Basics of Mechanical Engineering-1

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Week 01

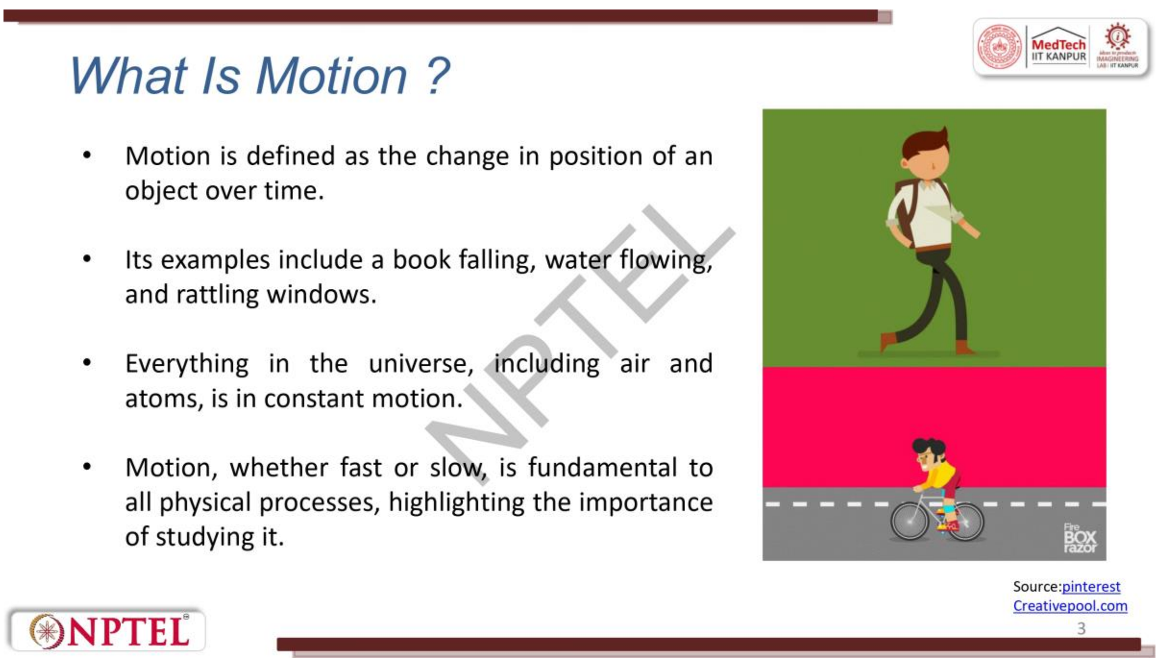
Lecture 03

Laws of Motion, Inertia and Momentum

Welcome to the next lecture in our course. In this lecture, we will try to cover the Laws of Motion, Inertia and Momentum.

The content for this lecture is going to be, we will talk about types of motion, then Newton's law of motion, inertia, law of inertia, momentum and Law of conservation of momentum. Then we will try to have one or two simple questions to solve. And finally, we will have a recap of this lecture. This lecture is very important because in engineering, if things have to be developed or if it has to move, then all these law play a very important role.

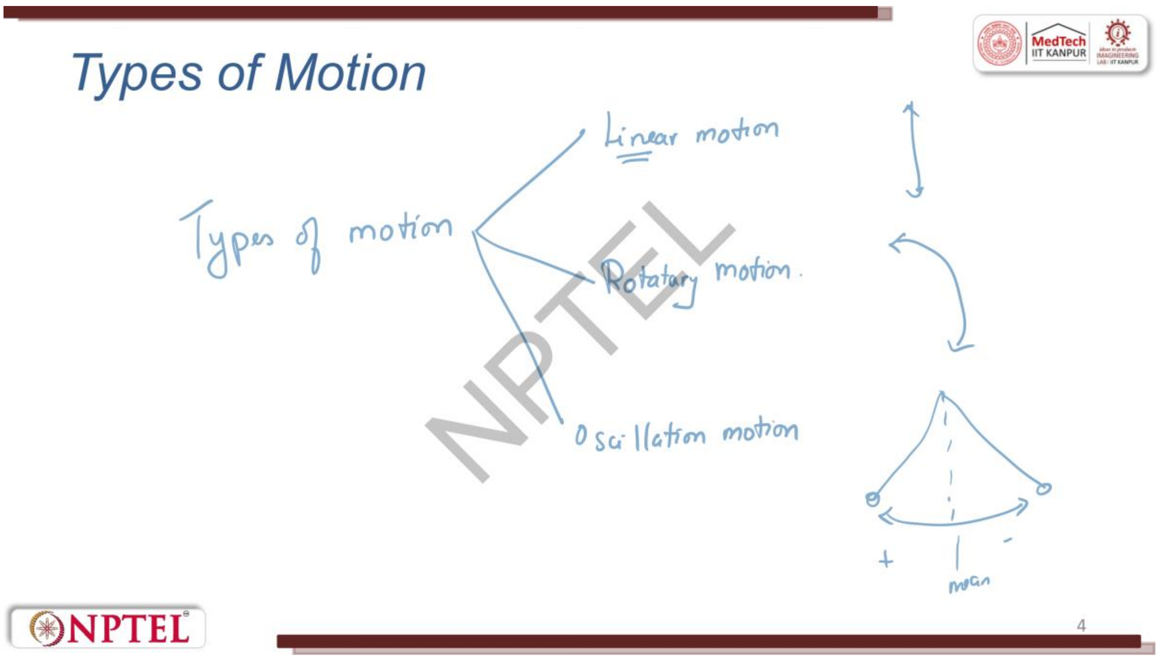
Many a times, what happens is for engineering application, we use the basic science predominantly and we call it as first principle. And then in that, we try to add an error approximation and then we try to build a solution keeping that thumb rule or the first principle plus the error approximation equal to the new technology whatever we develop. In a lighter sense, if we want to develop a wall, we try to find out what is the force which is coming to the wall, take this wall as a dam. So what is the force? the water will give on or the pressure will give by the water onto the wall, so we try to take it and then what we do is we multiply it with a factor of safety 10 times, 20 times, 3 times, whatever it is and then finally we construct a wall. So, basically, all the higher end derivations which is happening will start from simple principles only. So, this lecture is very important when we are looking it from the technology point of view.



So, what is motion? Motion is defined as a change in position of an object over time. It can be walking or It can be a ball falling. It can be a pendulum swinging. It can be a centrifugal force. It can be a clock moving. It can be anything. It can be a rocket moving. So all these things are called as motion. Its example include book falling, water flowing and rattling windows. If you see a cyclist going, it is a motion. A man walking is a motion. Ant crawling is a motion. Earthworm inching is a motion.

So all these things are motion. The only difference between all the man walking, ant walking, earthworm inching, the difference will be the speed. So examples include book falling, water flowing and rattling windows. Everything in this universe, including air and atom, is in a constant motion. If you heat it, the vibration comes into existence, atoms move randomly faster, but without that in a piece, it also has its small motion.

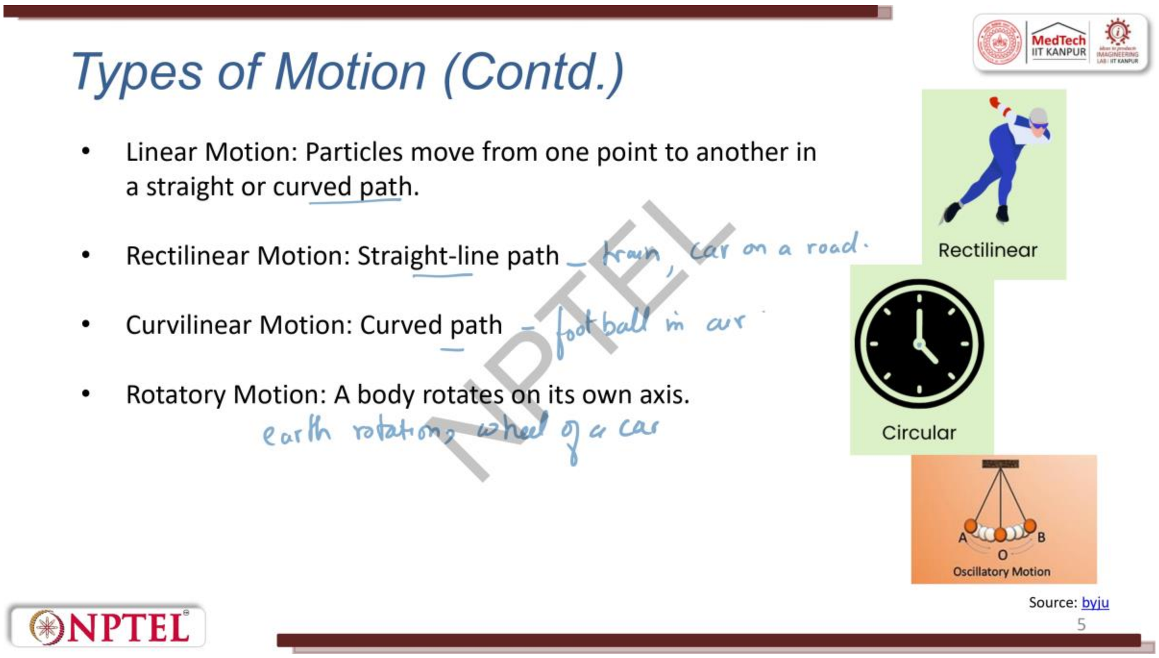
Motion, whether fast or slow, is fundamental to all physical process, highlighting the importance of this study. There are different types of motion.



