change in velocity of object with the passage of time.

If the velocity of an object changes from an initial value u to the final value v in time t, the acceleration a is given by,
a=(v-u)/t
and this kind of motion is called accelerated motion.

Important Points about Acceleration Formula

1) Since velocity of a moving object has both magnitude and direction likewise acceleration depending on velocity has both magnitude and direction and hence acceleration is a vector quantity.

2) SI unit of acceleration is ms^{-2}

3) A body has uniform acceleration if it travels in a straight line and its velocity increases by equal amount in equal intervals of time for example freely falling bodies, motion of ball rolling down the inclined plane etc.

4) A body has non-uniform acceleration if its velocity increases or decreases by unequal amount in equal intervals of time.

5) If acceleration is in the direction of the velocity then it is positive acceleration and if it is in the direction opposite to the direction of velocity then it is negative and the negative acceleration is termed retardation or deceleration.

Example -1

A motorbike moves in a straight road. The velocity at point A is 36 km/hr, It presses the accelerator paddle and reach point B in 10 sec. The velocity at point B is 54Km/hr
Find the average acceleration of the car from point A to point B?

Solution

Average acceleration is given by

$$Acceleration = \frac{change\ in\ velocity}{time\ taken}$$

Initial velocity= 36 km/hr=10 m/s
Final Velocity = 54 km/hr=15 m/s
Average acceleration= (15-10)/10= .5 m/s^2

Example -2

True and False Statement
a) Acceleration is a scalar quantity?
b) if the velocity of the object is zero, then acceleration will always be zero
c) If a car is moving fast, does it always have acceleration?

Solution

a) False. Acceleration is vector quantity
b) False.
c) False. Fast does not mean acceleration always. It may be moving with high velocity but velocity may not be changing

Motion with constant acceleration

Motion with constant acceleration or uniformly accelerated motion is that in which velocity changes at the same rate throughout motion.
Here are the equations for uniformly accelerated motion in a straight line

$v=u+at$

$v^2 = (u)^2 + 2as$

$s = ut + \frac{1}{2}(at^2)$

Where
v=Final Velocity
u=Initial Velocity
a= Constant acceleration
t= time interval
s= displacement

Example -3
A train starts from rest and accelerate uniformly at the rate of 5 m/s^2 for 10 sec.
a) Calculate the velocity of train in 10 sec.
b) Distance traveled by train in 10 sec
Solution
Here it is the example of uniformly accelerated motion
$a=5\ m/s^2$
u=0
t=10 sec
v=?
s=?
From
$v=u+at$
$v= 0 + 5\times10$
=50 m/sec
From
$s = ut + \frac{1}{2}(at^2)$
$s= \frac{1}{2}(5\times10^2)=250$ m

Free fall acceleration

Freely falling motion of anybody under the effect of gravity is an example of uniformly accelerated motion.
Kinematic equation of motion under gravity can be obtained by replacing acceleration **'a'** in equations of motion by acceleration due to gravity **'g'**.
$v=u+gt$

$v^2 = (u)^2 + 2gs$
$s = ut + ½ (gt^2)$

Where
v=Final Velocity
u=Initial Velocity
g= Constant acceleration
t= time interval
s= displacement

The value of g is taken positive when the body falls vertically downwards and negative when the body is projected up against gravity.
Value of g is equal to 9.8 $m.s^{-2}$.

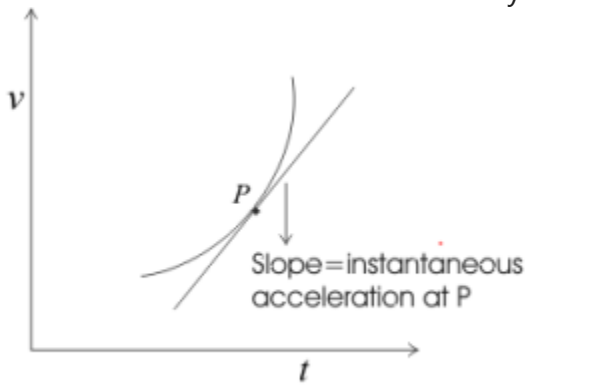
Example -4
An object dropped from a cliff falls with a constant acceleration of 10 m/s^2. Find its speed 5 s after it was dropped
Solution
It is an example of Free Fall acceleration
u=0
t=5 s
g=10
v=?
From
v=u+ gt
=10×5 =50 m/s

Instantaneous acceleration formula

The acceleration of the moving body at any instant of time is defined as its instantaneous acceleration.
Instantaneous acceleration can be defined in the same way as instantaneous velocity

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

The instantaneous acceleration at any instant is the slope of v-t graph at that instant.



Velocity time graph of particle

Above figure shows instantaneous acceleration at point P is equal to the slope of tangent at this point P.

