CLASS 9th

FORCE & LAWS OF MOTION

Best Handwritten Notes

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Force and laws of Motion

- Force and it's Effects
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- 1st Law of Motion
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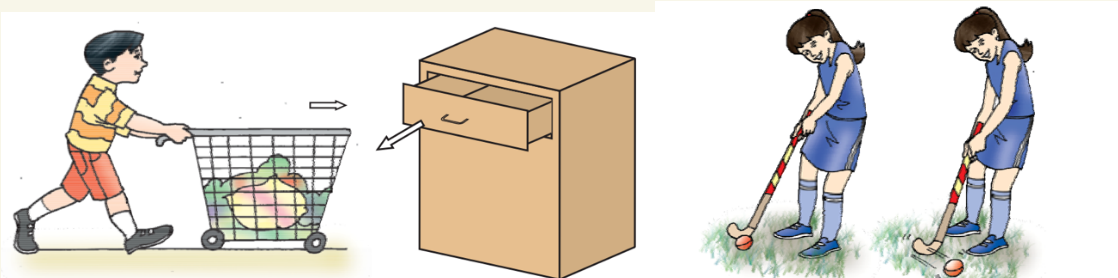
Some effort is required to put a stationary object into motion or to stop a moving object, this 'effort' is called Force.
Either we push, hit or pull the object to change its state of motion.



(a) The trolley moves along the direction we push it.
(b) The drawer is pulled.
(c) The hockey stick hits the ball forward

Effect of Force:

1. Force can be used to change the magnitude of velocity of an object.

For example, if you push a toy car, it goes faster. If you push it gently, it goes slower. So, force can change how fast things move.

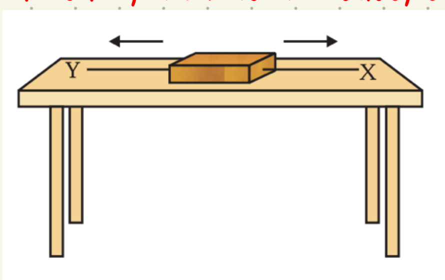
2. Force can change the shape and size of object.

If you push or pull on something really hard, it can change its shape or size. For instance, if you squeeze a soft ball really tight, it gets smaller. That's another way force works.

Force → Balanced Force
Force → Unbalanced Force

BALANCED FORCE:

Balanced forces are like a Tug of War between two teams that are equally strong. Neither side wins, and the rope stays in the same place.
When these equal forces act on an object, they cancel each other out. It's like they are fighting against each other, and as a result, the object doesn't move.



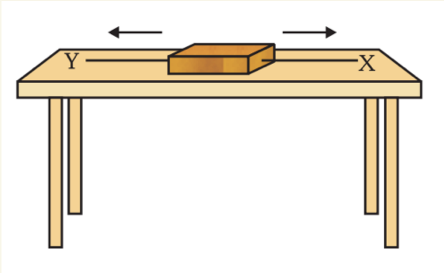
1. Balanced forces can also change the shape and size of an object if they are applied from different directions.
2. The important thing to remember is that when balanced forces are at play, there's no change in the state of motion (whether it's moving or at rest) of an object.

3. In balanced forces, the "resultant force" is equal to zero, meaning there's no overall force pushing or pulling the object. That's why it doesn't move.

#UNBALANCED FORCE:

Unbalanced forces are like a friendly competition where one team is stronger than the other in a Tug of War. This means someone's going to win, and things are going to change.

When unbalanced forces are at work, the "resultant force" is greater than zero. This means there's a winner in the tug of war, and the object will start moving in the direction of the stronger force.



1. Unbalanced forces don't just affect motion. They can also change the shape and size of objects if they're strong enough
2. Unbalanced forces are the ones that make things start moving or stop moving. They can also make objects speed up or slow down.

1st Law of Motion

It states- "An object remains in a state of rest or of uniform motion in a straight line unless compelled to change that state an applied force."