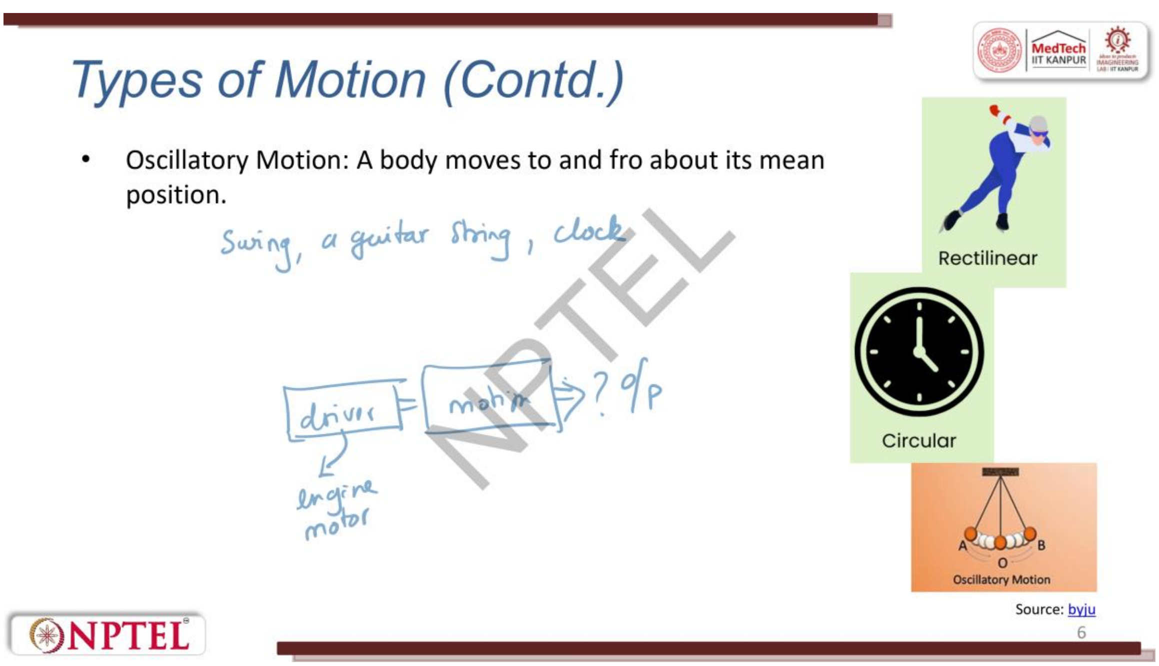
So, types of motion. They are linear motion, rotatory motion, and oscillating motion. As the word clearly says, linear, it can be up and down. Rotary moving around an arc.

Oscillatory moving a pendulum. So, these are oscillatory motions. You can see in reality, there are lot of linear motion. For example, the piston which moves inside a cylinder, which is used in a car. The piston which is used for a single cylinder, which is placed in a drone, linear motion, right.

So, A boy or a girl jumping in a trampoline is also a linear motion. Rotary motions are which moves around a circular one. So oscillation is there is a mean position and you move to the plus side and minus side and come back to the center. And when you move, it gets settled down.



So linear motions are, particle move from one point to the another in a straight or a curved path is linear. Rectilinear motion means moving along a straight line path. So curved or curvilinear means it is moving along a curve. Rotary motion, a body rotates on its own axis. That is rotary motion. And the oscillation motion is, as I said, O is the mean moving towards A, moving towards B is oscillation.

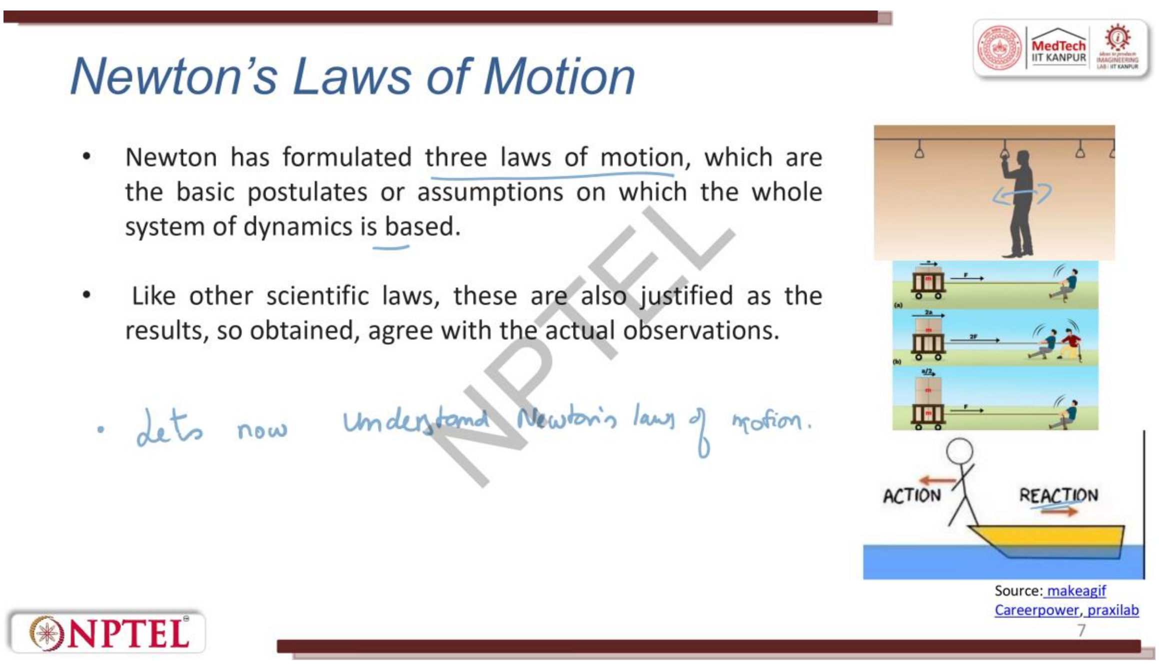


In oscillation motion, we have a body which moves to and fro about its mean position is called as oscillatory motion.

So let us write some of the examples. So the examples are trains, car on a road, right. This is rectilinear, the football in air is curvilinear. Then rotation is earth rotation or wheel of a car They are rotation motion. For oscillation, we have a swing, a guitar, string, and a clock. These are few examples of oscillatory motion.

So, if you understand these motions, then it becomes easy for you to plan a drive. Generally, in an engineering system, what happens? You will have a drive or a driver. This will be attached to a motion so that you will try to get an output. That is how it is. So now you know the motion, you have to understand the motion. So once you understand the motion, then you can plan the driver.

So driver here, it can be an engine, it can be a motor, whatever it is. For the required output, you plan everything in line. So you have to understand the importance of motion.

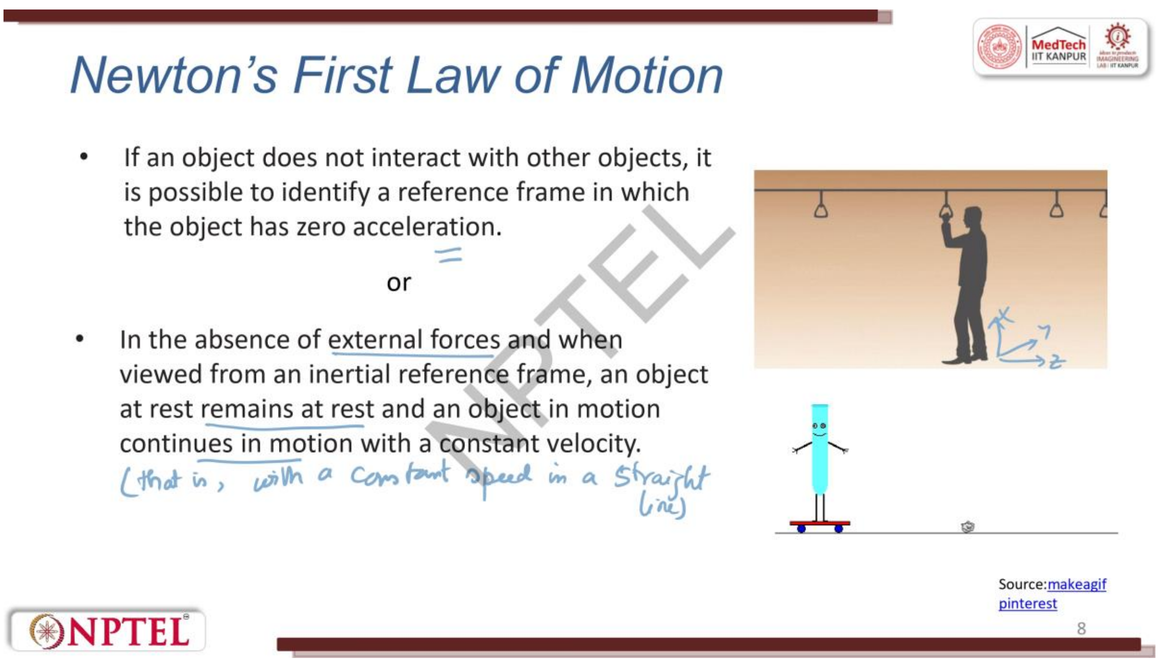


From here, let us move to Newton's laws of motion. Newton has formulated three laws of motion, which are the basic postulates or assumptions on which the whole system of dynamics is based.

Later in our lecture, we will be studying about kinematics and dynamics. So for dynamics, these laws of motion are the fundamental assumption. Like other scientific laws, these are also justified as the results so obtained agree with the actual observation. So let us now understand Newton's. Laws Of Motion, Okay. So if you can see a man standing in a boat, Sailor.

So this is the action. And opposite to him he has a reaction. So when we try to stand in a bus or a train. When the train is moving. And when you apply brake, the man moves, Okay. So that is also part of laws of motion.

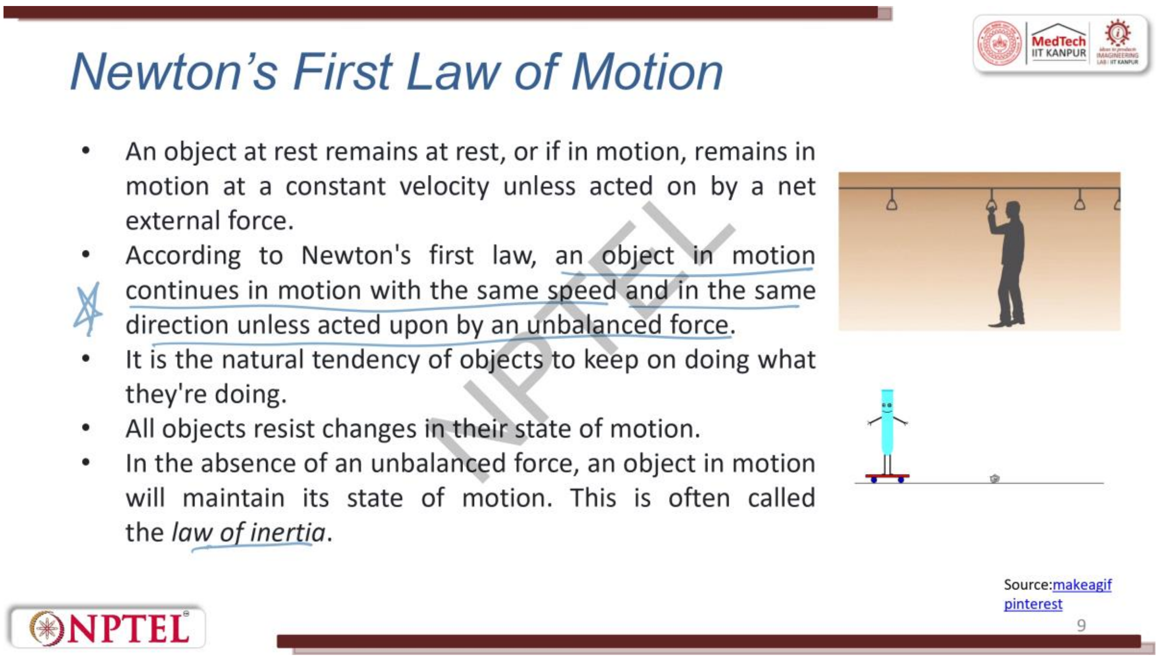
When when two people are trying to pull and one person, when he is trying to pull with some load. So you can see here all these things follow laws of motion.



