Basics of Mechanical Engineering-1

Prof. J. Ramkumar

Dr. Amandeep Singh

Department of Mechanical Engineering

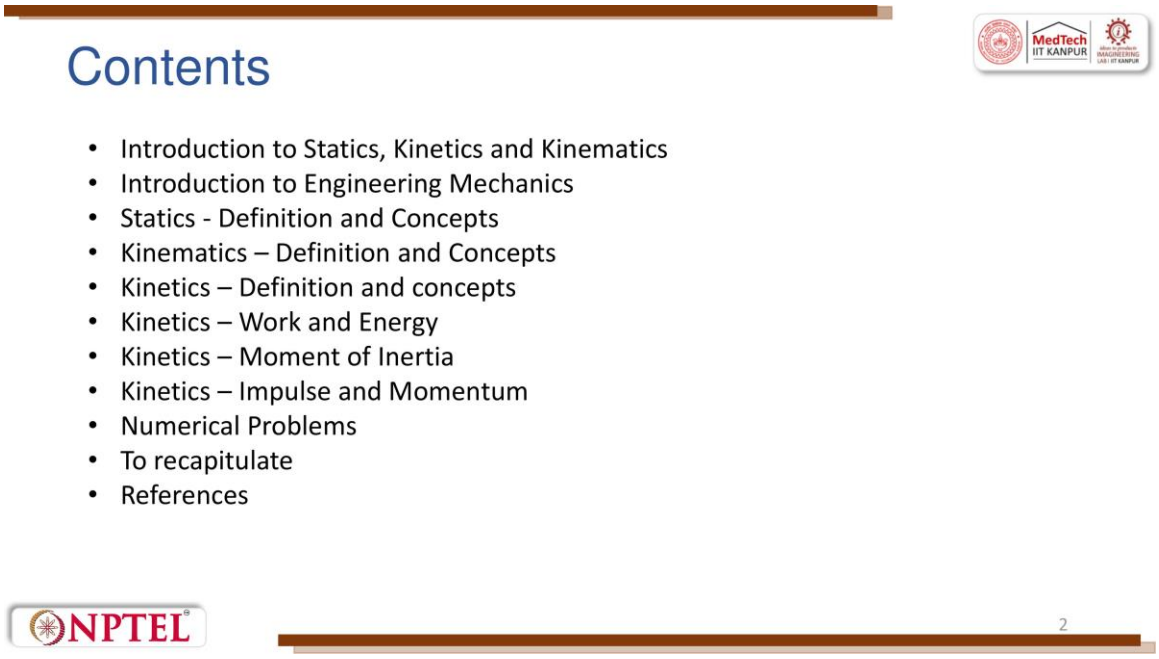
Indian Institute of Technology, Kanpur

Week 02

Lecture 05

Statistics, Kinetics and Kinematics

Welcome to the next lecture on Statics, Kinetics and Kinematics.