1. In simple terms, objects are a bit lazy and don't like to change their behavior by themselves. They need a push or a pull to start moving, stop moving, or change how they're moving.
2. It is also called "The Law of Inertia"

APPLICATION OF FIRST LAW OF MOTION IN EVERY DAY'S LIFE:

1. Braking in a Car:

- Imagine you're in a moving car, and suddenly, the driver slams on the brakes. What happens? You lurch forward, right?
- This happens because both you and the car were in motion, moving forward. When the driver hits the brakes, the car stops suddenly, but your body wants to keep going forward because of its motion.
- So, when the car brakes sharply, the part of your body in contact with the car stops, but the rest of your body keeps moving. That's why you feel like you're leaning forward when the car stops suddenly.

2. Turning in a Car:

• Now, assume a car taking a sharp turn at a high speed. What do you feel? You tend to slide to one side, right?

• This occurs because your body likes to keep going in a straight line unless something pushes or pulls it in a different direction. So, when the car suddenly turns, your lower body, which is connected to the car, starts moving with it.

• However, your upper body doesn't immediately change its direction. It wants to keep going straight. So, you feel like you're leaning or sliding to one side as the car turns because your body is trying to keep its original motion.

INERTIA and MASS:

Imagine if you try to make something that's not moving start moving, like a football on the ground. It's much easier to do this than trying to do the same with a big heavy stone.

• Inertia is all about how hard it is to change an object's state of motion (whether it's at rest or already moving).

#Kitaabi Definition: The minimum force required to change the state of motion of rest of a body is called Inertia.

• The more massive (heavier) an object is, the more inertia it has. Inertia is like a force of laziness, and it takes more effort (force) to change the motion of something with more mass.

• For example, think about a train and a shopping cart. The train is much heavier (has more mass) than the cart. So, it has more inertia. It's harder to make the train start moving or stop than it is with the cart because the train has more of this "inertia laziness".

L.P. [NCERT Intext Pg91]

L.P. 1: Which has more inertia, a rubber ball or a stone of the same size?

Answer: Inertia depends on an object's mass, and the stone is heavier (has more mass) than the rubber ball. So, because the stone is heavier, it has more inertia.

L.P. 2: Explain why leaves fall when you shake a tree branch.

Answer: • Normally, when a tree is not moving, its leaves also stay still. But when you shake the branch vigorously, you're putting the tree in motion.

• When the tree is moving, the leaves want to stay at rest because of their inertia. But the force from shaking the branch acts on the leaves, making them change direction.

• This change in direction causes the leaves to fall from the tree. It's like when you're in a moving car, and you suddenly stop; things inside the car tend to keep moving until something (like a seatbelt) stops them. In this case, the shaking of the branch makes the leaves fall from the tree.

Momentum: Imagine you're playing with a big, heavy toy car, and you give it a strong push. It's going to be hard to stop it because it has a lot of momentum. But if you have a small, light ball and you give it a gentle push, it's easy to stop because it has less momentum.

So, momentum is like a measure of how "pushy" things are when they're moving. The heavier and faster they are, the more momentum they have, and the harder they are to stop.

- Denoted by 'p'
- Mathematically, it is the product of the mass of an object and its velocity.

$$p = m \times v$$

- It has both magnitude and direction.
- Direction is same as that of velocity. So, if something is moving to the right, its momentum is also to the right.
- Its SI Unit is Kg m /s

2nd Law of Motion

It states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force.

MATHEMATICAL FORMULATION OF SECOND LAW OF MOTION:

Imagine an object with mass 'm' that's moving in a straight line with an initial speed 'u'. If we want to make it speed up to 'v' by applying a constant force 'F' for a time t', we can calculate the change in its momentum.

The initial momentum (p1) is 'mu', and the final momentum (p2) is 'mv'. The change in momentum is like the difference between the final and initial momentum, and it's proportional to 'm' times the change in speed (v - u).

Now, the rate at which momentum changes is proportional to 'm', 'v', 'u', and '. This is the same as the applied force 'F'. So, we have the formula:

Or the force applied $F \propto \dfrac{m(v-u)}{t}$

$$F = \frac{Km(v-u)}{t}$$

also $= F = Kma$ $\left[\text{where } a = \dfrac{v-u}{t}\right]$

k = constant of proportionality
F = force
m = mass of object
a = acceleration

S.I unit $kg\ m/s^2$ or Newton.

One Newton : When acceleration of $1 m/s^2$ is produce on an object of mass 1 kg by an application of 1 N force.