If an object does not interact with other object, a stationary object, it is possible to identify a reference frame. This is important when you are getting into robotics field. So, there we talk about reference frame.

What is a reference frame? You try to say x, y and z. That is the reference frame, right. So, it is possible to identify a reference frame in which the object has zero acceleration or acceleration. In the absence of external force and when viewed from an inertial reference frame, an object at rest remains at rest and an object in motion continues in motion with a constant velocity. You can either frame like this or like this.

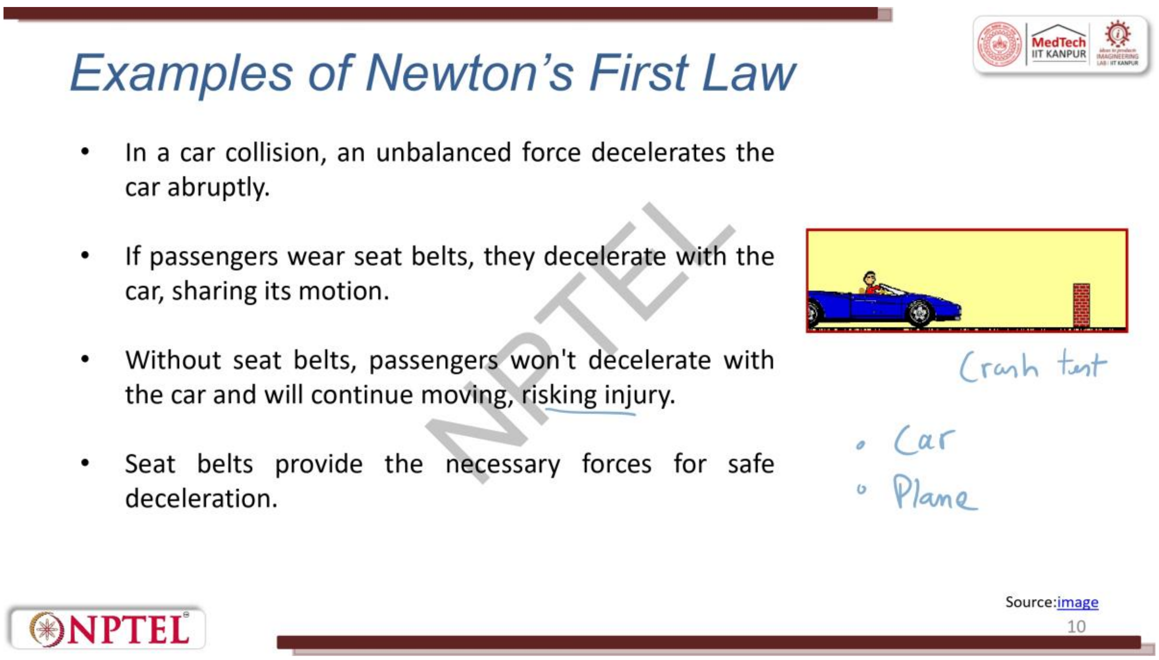
So in the absence of external force, if I don't push, when viewed from an inertial reference frame, an object remains at rest and an object in motion continues in motion with a constant velocity. So, here that is with a constant speed. in a straight line.



So an object at rest remains at rest or if in motion remains in motion at a constant velocity unless acted on by a net external force. So according to Newton's first law, an object in motion continues in motion with the same speed and in the same direction unless acted upon by an unbalanced force. So this is important. The object continues to stay in rest.

A moving object continues to move, keep on moving with the same speed until and unless you apply an external force that does not get disturbed. It is the natural tendency of objects to keep on doing what they are doing. All objects resist change in the state of motion. For example, you are going in a car at 100 km speed, you are traveling, and suddenly there is a hippopotamus coming in between, or there is an elephant coming in between, or a person is coming in between, you apply brake. So you see, there is a huge load on the passenger or you move up and down front and back in in the car, right. So for that only, to avoid that front and back motion, we try to request all the passengers to wear a belt while traveling in the car. So all objects resist changes in their state of motion In the absence of an unbalanced force, an object in motion will remain its state of motion.

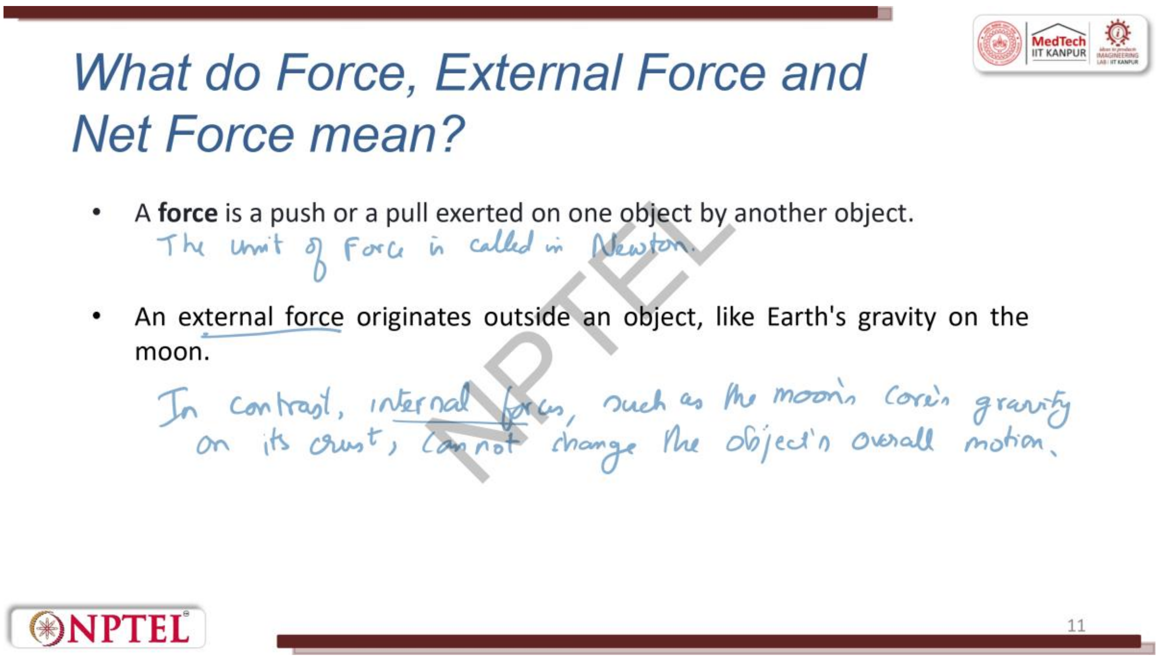
This is often called as Law of Inertia. If you see, the person was walking or he was going in a skateboard and he was continuing to be in motion until he hits an obstacle. Moment he hits an obstacle, there is a resistance and there is imbalance, so he falls down.



So examples of Newton's first law, in a car collision, an unbalanced force decelerates the car abruptly. So when we have to do a crash test, before every car is released to the market, the automobile industry does a crash test.

In crash test, basically what they do is, they try to put an obstacle and try the car to move in multiple speeds and try to hit at the wall, see what is the damage. So if you see, this is an example of Newton's first law. If passenger wear seat belt, they decelerate with the car sharing its motion. Without a seat belt, passengers would not decelerate with the car and will continue to move, risking injury. Seat belt provide the necessary force for safe deceleration.

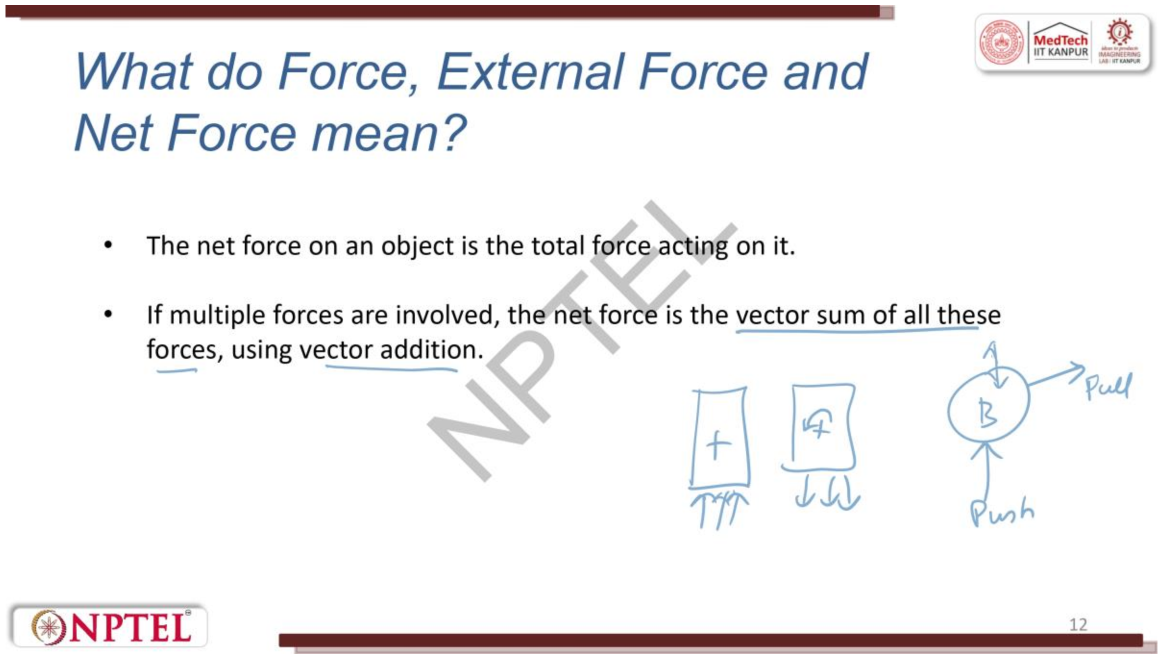
So that is why we ask all the passengers to wear seat belt while traveling in a car or traveling in a plane. We ask the passengers to wear it because when there is a turbulence created in the air, the plane undergoes lot of change in velocity. So at that point there will be lot of Front and back. So we are supposed to wear a seat belt which we'll try to provide the necessary force for safe deceleration.



