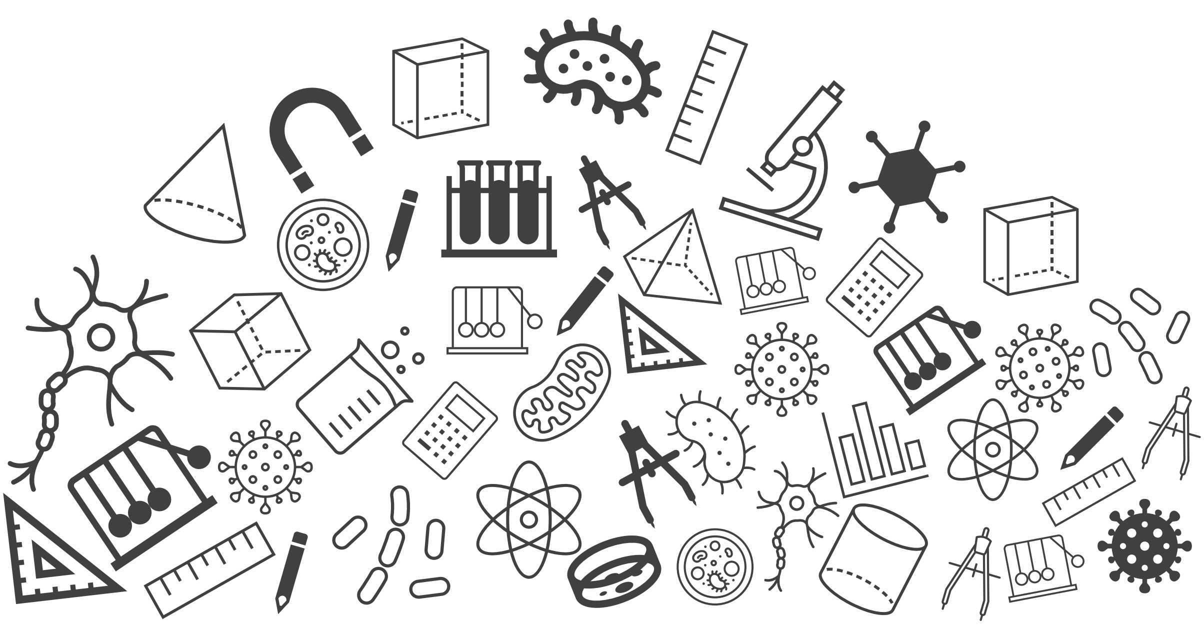
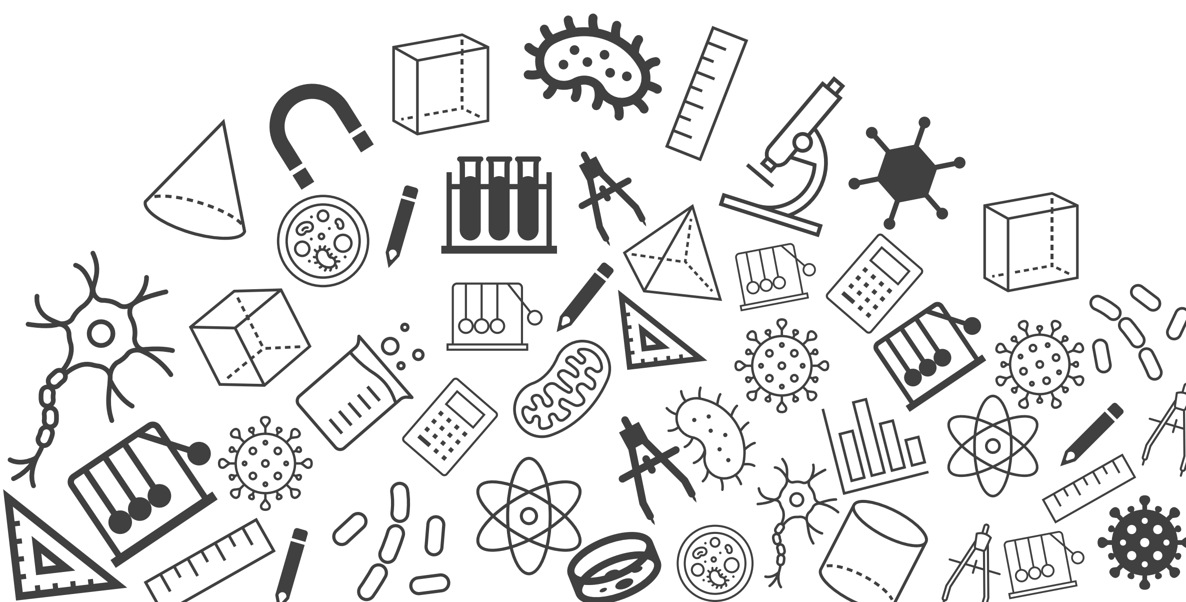
Grade 09

Science Chapter Notes



Force and Laws of Motion



Force and Laws of Motion

1. Why is the luggage kept on the roof of a bus tied with a rope?

   [1 Mark]

   [Inertia]

   Solution:
   In a moving vehicle, like a bus, the motion is not uniform. The speed of the vehicle varies and there are instances of sudden brakes or turns throughout the journey.