The first law of motion can be mathematically stated from second law of motion

$$F = ma$$

or $$F = \frac{m(v-u)}{t}$$

$$Ft = mv - mu.$$

*Solve Example 9.1 to 9.5 from NCERT

Examples of the Second Law of Motion:

1. A Ball Accelerating:

- Imagine you have a ball, and you give it a good push. If you push it harder, it moves faster, right? That's because the speed (acceleration) the ball gets is directly connected to how hard you push it.
- So, the more force (push) you apply to the ball, the faster it goes. It's like a super-fast race car needs a strong engine (force) to go really fast.

2. Pushing a Cart:

- Think about pushing a cart. If the cart is empty (not carrying anything), it's pretty easy to push, right? But if you put a lot of heavy stuff in it, it becomes harder to move.
- This is because the amount of stuff (mass) in the cart affects how much you need to push (force) to make it move. The more stuff (mass) you add, the more force you need to make it go.

So, the Second Law of Motion tells us that how fast something moves (its acceleration) depends on how much force you apply to it. And when there's more mass (stuff) to move, you need more force to get it going.

L.P. Which would require a greater force? - Accelerating a 2kg mass at 5 m/s^2 or 4kg at 2 m/s^2 ?

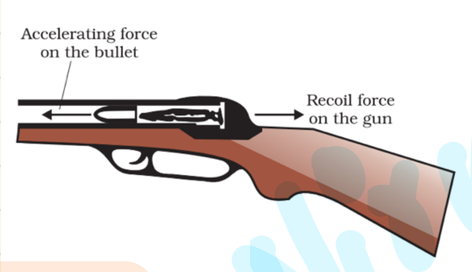
Answer: We know F=ma, so we only have to find put whether F1 > F2 or F2 > F1
Now, F1= m1 x a1 = 2x5= 10
F2=m2 x a2= 4x2= 8

Clearly, F1 > F2, so accelerating a 2kg mass at 5 m/s^2 would require a greater force.

3rd Law of Motion

States that "For every action there is an equal and opposite reaction".

When any object applies force on another object, the object instantaneously exerts back equal force back on the first object.
For example: When bullet is fired, it exerts a forward force on bullet. Then bullet exerts a equal and opposite force on the gun. This result in recoil of the gun.



Characteristics of 3^{rd} Law of Motion:

1. Equal and Opposite: Action and reaction forces are like a pair of friends pushing each other with the same amount of strength but in opposite directions. They are equal in size but point in opposite ways.
2. Different Objects: These forces never act on the same object. One force pushes one object, and the other force pushes a different object.
3. Action and Reaction Names: You can think of these forces like a duo where you have a "doer" and a "receiver." It doesn't matter which one you call "action" or "reaction"; they both play equal roles. One pushes, and the other pushes back.
4. Two Objects at Once: Action and reaction forces always happen between two different objects at the same time. When you push on something, it pushes back on you, even if it's not so obvious.

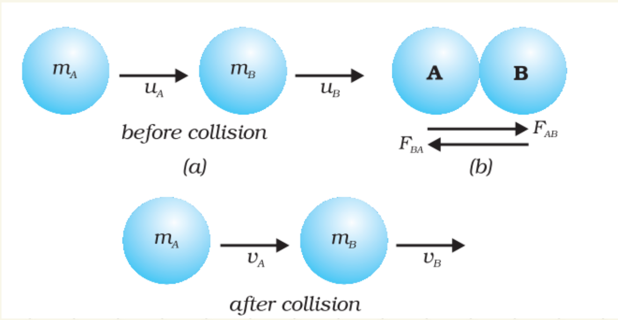
Now, here's something interesting: even though action and reaction forces are the same size, they don't always cause the same changes. Why?
Because the objects they act on might have different weights (masses). If you push a feather and push a brick with the same force, the feather will move a lot more because it's lighter. So, it's not just about how hard you push; it's also about how

heavy the object is that you're pushing. That's why they might not produce equal acceleration (how fast something speeds up or slows down).