What do force, external force and net force mean? A force is a push or a pull exerted on an object by another object. The unit of force is called in Newtons. We saw in the last class, units are very important, a force is a push or a pull for example, when we are trying to close the door, it is pull when we are trying to open, it is push, when we are trying to go for a hammer throw, it is pull. When we are trying to throw the shot put, it is push. When we are trying to throw a javelin, push. When we are trying to hold human chain when it is done, so we are trying to pull people, that is pull.

Holding hands and pulling each other, that is pull. So force can be either push or it can be pull, which is exerted on a body by another object. An external force originates outside an object like Earth's gravity on the moon. In contrast, internal force, there is external force, there is internal force. Internal forces such as the moon's core gravity on its crust cannot change the object.

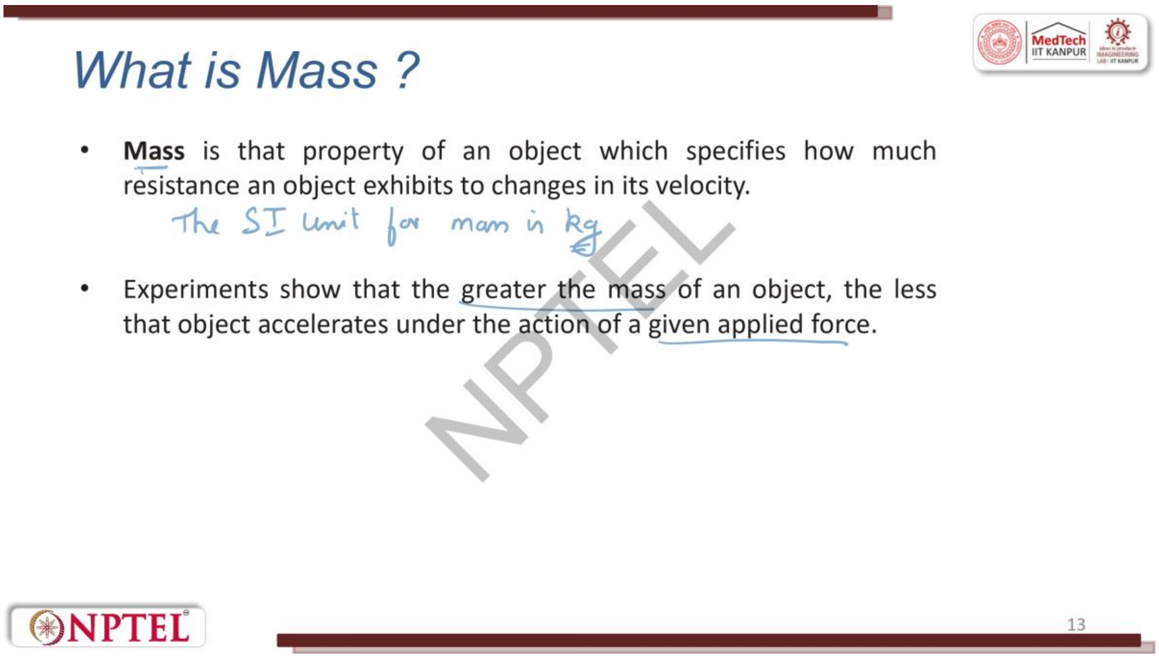
So, I am trying to talk about external force and I am also talking about internal force, right. So, an external force originates outside, internal force originates internal.



The net force of an object is the total force acting on it. If multiple forces are involved, the net force is the vector sum of all these forces using vector addition. There can be multiple force. For example, there is a body. There can be a pull. There can be a push.

This can be pull. This can be push. Right. So assuming that the ball is trying to jump and pull. So here there are multiple forces. So when there are multiple forces acting, we have to take the vector sum of all these forces using vector addition. This is very important. When you are trying to push a rocket into the atmosphere, we will have multiple forces. When there is a thrust force coming, this thrust force will also try to give a torsional.

Say for example, when you are trying to move an object or when an object is trying to push. So if we don't exactly hold it or pivot it properly, there is a circular motion which comes, which will lead the box or the rocket to oscillate. So now we have to make sure all these forces and then balance it to make sure that the net force, whatever you want can be zero or it can be whatever you want. right. So, if multiple forces are involved, the net force is the vector sum of all these forces using vector addition.

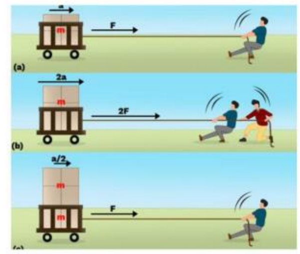


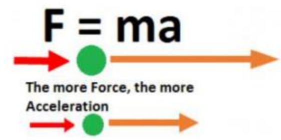
What is a mass? Mass is the property of an object which simplifies how much resistance an object exhibits to changes in its velocity. So, Mass is very important term.

The SI unit for mass is kgs, okay. I am trying to give you the units also. So that last lecture we studied about units. Now whatever we study, I am trying to link with it you will have a connectivity. So mass will be always in kg, it is the property of an object which specifies how much resistance an object exhibits to changes in its velocity experiment to show that Greater the mass of an object, the less that object accelerates under the action of a given applied force.

Newton's Second Law of Motion

- Newton's first law explains what happens to an object when no forces act on it.
- It maintains its original motion; it either remains at rest or moves in a straight line with constant speed.
- Newton's second law answers the question of what happens to an object when one or more forces act on it.





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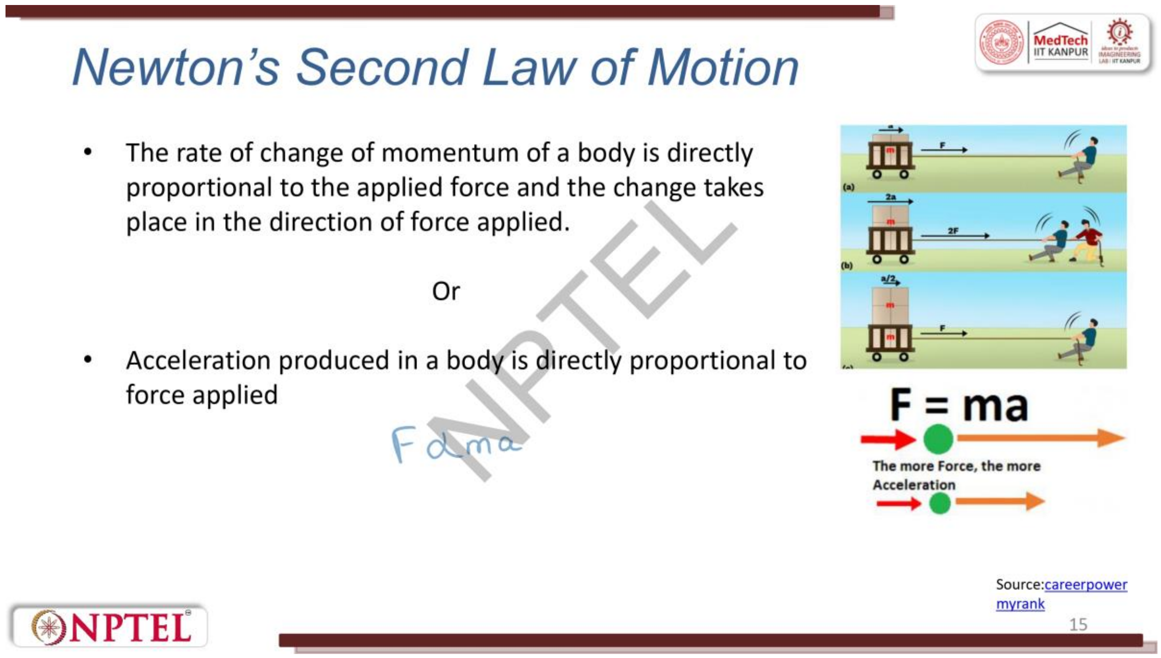
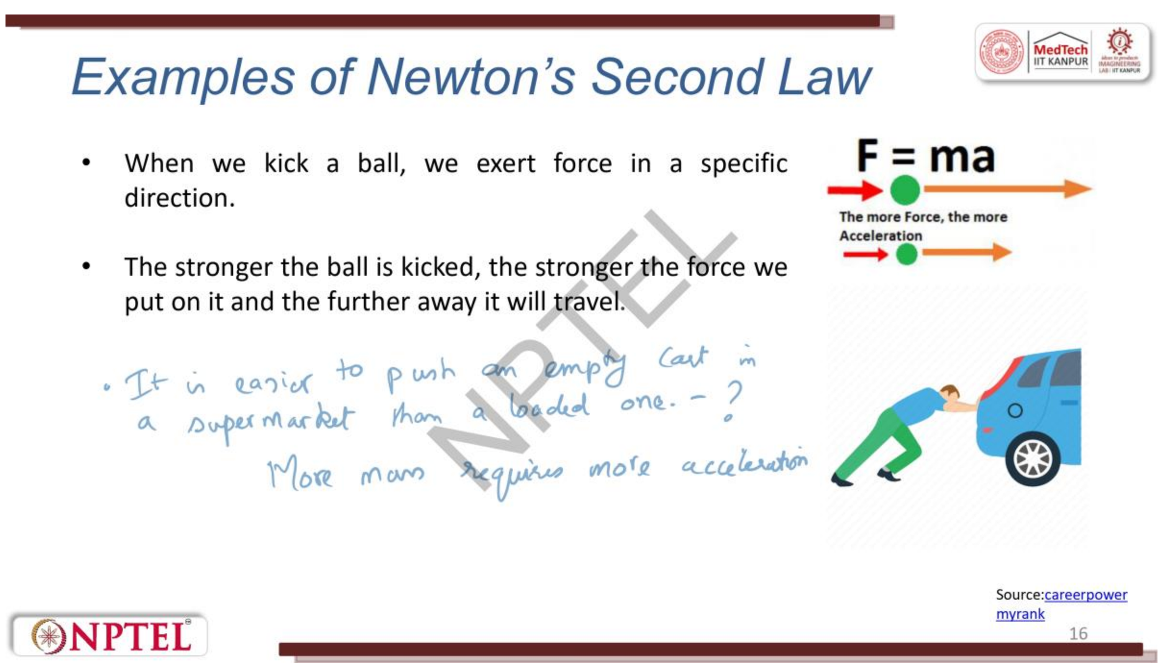
Let's move on to Newton's second law of motion. Newton's first law explains what happens to an object when no force acts on it. It maintains its original motion. It either remains at rest or moves in a straight line with constant speed.