   [0.5 Mark]

   Due to inertia, the luggage kept on top will resist any change in its state of rest or motion or direction and will have a higher tendency to fall.

   [0.5 Mark]

   Thus, it is secured with a rope to prevent it from falling.

2. A horizontal force of $200\ N$ is applied to move a wooden cabinet across a floor at a constant velocity. What is the friction force that is exerted on the cabinet?

   [2 Marks]

   [Newton's First Law of Motion]

   Solution:
   Since the velocity of the cabinet is constant, its acceleration must be zero. Therefore, the effective force acting on it must also be zero.

   [0.5 Marks]

   This implies that the magnitude of opposing frictional force is equal to the force exerted on the cabinet, which is $200\ N$.

   Therefore, the total frictional force is $200\ N$ in the opposite direction of applied force.

   [1.5 Marks]

3. A stone of $1\ kg$ is thrown across a frozen lake with a velocity of $20\ ms^{-1}$. After travelling a distance of $50\ m$, it comes to a rest. What is the force of friction between the stone and the ice?
[4 Marks]
[Newton's Second Law of Motion]

Solution:

Given:

Mass of the stone, $m = 1\ kg$

Initial velocity, $u = 20\ ms^{-1}$

Final velocity, $v = 0\ ms^{-1}$

Distance travelled, $s = 50\ m$

As per the equation of motion,

$v^2 – u^2 = 2as$ [1 Mark]

$a = (v^2 – u^2)$

$a = (0 – 400)$

$a = -4ms^{-2}$ [2 Marks]

As per the second law of motion, $F = ma$

Force F acting on the stone $= 1kg \times (-4ms^{-2})$

$F = -4N$ [1 Marks]

The magnitude of the force of friction is $4N$, and it acts in the opposite direction of the motion of the stone.

4. A motorcar of mass 1200 kg is moving along a straight line with a uniform velocity of 90 $kmph$. Its velocity is slowed down to 18 $kmph$ in 4 s by an unbalanced external force. Calculate the acceleration and change in momentum. Also calculate the magnitude of the force required.
[4 Marks]
[Newton's Second Law of Motion]

Solution:
Mass of the motor car, m = 1200 kg
Initial velocity of the motor car, u = 90 $kmph$ = 25 ms^{-1}
Final velocity of the motor car, v = 18 $kmph$ = 5 ms^{-1}
Time taken, t = 4 s
According to the first equation of motion:
v = u + at [0.5 Marks]
5 = 25 + a (4) [0.5 Marks]
a = - 5 ms^{-2} [1 Mark]
Negative sign indicates that its a retarding motion i.e., velocity is decreasing.
Change in momentum = mv - mu = m(v-u) = 1200 (5 - 25) = - 24000 kgms^{-1}
[1 Mark]

Force = Mass $\times$ Acceleration = 1200 $\times$ - 5 = - 6000 N
[1 Mark]
Acceleration of the motor car = - 5 ms^{-2}
Change in momentum of the motor car = - 24000 kg ms^{-1}
Hence, the force required to decrease the velocity is 6000 N.
(Negative sign indicates retardation, decrease in momentum and retarding force.)

5. If the mass of the object is doubled and acceleration is reduced to half of it, then net force will:

a) get doubled
b) remain same
c) reduce to half
d) reduce to $\frac{1}{4}^{th}$

[1 Mark]
[Newton's Second Law of Motion]

Solution:
Correct answer is option b. [1 Mark]
Force = $m \times a$
Let m be the mass and a be the acceleration.
Now, mass is doubled, (2m) and acceleration is reduced to half, $\frac{a}{2}$.
$\therefore$Force =$2m \times \frac{a}{2}$
=$m \times a$
$\therefore$Force = $m \times a$; which remains same.