Conservation of Momentum

It says that – "The sum of momenta of the two objects before collision is equal to the sum of momenta after the collision provided there is no external force acting upon them"

Sum of initial momentum = sum of final momentum



Suppose two objects (say ball A & B) of masses m_B and m_B are travelling along a straight line with different velocities u_A and u_B respectively. These two balls collide for time t and acquire force F_{AB} i.e. ball A exerts a force on Ball B and Ball B exerts F_{BA} force on ball A. They acquire velocity v_A and v_B respectively.

Initial momentum of Ball A= $m_A u_A$
Initial momentum of Ball B= $m_B u_B$

Final momentum of Ball A= $m_A v_A$
Final momentum of Ball B= $m_B v_B$

The rate of change of its momentum for ball A,

$$F_{AB} = \frac{\text{Final momentum} - \text{Initial Momentum}}{t}$$

$$= \frac{mv_A - mu_A}{t} = \frac{m(v_B - u_B)}{t}$$

Similarly, rate of change of momentum for Ball B (F_{BA}) = $\frac{m(v_B - U_B)}{t}$

Now, according to 3rd Law of motion: The force F_{AB} exerted by ball A on ball B and force F_{BA} exerted by ball B on ball A must be equal and opposite to each other.

Therefore – $F_{AB} = - F_{BA}$

$$= \frac{m(v_A - u_A)}{\cancel{t}} = - \frac{m(v_B - u_B)}{\cancel{t}}$$

$$mv_A - mu_A = -mv_B + mu_B$$
$$mv_A + mv_B = mu_A + mu_B$$

rearranging the above equation we get,

$$\boxed{mu_A + mu_B = mv_A + mv_B}$$

L.P. [NCERT Intext Ex]

Example 9.6 A bullet of mass 20 g is horizontally fired with a velocity 150 m s^{-1} from a pistol of mass 2 kg. What is the recoil velocity of the pistol?

Solution:

We have the mass of bullet, m_1 = 20 g (= 0.02 kg) and the mass of the pistol, m_2 = 2 kg; initial velocities of the bullet (u_1) and pistol (u_2) = 0, respectively. The final velocity of the bullet, v_1 = + 150 m s^{-1}. The direction of bullet is taken from left to right (positive, by convention, Fig. 9.17). Let v be the recoil velocity of the pistol.

Total momenta of the pistol and bullet before the fire, when the gun is at rest

$= (2 + 0.02)\ \text{kg} \times 0\ \text{m s}^{-1}$
$= 0\ \text{kg m s}^{-1}$

Total momenta of the pistol and bullet after it is fired

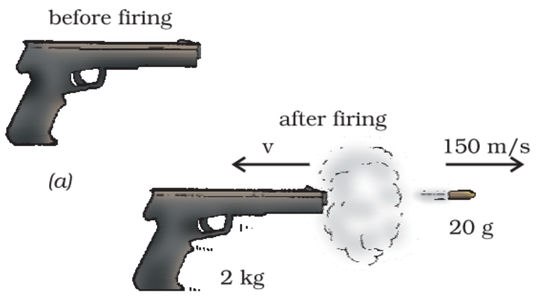
$= 0.02\ \text{kg} \times (+\ 150\ \text{m s}^{-1}) + 2\ \text{kg} \times v\ \text{m s}^{-1}$
$= (3 + 2v)\ \text{kg m s}^{-1}$

According to the law of conservation of momentum

Total momenta after the fire = Total momenta before the fire

$3 + 2v = 0$
$\Rightarrow v = -1.5\ \text{m s}^{-1}$.

Negative sign indicates that the direction in which the pistol would recoil is opposite to that of bullet, that is, right to left.



(a) (b)

Example 9.7 A girl of mass 40 kg jumps with a horizontal velocity of 5 m s^{-1} onto a stationary cart with frictionless wheels. The mass of the cart is 3 kg. What is her velocity as the cart starts moving? Assume that there is no external unbalanced force working in the horizontal direction.

Solution:

Let v be the velocity of the girl on the cart as the cart starts moving.

The total momenta of the girl and cart before the interaction

$= 40\ \text{kg} \times 5\ \text{m s}^{-1} + 3\ \text{kg} \times 0\ \text{m s}^{-1}$
$= 200\ \text{kg m s}^{-1}$.