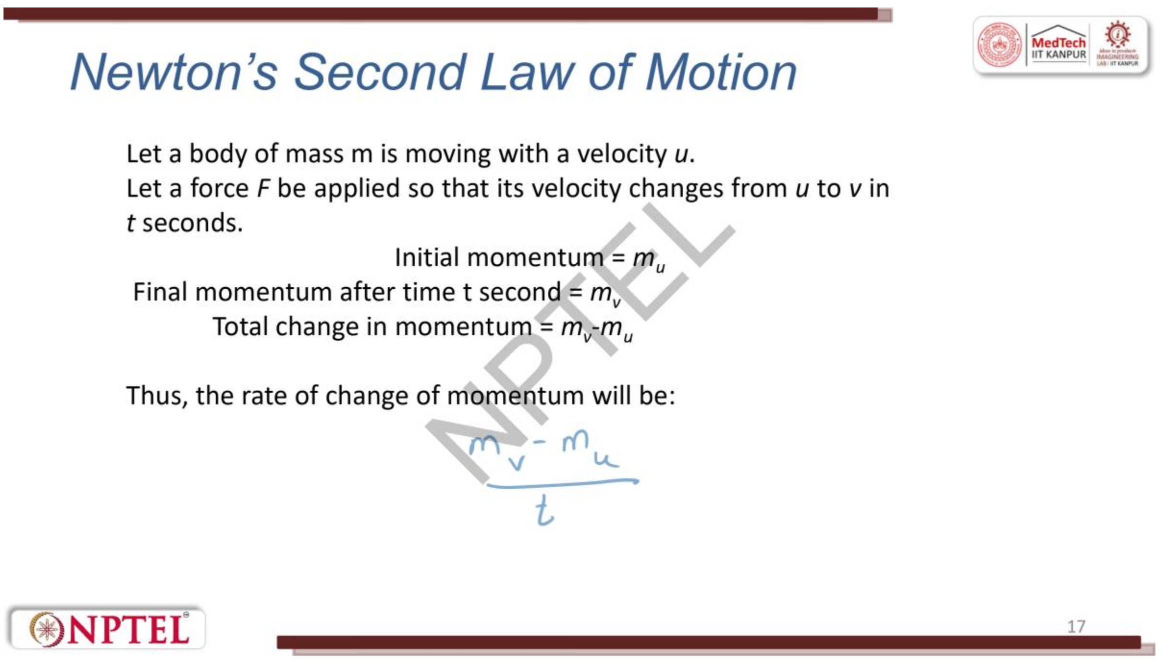
The Newton's second law answers the question of what happens to the object when one or more force act on it. So here, the second law leads to the formulation of F equal to MA. The more force, the more acceleration. So here is an object, a person is trying to pull. The object is pulled by two person, then if the shape of the object is reduced from A, it goes to 2A, then it goes to A by 2, we are trying to find out the forces. So, what should be the packing density of your carton box, which is kept in a trolley and when you are trying to pull? So that's what is the experiment which people are doing to find out what should be the shape such that a single man can take maximum number of boxes.



So the second law states that the rate of change of momentum of a body is directly proportioned to the applied force and the change takes place in the direction of the force applied. Acceleration produced in a body is directly proportional to the applied force. So what we are trying to say is F α ma. So acceleration produced in a body is directly proportioned to the force applied.



Examples of Newton's second law. When we kick a ball, we exert force in a specific direction. The stronger the ball is kicked, the stronger the force we put on it and further away it will travel. The same is for javelin. The same is for shot put. The same is for discuss throw. The same is for car also getting accelerated. The same is for the thrust which is given by a rocket into the air. It is easier to push an empty cart in a supermarket than a loaded one. Why? It is because more mass requires more acceleration. Okay. And here also you can see if the car is heavy, then when you try to push your car, it takes lot of energy to push the car. Right. So F = ma.

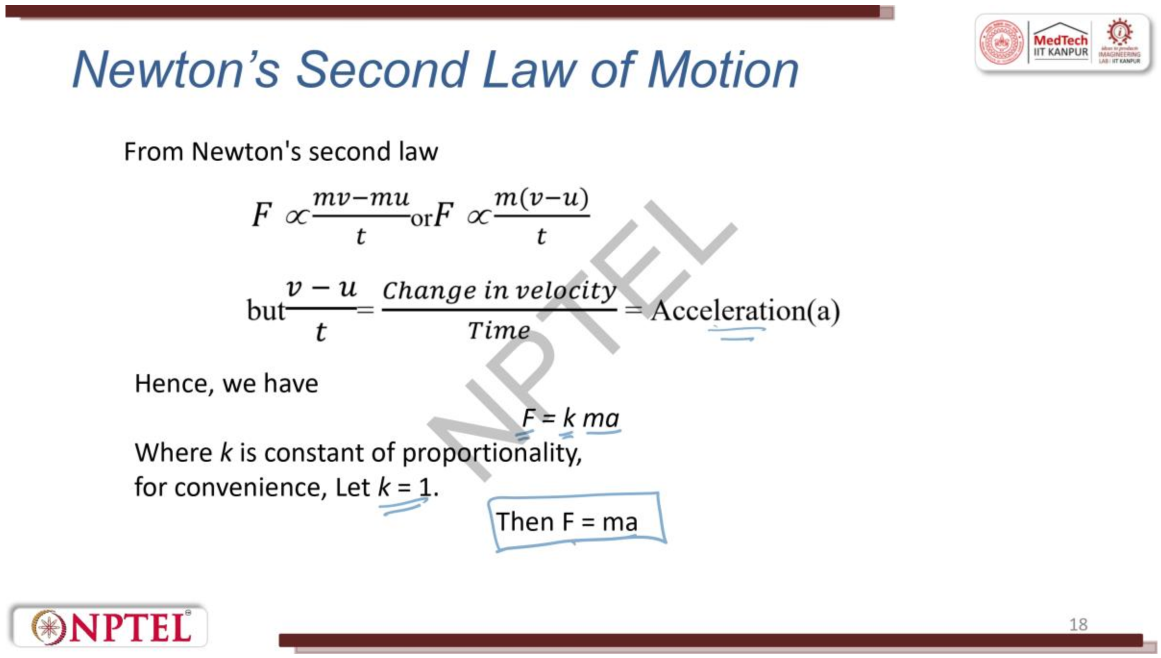


Newton's second law of motion. Let a body of mass m is moving with a velocity u. Let the force F be applied so that its velocity changes from u to v in t seconds. So initial momentum is going to be m suffix u. What is u? With a velocity u. Final momentum after a time t changes. Seconds is going to be mv.

Why? Because the velocity is moving from u to v. So, the change of momentum is nothing but m_v - m_u. Thus, the rate of change of momentum will be

$$\frac{m_v - m_u}{t}$$

So this tries to explain the second law of motion.



From the second law of motion,

$$F \propto \frac{mv - mu}{t} \ or \ F \propto \frac{m(v-u)}{t}$$

$$\frac{v-u}{t} = \frac{Change\ in\ velocity}{Time} = Acceleration\ (a)$$

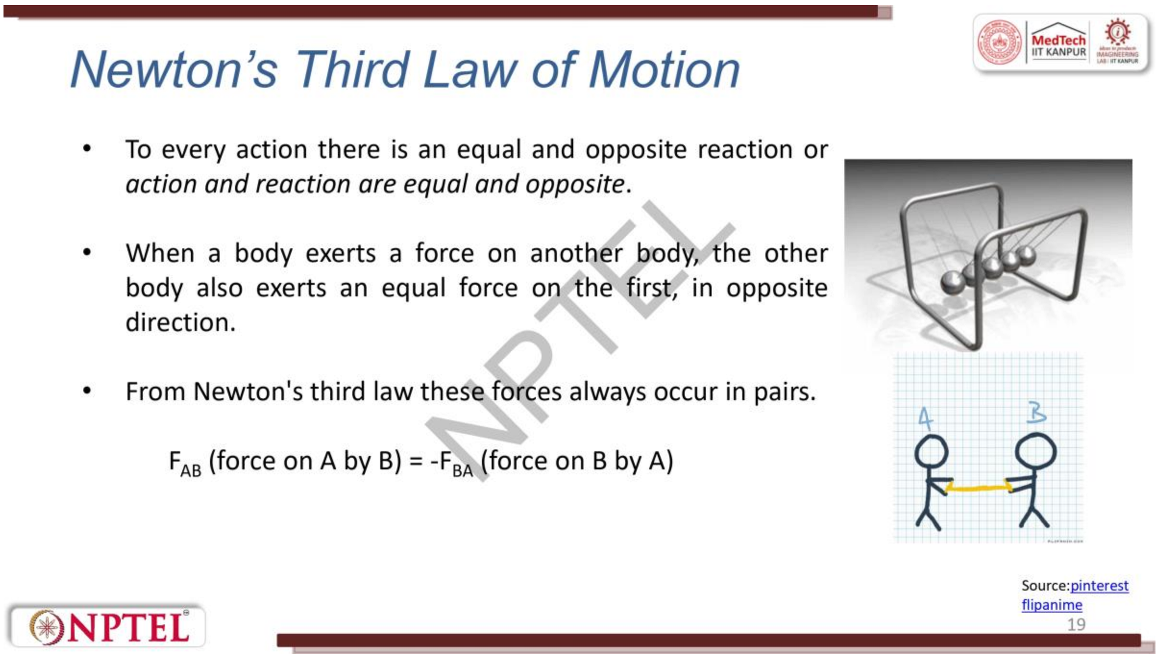
$$F = kma$$

$$Let\ k = 1,$$

$$F = ma$$

So from the second law, we are getting this relationship F = ma.