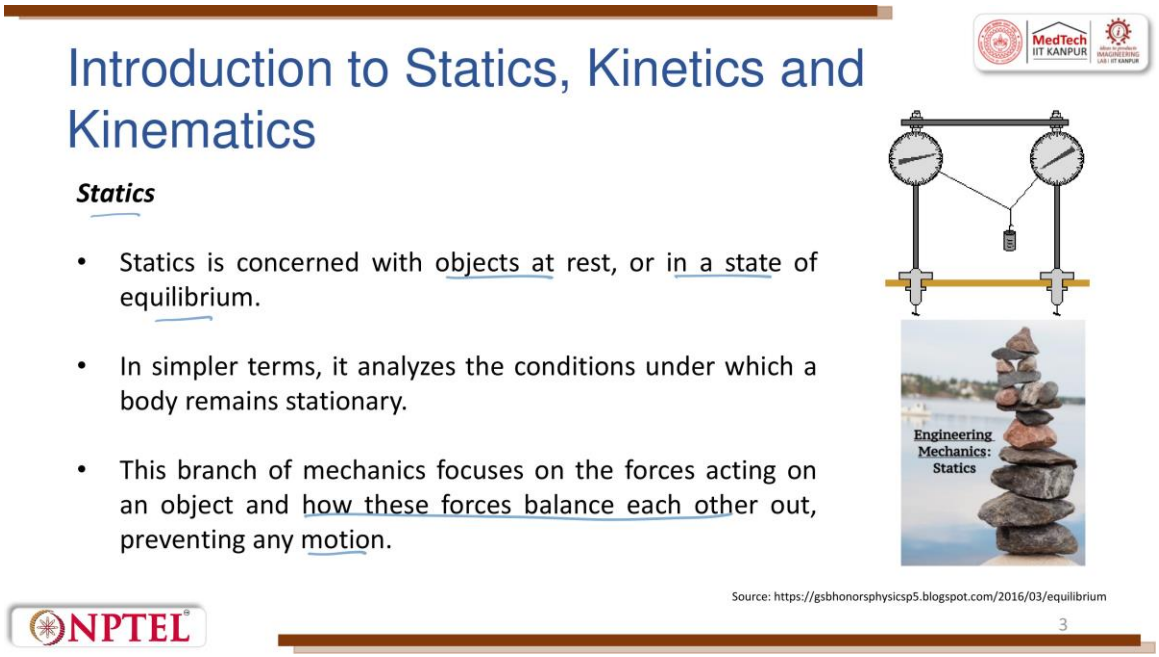


In this lecture, we will try to cover the introduction of Statics, Kinetics and Kinematics. Then we will try to see introduction to Engineering mechanics. We are slowly getting into the application of the fundamentals what we have seen here into engineering. Then Statics definition and concepts.

Kinematics definition and concepts. Kinetics definition and concepts. Then under kinetics, we will be seeing work, energy and momentum inertia. Then impulse and

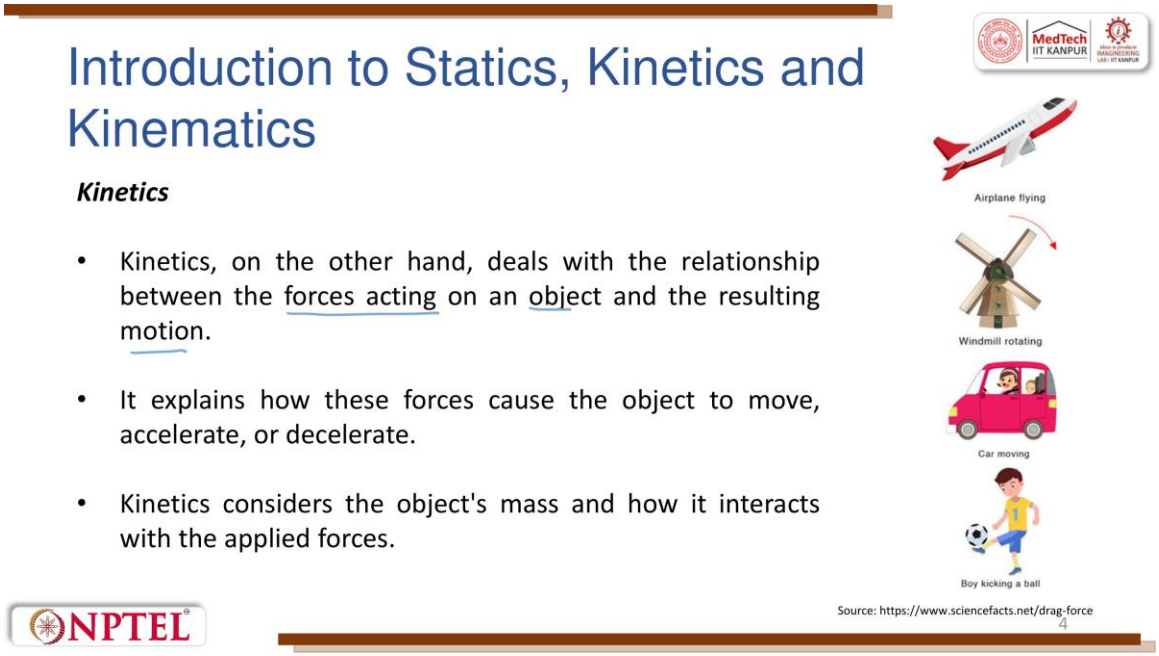
momentum will be seen. Finally, like every time we will try one or two numerical problems.