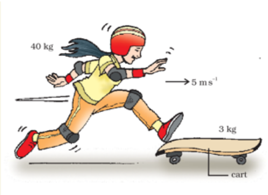
Total momenta after the interaction

$= (40 + 3)\ \text{kg} \times v\ \text{m s}^{-1}$
$= 43\ v\ \text{kg m s}^{-1}$.

According to the law of conservation of momentum, the total momentum is conserved during the interaction. That is,

$43\ v = 200$
$\Rightarrow v = 200/43 = +\ 4.65\ \text{m s}^{-1}$.

The girl on cart would move with a velocity of 4.65 m s^{-1} in the direction in which the girl jumped (Fig. 9.18).



(a)

(b)

CONSERVATION LAW:

Conservation laws in physics are like the most important rules. Scientists found them through experiments, not guesses. You can't prove these rules like math, but you can check them with tests. One rule is the conservation of momentum, which says that in most cases, the total momentum in the universe stays the same. It's like a rule that works for things that move. Scientists have tested it for a long time, and it always seems to be true. It helps us understand how things move, like in car crashes and when rockets take off.

L.P.

[NCERT Intext Pg126]

L.P. 1: If action is always equal to the reaction, explain how a horse can pull a cart.

Answer: In order to pull a cart, horse pushes the ground with its foot in the backward direction by pressing the ground (action). As a result of this, the ground applies an equal and opposite force on the horse (reaction). This force moves the horse and cart forward.

L.P. 2: Explain, why is it difficult for a fireman to hold a hose, which ejects large amounts of water at a high velocity.

Answer: When fireman ejects a large amount of water at high velocity on a fire from a hose pipe, they have to hold it strongly because of its tendency to move back due to Newtons third law of motion. This backward movement is because of backward (reaction) force due to water rushing out (action)

L.P. 3: From a rifle of mass 4 kg, a bullet of mass 50 g is fired with an initial velocity of 35 m/s. Calculate the initial recoil velocity of the rifle.

Ans-

A-3 given, mass of bullet (m_1) = 50g or 0.05kg

mass of the pistol (m_2) = 4 kg

Initial velocity of the bullet (u_1) & pistol $(u_2) = 0$

The final velocity of bullet $(v_1) = +35\ m/s$

Let recoil velocity of the pistol/riffle = v_2

Total momenta of the riffle and bullet before the fire, when riffle is at rest

$= (m_1 u_1) + (m_2 u_2) = (m_1 + m_2)u \quad [u_1 = u_2 = u = 0]$

$= (4 + 0.05) \times 0$

$= 0\ kg\ m/s$

Total momenta of riffle and ~~p~~ bullet after its fired

$$m_1v_1 + m_2v_2$$

$$(0.05 \times 35) + (4 \times v_2)$$

$$+ 4v_2$$

Total momenta after the fire = Total momenta before the fire

$$1.75 + 4v_2 = 0$$

$$4v_2 = -1.75$$

$$v_2 = -1.75/4$$

$$v_2 = -0.4375 \ m/s$$

negative sign indicates that the direction in which riffle would recoil is opposite to that of bullet.

L.P. 4: Two objects of masses 100 g and 200 g are moving along the same line and direction with velocities of 2 m/s and 1 m/s respectively. They collide and after the collision, the first object moves at a velocity of 1.67 m/s. Determine the velocity of the second object.

Ans-

given

mass of object 1 (m_1) = 100 g or 0.01 kg

mass of object 2 (m_2) = 200 g 0.02 kg

Initial velocity of object 1 (u_1) = 2 m/s

Initial velocity of object 2 (u_2) = 1 m/s

final velocity of object 1 (v_1) = 1.67 m/s

Let final velocity of object 2 be v_2

from law of conservation of momentum.

sum of Initial momentum = sum of final momentum

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$(0.01 \times 2) + (0.02 \times 1) = (0.01 \times 1.67) + (0.02 \times v_2)$$

$$0.04 = 0.0167 + 0.02v_2$$

$$0.0233 = 0.02v_2$$

$$v_2 = \frac{0.0233}{0.2}$$

$$v_2 = 1.165 \text{ m/s}$$

The final velocity of second object after the collision is 1.165 m/s