So F is the force what we apply, m is the mass and a is the acceleration. Acceleration is nothing but change in velocity which is nothing but -mu.



Now let us move to Newton's third law of motion. To every action there is an equal and opposite reaction or action and reaction are equal and opposite. That's the third law. When a body exerts a force on another body, the other body also exerts an equal force on the first in opposite direction.

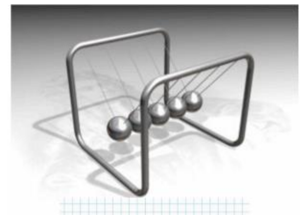
So if you see the pendulum whatever is there, the pendulum knocks, one object moves and it moves the third, fourth and when the fifth one is free to move, so it oscillates. When it hits back, it comes the same. From the Newton's third law, these forces always occur in pair.

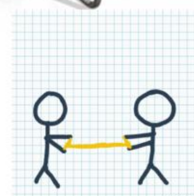
F_{AB} (force on A by B) = $-F_{BA}$ (force on B by A)

Newton’s Third Law of Motion

This law represents a certain symmetry in nature: forces always occur in pairs, and one body cannot exert a force on another without experiencing a force itself.

We sometimes refer to this law loosely as action-reaction, where the force exerted is the action and the force experienced as a consequence is the reaction.





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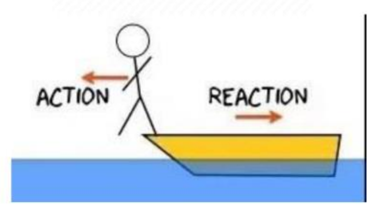
This law represents a certain symmetry in nature. Forces always occur in pairs, and one body cannot exert a force on the another without experiencing a force itself. We sometimes refer to this law loosely as action-reaction law, where the force exerted in the action and the force experienced as a consequence is the reaction. So any force, for example, when the thrust force is given, when the burning happens in a rocket, the thrust force is pushed down, the opponent force is given and such that the body moves up. So action-reaction law is also part of Newton's third law.

Examples of Newton's Third Law

- Examples of Newton’s third law are easy to find in daily life. As a professor paces in front of a whiteboard, he exerts a force backwards on the floor.
- The floor exerts a reaction force forward on the professor that causes him to accelerate forward.



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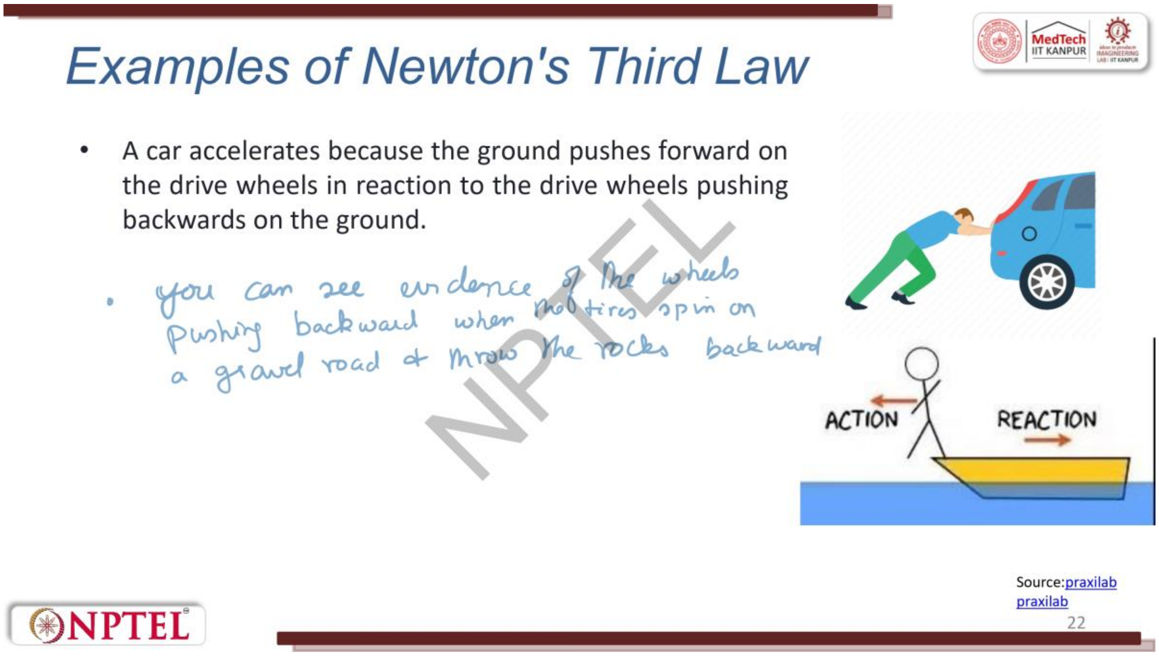
Examples of Newton's third law are easy to find in daily life. As a professor paces in front of a whiteboard, he exerts a force backward on the floor. The floor exerts a reaction force forward on the professor that causes him to accelerate forward.

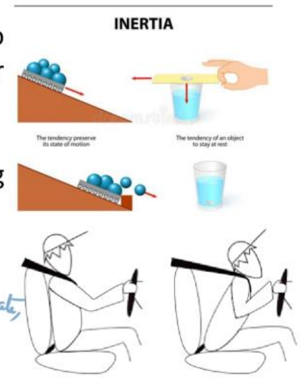


Another example we take is a car accelerates because the ground pushes forward on the driver wheels in reaction to the drive wheels pushing backward on the ground. You can see evidence of the wheels pushing backward when the tires spin on a gravel road and throw the rocks backward. pushing backward when the when the tires spin on a gravel road and throw the

Rocks backward. Even when you try to use a tractor, that's what happens. When you give a heavy torque, the tractor wheel, when it rotates, whatever was the mass of the loose stone, it just throws out. Or when we are trying to go at very high speeds in highway, if there is a stone, the previous vehicle, if it throws or when there is a stone comes in contact with the tyre, if it throws it, then the stone will have so much of acceleration, if it hits your windshield, it might even crack. So, this is an example for Newton's third law of motion.

What is Inertia ?

- Inertia is a property of a body that resists any attempt to change its state of motion or, if it is already in motion, to alter the magnitude or direction of its velocity.
- Inertia is a passive attribute, preventing the body from acting except to oppose forces and torques.
- A moving body continues its motion not due to inertia, but because no force acts to decelerate, alter its path or accelerate it.



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Now, let us move to inertia. What is inertia? Inertia is a property of a body that resists any attempts to change its state of motion or if it is already in motion to alter the magnitude or direction of its velocity. Inertia is very important. Inertial force, we talk a lot.

Inertia is a passive attribute. preventing the body from acting except to oppose forces and torques. So, a moving body continues its motion not due to inertia, But because no force acts to decelerate, alter its path or accelerate. So the inertia, you can see some of the examples of inertia.

You keep a paper and a coin. When you try to strike it, the coin falls inside. So a body moving with all the balls, heavy balls moving along a slope. So when it comes, the ball gets slipped down. And then, as I already discussed, placing the belt while driving in a car.

Types of Inertia

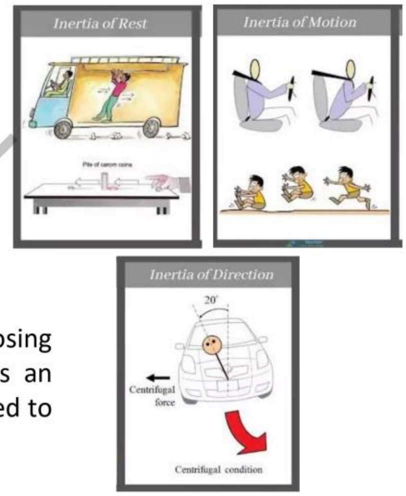
There are three types of Inertia that are,

- Inertia at Rest
- Inertia in Motion
- Inertia of Direction

Now lets us study in detail

- **Inertia at Rest**

A body remains at rest due to the inertia (opposing force) present inside the object until and unless an external force more than the inertial force is applied to it.



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There are three types of inertia. One is called as Inertia at Rest. The other one is called as inertia in motion. Then it is Inertia of Direction.

All the three are very important. They are all part of inertia. Inertia at Rest, when you are trying to travel in a bus, when the driver applies a brake, you move back and forth. That is inertia of rest. So when there is an object or a coin, when you are trying to strike at the coin, the coin moves. It is inertia at rest.

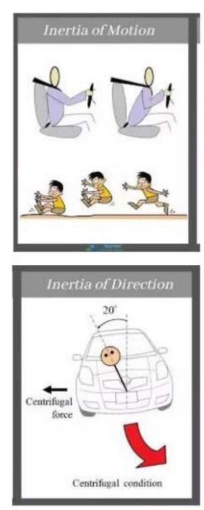
Types of Inertia

- **Inertia in Motion**

A body in motion remains in motion until and unless an external force (maybe brakes, friction, etc) is applied to the body.

- **Inertia of Direction**

A body moving in one direction remains in the same direction until and unless some force is applied in order to change the direction of the body.



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Then the next one is Inertia of Motion, is when you are trying to jump. Long jump, when you are trying to jump, it is inertia of motion.

Then while traveling in a car, applying a brake, seatbelt application is an inertia of motion. Then you also have an Inertia of Direction is when you are trying to go at a very high speed along a slope. Then what we have is Inertia of Direction. Now, let us study in detail. Inertia at Rest, a body remains at rest due to the inertia or opposing force present in the object until and unless an external force more than the inertial force is applied, it is called as inertia at rest. What is Inertia of Motion? When a body in motion remains in motion until and unless an external force is applied to the body.

So it can be a break, it can be friction, anything. By using a rope you are keep climbing and suppose if there is a resistance offered or if the rope moves, then what happens is the inertia in motion comes into action. Inertia of Direction, a body moves in one direction, remains in the same direction until and unless some force is applied in order to change the direction of the body. Suppose if a body is in one direction. It keeps on moving until and unless there is an opposite force is applied. And then in order to change the direction of the body, it is there.