We will have a recap then references.



So statics is concerned with objects at rest or in a state of equilibrium. In the simpler term, it analyzes the condition under which a body remains stationary. For example, a bus standing, a dam erected, a bridge constructed. A big shopping complex constructed.

A tripod where a camera is located while shooting is stationary. So, these are some of the examples. This branch of mechanics focuses on the forces acting on an object and how these forces balance each other out automatically preventing any motion. So if there is any stability problem, so then what we do is we first try to come to static analysis and find out what are the forces coming and how are the forces getting balanced. So that is very important for statics, kinetics.



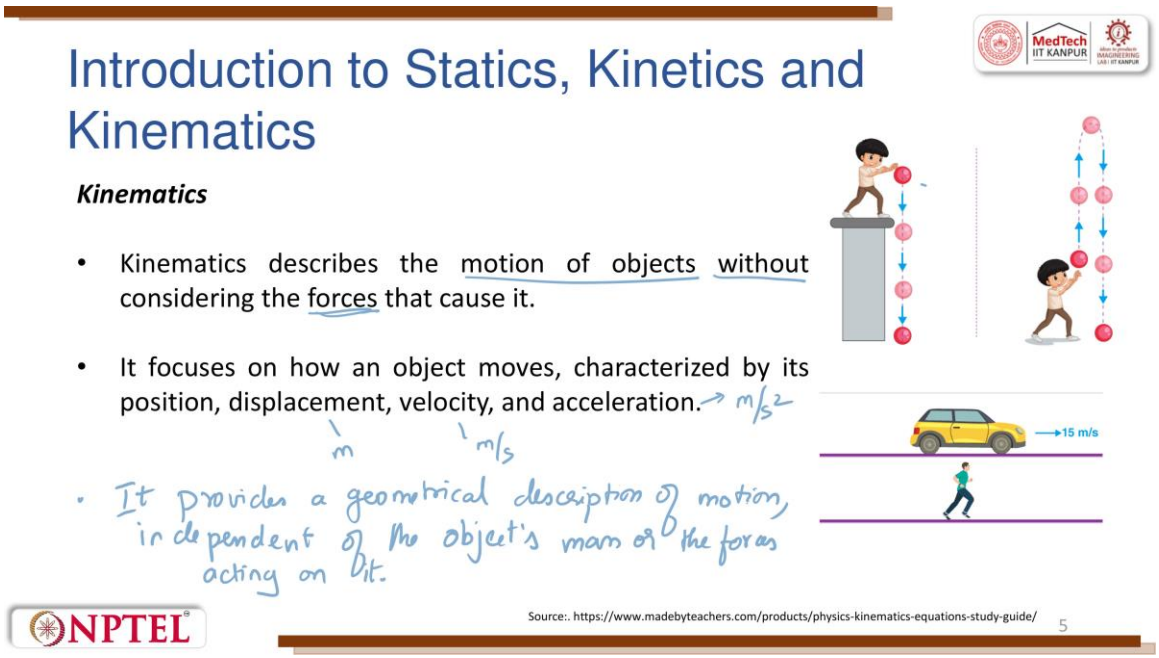
On the other hand, it deals with the relationship between the forces acting on an object and the resulting motion. For example, when the plane is flying, when the windmill is rotating, when the car is moving, a boy is playing football and kicking the football.