Example

A train is moving on the rail track. The distance traveled by it is defined by the following equation:

$x = t^3 + t + 4$

Find the instantaneous acceleration at time t = 1 se?

Solution

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

Now

$x = t^3 + t + 4$

We know that v= dx/dt

So

$v = 3t^2+1$

Acceleration would be given by

$a = 6t$

So, instantaneous acceleration at time t = 1 sec

$= 6\ m/s^2$

Practice Questions on Acceleration Formula with Distance

Question 1

On a highway with speed limit 80km/h, a car was stopped by applying brakes with a retardation of $5m/s^2$ in 5 seconds. What is the initial velocity of the car. Was it over-speeding?

Question 2

A cycle travelling with a velocity of 20km/h, accelerates at the rate of 0.10m/s^2. After what time will it achieve a velocity of 38km/h?

Question 3

A truck moves with a velocity of 36km/h. How much distance will it cover in 1 minute if it moves with a uniform acceleration of 1m/s^2?

Question 4

A car starts and attains a velocity of 60m/s in 30s. If the acceleration is uniform, what is the distance travelled by the car to achieve this velocity?

Question 5

A car travelling with a velocity of 10m/s stops on application of brakes. It produces a uniform retardation of 1.25m/s2. Calculate the distance travelled by the car before it comes to rest. Also, find the time taken by the car to stop.

Question 6

How much distance will a vehicle moving with uniform acceleration of 4m/s2 cover in 5 seconds if the initial velocity of the vehicle is 5m/s.

Question 7

A bullet leaves a rifle with a muzzle velocity of 521m/s. While accelerating through the barrel of the riffle, the bullet moves a distance of 0.840 m. Determine the acceleration of the bullet (assume a uniform acceleration).

Question 8

The observation deck of the tall skyscraper 370 m above the street. Determine the time required for a penny to free fall from the deck to the street below.

Question 9

Honda Activita accelerates uniformly from rest to a speed of 7.10 m/s over a distance of 35.4 m. Determine the acceleration of the bike.

Question 10

If a car has a constant acceleration of 4 m/s2, starting from rest, how fast is it traveling after 5 seconds?

Question 11

What is the acceleration of Honda with a constant velocity of 50 km/h for 20 second? Does the car have a constant acceleration?

Question 12

A boy on a bicycle increases his velocity from 5 m/s to 20 m/s in 10 seconds.
a) What is the acceleration of the bicycle?
b) What distance was covered by the bicycle during the 10 seconds?

Acceleration Direction

Acceleration is a vector quantity so it has both magnitude and direction. Direction of acceleration is in the direction of velocity if it is increasing and opposite to the direction of velocity if the velocity is decreasing

Now we use + and – to specify direction in physics. + stands for positive direction and – negative stands for the opposite of positive dimension

if the velocity is in positive direction and it is increasing, acceleration will be positive direction and will be positive

Example
u= 2 m/s (+ as positive direction)
v=3m/s ,t=1 sec
a= (3-2)/1= 1m/s^2
o acceleration is positive

if the velocity is in positive direction and it is decreasing, acceleration will be negative direction and will be negative

Example
u= 2 m/s (+ as positive direction)
v=1m/s ,t=1 sec
a= (1-2)/1= -1m/s^2
So acceleration is negative

if the velocity is in negative direction and it is increasing, acceleration will be negative direction and will be negative

Example
u= -2 m/s (– as negative direction)
v=-3m/s ,t=1 sec

a= (-3+2)/1= -1m/s^2
So acceleration is negative

if the velocity is in negative direction and it is decreasing, acceleration will be positive direction and will be positive

Example
u= -2 m/s (– as negative direction)
v=-1m/s ,t=1 sec
a= (-1+2)/1= 1m/s^2
So acceleration is positive.

Acceleration in Curvilinear Motion

So far we have seen acceleration examples in One dimensional motion. Now we will study the acceleration in Curvilinear motion. Curvilinear motion happens when object or particles moves along a specific curve path. It can be two dimensional or Three dimension.

Basic principle of acceleration remains same but we must deal with 2 or 3 direction in curvilinear motion.

Please look at the below links to get good knowledge on Acceleration in Two or Three-dimensional motion. It provides acceleration formula for those motions also. This also contains example to solve such problem

Centripetal Acceleration Formula

when a particle moves along a circular path it must have components of acceleration perpendicular to the path when its speed is constant. Such type of circular motion is called Uniform circular motion

The magnitude of the instantaneous normal acceleration is equal to the square of the speed divided by the radius. Its direction is perpendicular to velocity vector and acts along inward direction along the radius of the circular path towards the center of the circle.

Because of this it is called central or centripetal acceleration. The term centripetal means seeking the center.

Centripetal Acceleration Formula = v^2/R

Where v is the speed of the object and R is the radius of the circular path