For example, a ball is rolling in this direction. Now somebody comes and kicks the ball. So now the direction of the ball changes. This is a football. The ball is moving in this direction. This is moving. And somebody comes and kicks the ball. So you see the ball is now swinging in air and the direction of the ball is changed.

What is law of Inertia ?

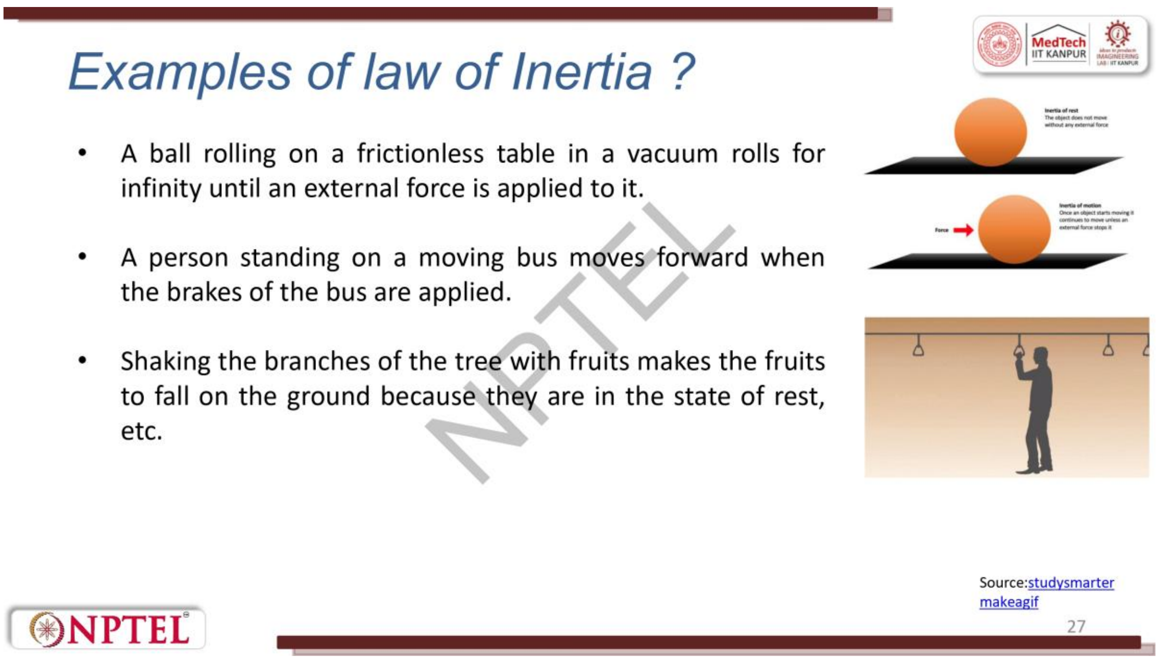
- The law of inertia also called the first law of motion is the fundamental law of physics that was proposed by famous English Scientist Sir Issac Newton.

The law of inertia states that,

- "An object in the state of rest or motion always remains in its initial state until and unless external force is applied to it.

Source:image

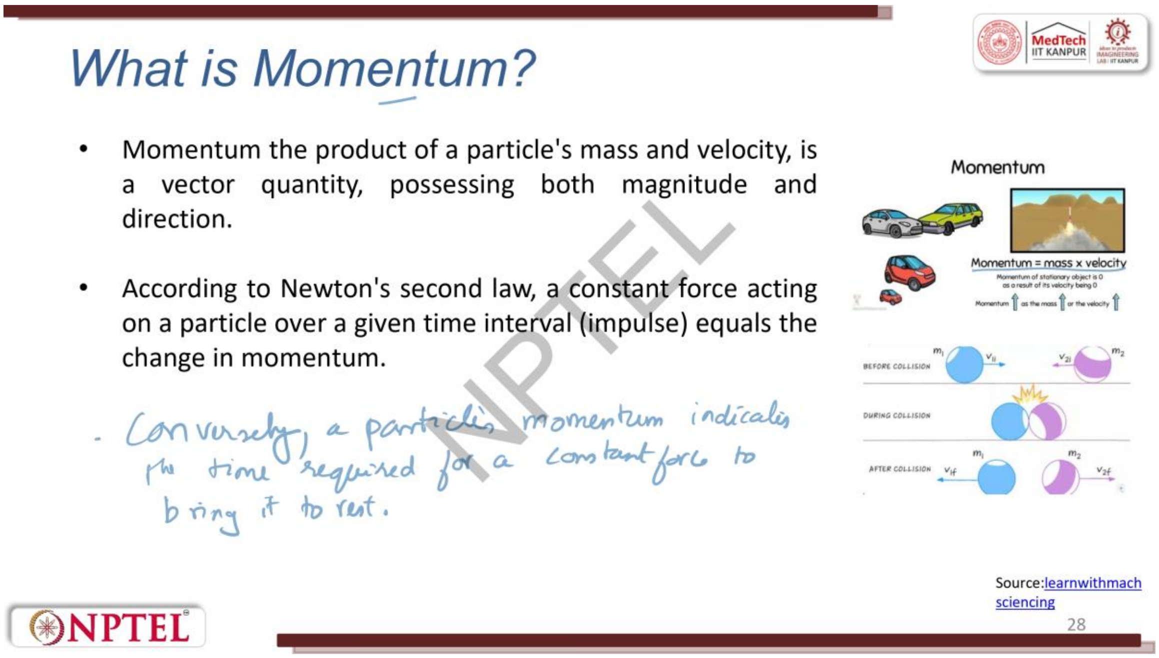
The law which is involved are Law of Inertia. The Law of Inertia, also called the first law of motion, is the fundamental law of physics that was proposed by famous English scientist Sir Isaac Newton. The law of inertia states that an object in the state of rest or motion always remains in its initial state until and unless external force is applied on it. This is the Law of Inertia.



So let us see some of the examples of law of inertia. A ball rolling on a frictionless table in a vacuum rolls for infinite time until an external force is applied on it.

A ball is rolling on a table where there is no friction at all. And if there is friction, friction on the table is zero. Then when the ball is rolling, there can be an air resistance. So that was also taken care by vacuum rolls for infinite time. Once you kick the ball, the ball keeps on rolling. A person standing on a moving bus moves forward when the brake of the bus are applied.

Shaking the branch of a tree with fruits makes the fruits to fall on the ground because they are in the state of rest etc. So all these things are examples of law of inertia.



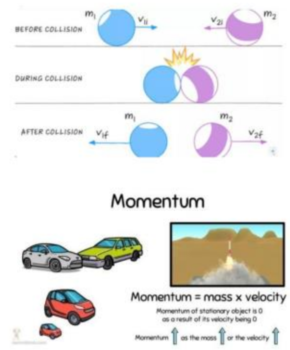
Now let us move to the next topic of Momentum. Momentum is a product of particle mass and velocity in a vector quantity possessing both magnitude and direction. According to Newton's second law, a constant force acting on a particle over a given time interval equals the change in momentum.

So before collision, you can see balls moving, then you see during collision, then you see after collision what happens. So momentum is nothing but mass into velocity. Conversely, a particle's momentum indicates the time required for a constant force to bring it to rest, okay. So this is a statement which is made conversely, a particles momentum indicates the time required for an constant force to bring it to rest. So I have already told you ball moving with the two velocities, they hit, the collision happens and then they reverse car hitting. Okay, so then you see what happens. So you can see here momentum is equal to mass into velocity and then momentum increases as the mass increases or the velocity increases.

So that means to say, when there is a very high velocity, collision happens. Momentum is very high.

What is Momentum?

- The total momentum of a collection of particles is the vector sum of their individual momenta.
- As per Newton's third law, particles exert equal and opposite forces on each other, balancing any change in one particle's momentum with an equal and opposite change in another's.
- Thus, in the absence of an external force, the total momentum of a system remains constant.



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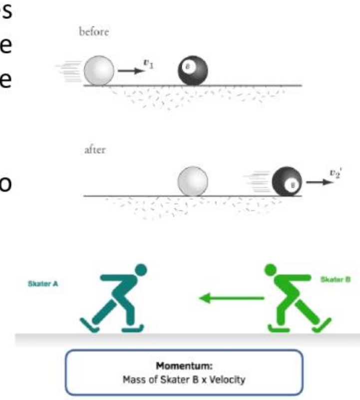
So, it is nothing but a total momentum of a collection of particles is the vector sum of their individual momenta. As per Newton's third law, particles exert equal and opposite force on each other, balancing any change in one particle momentum with an equal and an opposite change within other. Thus, in the absence of external force, the total momentum of a system remains constant. This is very important statement.

Conservation of Momentum

- The principle of conservation of momentum constitutes a fundamental tenet of physics, asserting that the momentum of a system remains invariant in the absence of external forces.
- This principle is enshrined in Newton's First Law, also referred to as the Law of Inertia.
- According to the law of conservation of momentum

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$



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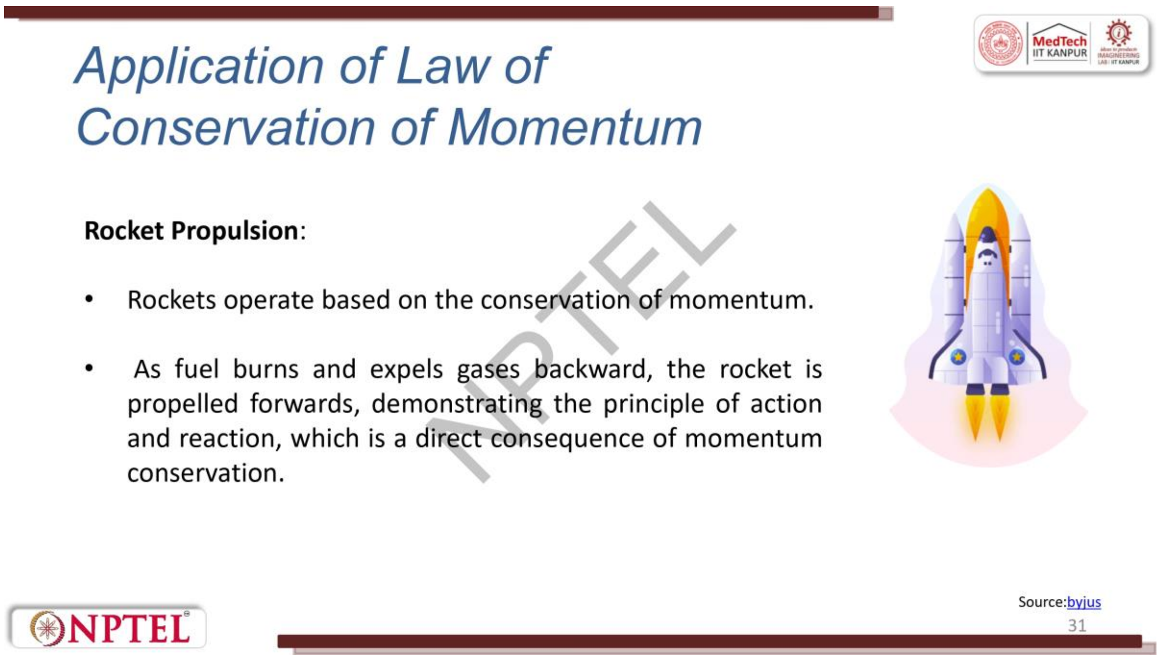
Conservation of momentum. The principle of conservation of momentum constitutes a fundamental tenet of physics, asserting that the momentum of a system remains invariant in the absence of an external force. The principle is enshrined in Newton's first law, also refers to the Law of Inertia. According to the Law of Conservation of Momentum,

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

Two masses, two initial velocities, two final velocities. So this is the Law of Conservation of Momentum.