So, these are all where there is a force acting on the object and there is a resulting motion. It explains how these forces cause the object to move, accelerate or decelerate. For example, if you are playing a ball tennis game, so you are trying to strike or hit the ball as against the wall. So the force what you apply, hits on the wall and the ball bounces and come back. What will be the force?

Will it be same? Will it increase? Will it decrease? Right? You try to take a dry ball and then hit it against the wall. Dry tennis ball, you try to hit it against the wall. Then you try to take a semi moist or a wet ball, try to hit it against the wall. Then you try to soak the ball in water and then try to ball against the wall.

So when you try doing all the three, you will try to see different forces are required, if you want to maintain the same force with which the ball comes back. So, these things explain how these forces cause the object to move, accelerate or decelerate. Kinetics

considers the object mass and how it interacts with the applied force. Even when you are trying to use a spoon while eating, that is also a force which is there. How this mass force interacts and what happens to the motion?



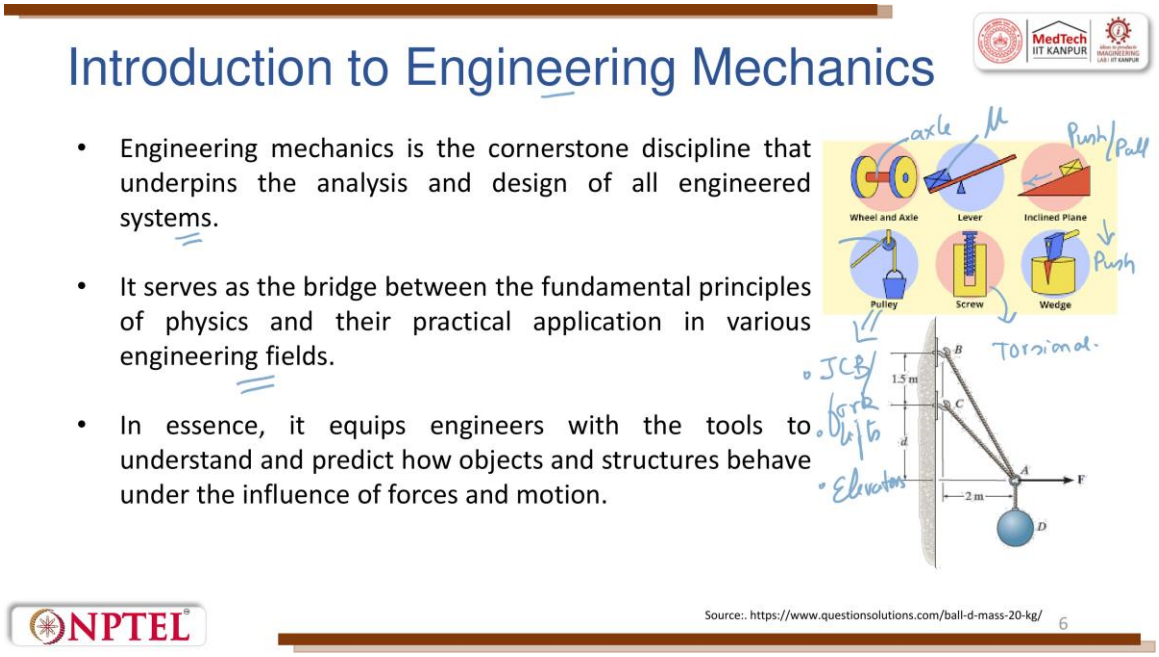
Kinematics describes the motion of the object without considering the forces that causes it. So, here you should be very clear, the motion of the ball without considering the forces. So, in the last two cases, what happens? Kinetics is the relationship between the force acting on the object and the resulting motion. The first one is it is focused towards the concern of the object at rest or in a state of equilibrium.