6. What is the momentum of a man of mass 100 kg when he walks with a uniform velocity of 2 m s^{-1}?

a) 300 kg m s^{-1}
b) 50 kg m s^{-1}
c) 100 kg m s^{-1}
d) 200 kg m s^{-1}

[1 Mark]
[Momentum]

Solution:
Correct answer is option d. [1 Mark]
Given:
Mass, $\text{m} = 100 \text{ kg}$
Velocity, $\text{v} = 2 \text{ m s}^{-1}$
Let the momentum be $'\text{p}'$.
$\text{p} = \text{mv} = 100 \times 2 = 200 \text{ kg m s}^{-1}$

Force and Laws of Motion

7. Define Inertia. Describe a simple experiment to demonstrate the inertia of rest.
[2 Marks]

Solution:

Inertia is the property of matter by which it continues in its existing state of rest or uniform motion in a straight line, unless that state is changed by an external force. [1 Mark]

Here is an experiment to demonstrate the inertia of rest.

Activity:
1. Make a pile of similar carom coins on a table.
2. Attempt a sharp horizontal hit at the bottom of the pile using another carom coin or the striker. [0.5 Mark]

Observation:
If the hit is strong enough, the bottom coin moves out quickly. Once the lowest coin is removed, the inertia of the other coins makes them 'fall' vertically on the table.
Conclusion:
The activity given above illustrates that there is a resistance offered by an object to change its state of motion.
[0.5 Mark]

8. Derive the relationship F = ma, where each symbol has its usual significance. [3 Marks]

Solution:
Suppose an object of mass, m is moving along a straight line with an initial velocity, u. It is uniformly accelerated to velocity, v in time, t by the application of a constant force, F throughout the time, t. The initial and final momentum of the object will be, $p_1 = mu$ and $p_2 = mv$ respectively.

$$The\ change\ in\ momentum\ \propto\ p_2 - p_1$$

$$\propto\ mv - mu$$

$$\propto\ m \times (v - u)$$ [1 Mark]

The rate of change of momentum $\propto \frac{m(v-u)}{t}$
Or, the applied force,
$F\ \propto \frac{m(v-u)}{t}$
$F = \frac{km(v-u)}{t}$
$F = kma$ [1 Mark]
Here $\left[a = \frac{(v-u)}{t}\right]$ is the acceleration, which is the rate of change of velocity.
The quantity, k is a constant of proportionality. The SI units of mass and acceleration are kg and ms^{-2} respectively. The unit of force is so choosen that the value of the constant, k becomes one. For this, one unit of force is defined as the amount that produced an acceleration of $1\ ms^{-2}$ in an object of 1 kg mass. That is, $1\ unit\ of\ force = k \times (1kg) \times (1\ ms^{-2})$.
Thus, the value of k becomes 1.Hence
F=ma
The unit of force is $kgms^{-2}$ or newton, which has the symbol N. The second law of motion gives us a method to measure the force acting on an object as a product of its mass and acceleration. [1 Mark]

Force and Laws of Motion

9. A bullet of 10 g strikes sand-bag at a speed of $10^3\ m/s$ and gets embedded after travelling 5 cm. Calculate

(i) the resistive force exerted by the sand on the bullet
(ii) time taken by bullet to come to rest.
[4 Marks]

Solution:
(i) Given,
Mass $(m) = 10g = \frac{10}{1000} kg = 0.01\ kg$

Initial velocity, $u = 10^3\ m/s$

Final velocity, $v = 0$

Distance $s = \frac{5}{100} m = 0.05\ m$
Let the acceleration be a.

Using, the third equation of motion

$v^2 - u^2 = 2as$

$0 - (10^3)^2 = 2a \times \frac{5}{100}$

$\Rightarrow a = \frac{-1000 \times 1000}{2 \times 5} \times 100$

$= -10^7\ ms^{-2}$

According to Newton's second law of motion force,
$F = ma = 10^{-2} \times 10^7 = 10^5\ N$ [2 Marks]

(ii) Let time be t.

Using, the first equation of motion

$v = u + at$

$0 = 10^3 - 10^7 t$

$10^7 t = 10^3$

$\Rightarrow t = \frac{10^3}{10^7} = 10^{-4}\ s$ [2 Marks]

10. What is momentum? Write its S.I. unit. Interpret force in terms of momentum.
Represent the following graphically
(a) momentum versus velocity when mass is fixed.
(b) momentum versus mass when velocity is constant
[5 Marks]
[Newton's Second Law of Motion]

Solution:

Momentum of a body is defined as the product of its mass and velocity.It is a vector quantity.
Mathematically,
Momentum (p) = mass (m) x velocity (v)
or, p = m v

S.I. unit of momentum is $kg\, m/s$

According to newton's second law,
Force acting on a body is equal to the rate of change of momentum.
or,
Force (F) = Change in momentum / time

As, momentum (p) = mass x velocity [1 Mark]

(a) when mass is fixed,
momentum will vary linearly with velocity as shown in graph.
[2 Marks]

(b) when velocity is fixed
momentum will vary linearly with mass as shown in graph.
[2 Marks]