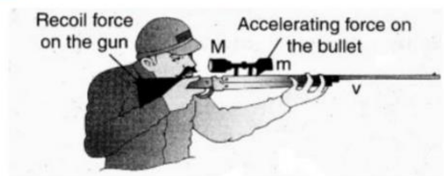
The application of Law of Conservation of Momentum in rocket propulsion, it is there. The rocket operates based on the conservation of momentum.

A fuel burns and expels gas backward. The rocket is propelled forward, demonstrating the principle of action and reaction, which is a direct consequences of momentum conservation. There are a lot of engineering applications.

Application of Law of Conservation of Momentum

Recoil in Firearms:

- When a gun is fired, the bullet gains forward momentum, and the gun gains an equal and opposite momentum, resulting in recoil.
- This principle is critical in designing firearms and predicting their behaviour.



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Recoiling of gun is also law of conservation of momentum. When a gun is fired, military soldier when he tries to put the gun at his shoulder, when a gun is fired, the bullet gains forward momentum and the gun gains equal and opposite momentum resulting in a recoil, so it moves back. So that's why the soldiers are always kept fit and their shoulders will always be strengthened because they have to withstand the recoiling of gun. The principle is critical in designing firearms and predicting their behavior

Problem on Newton's Law of Motion

A passenger in an elevator has a mass that exerts a force of 110N downwards. He experiences a normal force upwards from the elevator's floor of 130N. What direction is he accelerating in, if at all, and at what rate? Use g=10 m/s²

The net force is equal to = (130 − 110N) = 20N upward.

To find the mass of the passenger,

$F = mg \qquad m = F/g$

$m = 110\,N / 10\,m/s^2$

$= 11\,kg$

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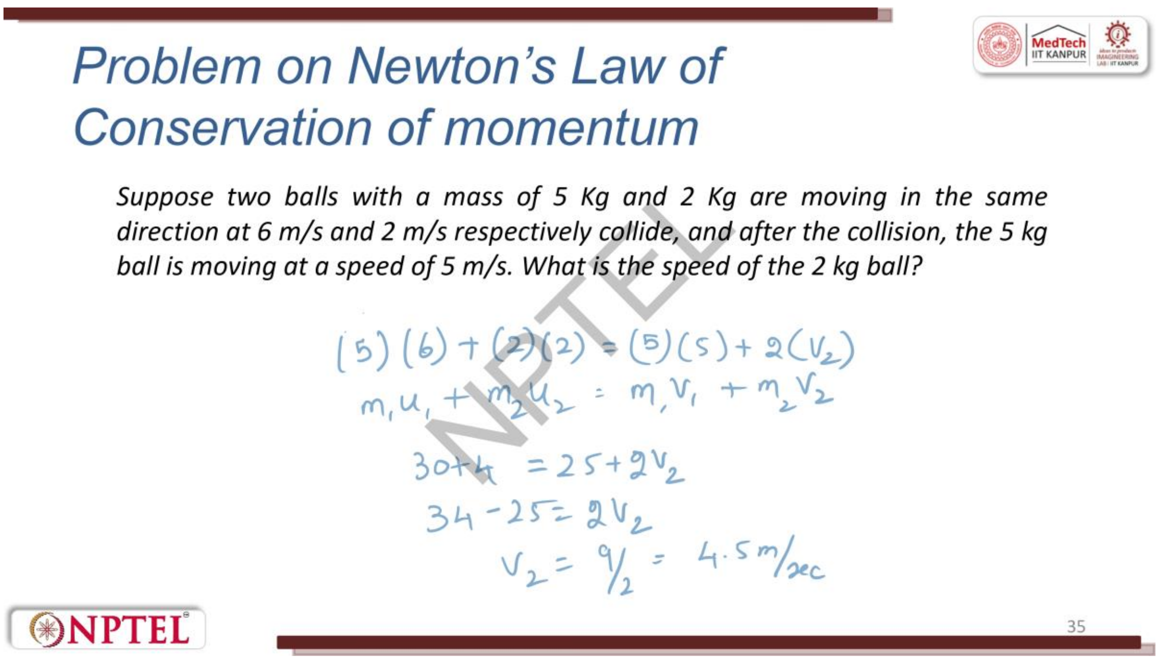
Now, let us look into few problems solving on Newton's law of motion. Let us take an example, a passenger in an escalator has a mass that exerts a force of 110 Newton downward. He experiences a normal force upward from the elevator's floor of 130 Newton. What direction is he accelerating in? If at all and at what rate?

Use $g = 10 \text{ m/s}^2$. So in order to solve this problem. So what we do is we try to take, first let us try to calculate the net force. The net force = 130 N - 110 N. So, it is 20 Newton upward because they have said clearly upward force then downward force. So, it is upward force to find the mass at the passenger.

We use F = mg. So if F = mg. If I wanted to find out m, m = f/g. So m = 110 $\text{N}/10\text{ms}^{-2}$ which is nothing but 11 kgs/ms^{-2}, okay.

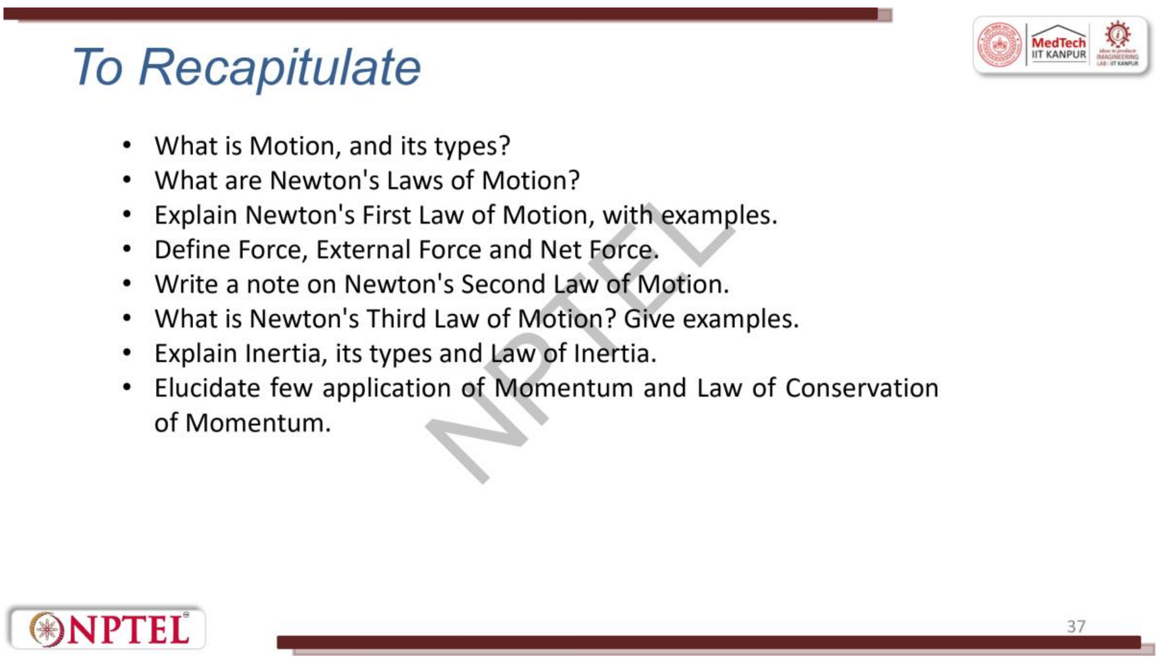


Next let us take another problem to solve a very simple problem. So here what we do is we will try to solve one more for Newton's law of conservation of momentum. Suppose two balls with a mass of 5 kg and 2 kg are moving in the same direction at 6 meters per second and 2 meters per second respectively.

And after the collision, the 5 kg ball is moving at a speed of 5 m/s. What is the speed of the 2 kg ball?

So here what do we do is we try to take 5 kg x 6 + 2 x 2 = 5 + 2 x v_2. So what is that? The formula will be $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$, Okay. So now what we are getting is it is nothing but 30 + 4 = 25 + 2 v_2.

So when we move it 34 - 25 = 2 x v_2 that is nothing but v_2 will try to have 9/2 which is 4.5 m/s, okay. So this is the way we solve law of conservation of momentum problem.



So to recap whatever we have studied in this lecture, we have studied what is Motion and its type, what are Newton's Law of Motion, then we have explained Newton's first law of motion with examples, define force, external force, net force, We have made note on second law of motion, then third law of motion, both we have discussed with examples. We have also introduced the topic of inertia, what are the different types of inertia.

Finally, we have looked into momentum, Law of Conservation of Momentum, engineering and solely depends on these basic principles. Let it be Aerospace engineering, let it be fluid mechanics, let it be Thermodynamics, let it be Electrical engineering, let it be Chemical engineering. So for all these departments, the fundamental studies starts from this Newton's law of motion, inertia, momentum. I am sure you would have learnt something new in this lecture. I wish you good luck.

And thank you so much.