How forces balance each other in order to prevent motion is statics. So three different be very clear in the definitions. It forces on how an object moves characterized by its position, displacement, velocity, acceleration. By this time, you would have learned what is the difference between position, displacement, velocity, acceleration. I can just give you a small lead. This is m/s^2.

This is m/s and this is meter. I hope you can go back, revise in the first lecture and get this. So, it also provides a geometrical description of motion independent of the object mass or the forces acting on it. So you can see the car with what velocity a person who runs at this speed, a boy trying to bounce the ball, a boy trying to throw the ball, the ball follows a projectile motion and he is trying to throw the ball in air. So, all these things

lead to usage in engineering mechanics and it these concepts are very much used in aerospace, chemical engineering, electrical engineering also they use it, right.

So, all areas of engineering, civil engineering also they use it in a large extent. So, in all areas of engineering they do static analysis, kinetic analysis and kinematic analysis depending upon the requirement.



So now let us see the introduction of Engineering mechanics. So, engineering mechanics is the cornerstone discipline that underspins the analysis and design of an engineering system. What is an engineering system?

For example, wheel axle is an engineering system. A lever which is used to lift. Wheel and axle are, you have two wheels. These two wheels are connected by a rod. So, that rod is called as axle. In automobile, it is exhaustively used. In train also it is used. So, inclined plane, a block placed on an inclined plane is an engineering system.

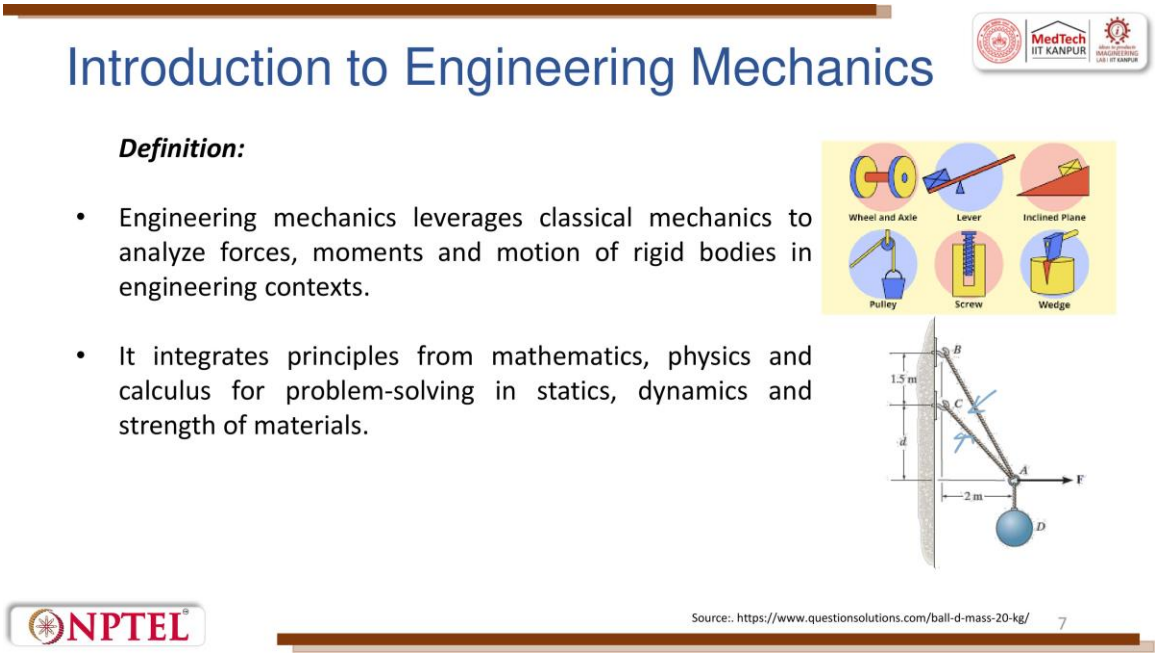
Then you have lever pulley for lifting. So, this is exhaustively used today in JCBs that is or forklifts. And even if you see that, it is exhaustively used in your elevators. They use a pulley mechanism. Then a screw which is used to fasten two blocks or whatever it is.

So then you also have a wedge system. So, all these things are engineering systems wherein which applied mechanics finds a very important role. So, if you go back here, I

would like to recollect what we saw in the initial days. We saw push-pull. So, in that way if you go, this is a push force.

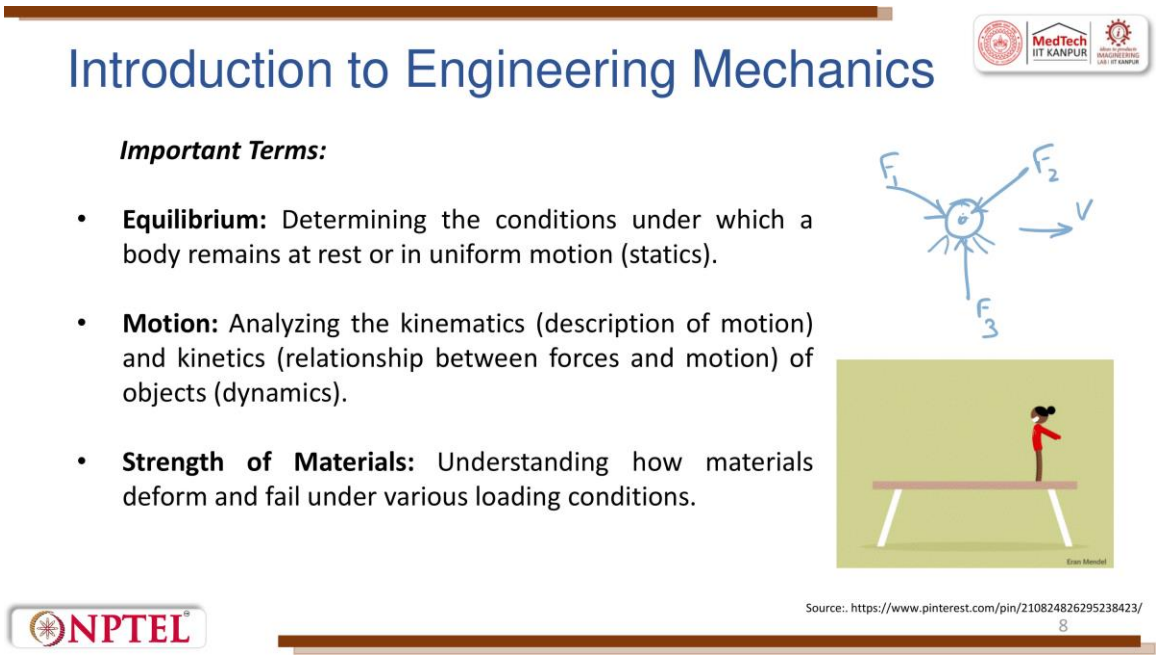
This is a torsional force. If it slips down, it is either a pull or a push whatever you are trying to do, right. Lever based and then this again we will have pull or push. So here everywhere the mu dominates, we saw the friction also dominates see as and when you start reading such courses you have to correlate with real time and you have to correlate back and forth knowledge such that you will start enjoying the course as and when it proceeds. It serves as the bridge between the fundamental principles of physics and their practical application in various engineering fields. In essence, it equips engineers with the tool to understand and predict how objects, structure behave under the influence of force and motion.

For example, a tree, when there is a strong wind blowing, the tree will swing or it moves. So that is nothing but tree, an object, interacting with the force and then what is the motion it has. I try to push an object. Object is stationary, it is a structure or an object you can say, it is a stationary one. I try to apply force and while applying force, it tries to fall down or sometimes it moves. So, all these things can be figured out in engineering mechanics.



So, if you go by definition, engineering mechanics leverages classical mechanics to analyze force moments, motion of rigid body in engineering context, for example you can

see here it is a system, a wall in which you have put two hooks, the rope is attached to a weight which is there which will try to slide or swing. So just by playing with this and then playing with the distance, the ball can be moved up or down or left or right to meet out the real time requirements. So it integrates principles from mathematics, physics,



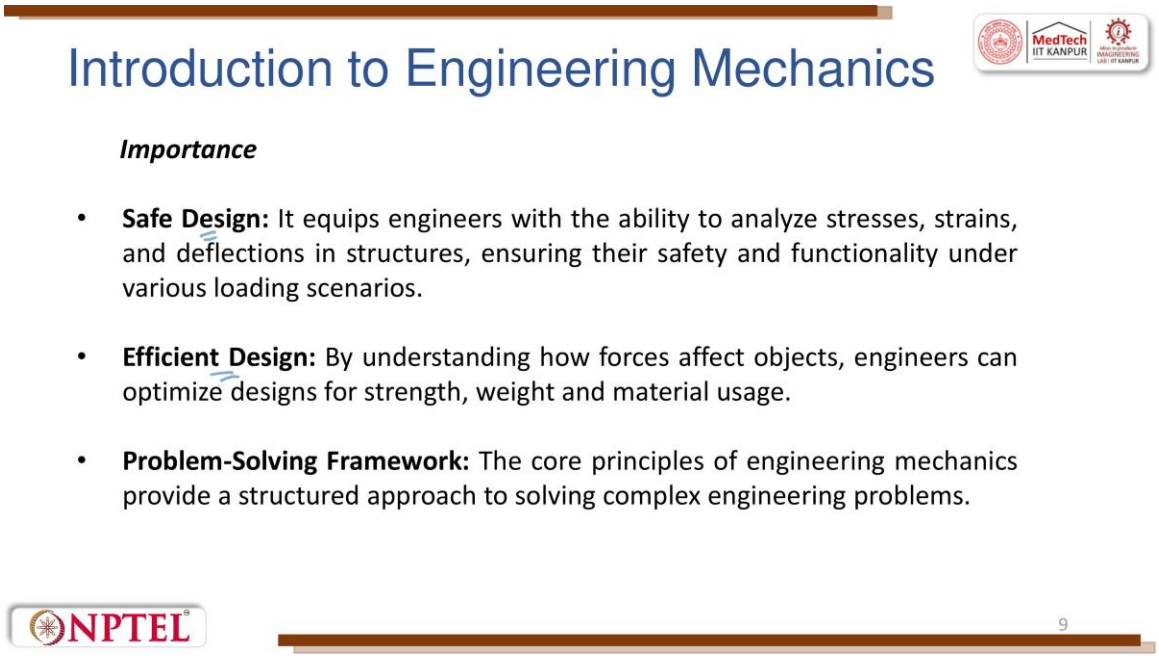
calculus for problem solving in statics, dynamics and strength of material. We will see what is strength of material later.

So, what are the important terminologies which are generally used in engineering mechanics? They are first is equilibrium. So, equilibrium will have a body. This can be F_1, F_2 and F_3. So, this can move with a velocity v. So, here this is an object where forces are there, it is moving stably. So, that is we can say is equilibrium. Equilibrium determines the condition under which a body remains at rest or in uniform motion.

What is motion? Analyzing the kinematics. And the kinetics of the object is motion. So in kinetics, relationship between the force and motion of the object, Strength of materials are nothing but understanding how materials deform and fail under the various loading conditions are nothing but strength of materials. So, applied mechanics, when it is extended to a material, it gets into strength of materials.

For example, you have a ball. Now, the forces are going on. So, it is in an equilibrium state. It is moving. Now let us assume if there is a hold there.

So for example, I hold it, grip it here. Now there is a material. So when the forces are applying, what is the response of this material such that it will try to respond to the requirements. So that is nothing but strength of materials.



Safe design. Then effective design. Problem solving framework. So, these are some more important terminologies which you should know. What is a safe design? It equips engineer with the ability to analyze stresses, strain and deflection in structure, ensuring their safety and functionality under various loading condition. For example, you try to buy a shoe. With using the shoe, you try to walk, you wear the same shoe for running, jogging, jumping, all these things you do.

But your shoe never gives away. So here what has happened is nothing but there is a safe design done on the system and then you can same way, for example, you take a cot where you sleep. So sometimes what happens, you go there, sit in a cot and sleep. A 60-year-old man or a 50-year-old man does it. When a 20-year-old adolescent boy or a 12-year-old child, if they go to bed, they jump on the bed.

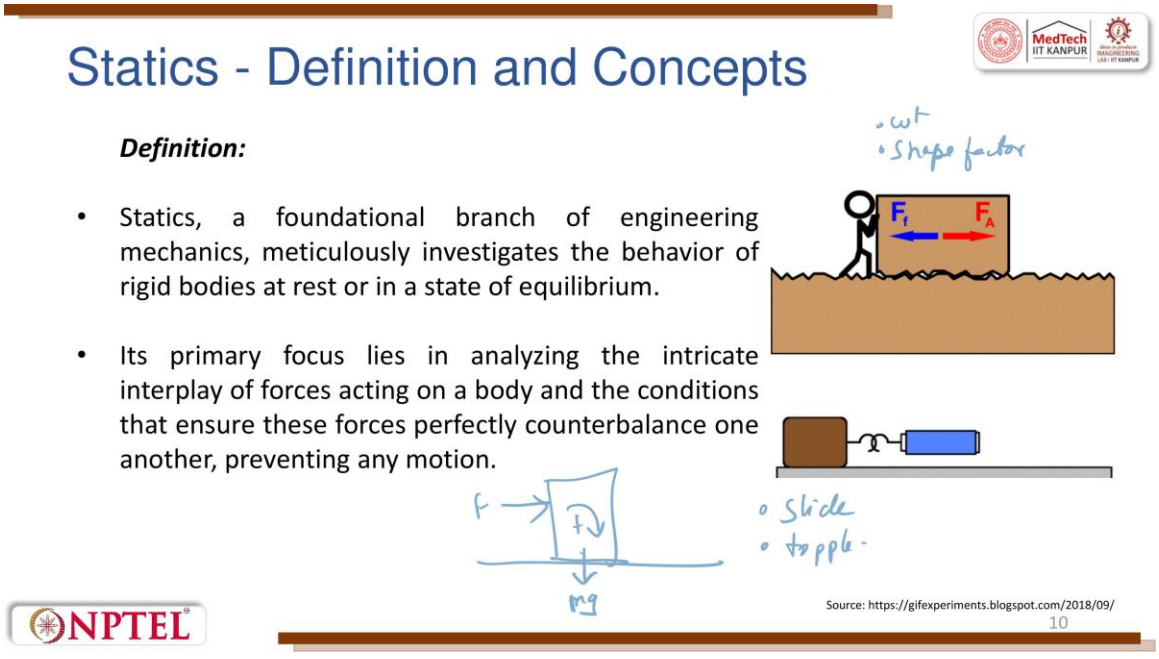
Still the cot has to withstand the impact load. And it also has to withstand the sliding load whatever it is. So that is safe design. So naturally what happens is the leg strength, the cot

base, the fastener which is used, their torque, everything is to be considered such that you make a safe design. Efficient design, by understanding how the forces act on the affect the object, engineers optimize designing for strength, weight and material use is effective design.

One is safe design, the other one is effective design. Effective design is predominantly used in aeroplane, rocket, automobile. See, even in your automobile car, you can increase the safety to a large extent. But when you increase the safety, you try to add more and more. When you add more and more material, the weight goes high, the mileage goes down.

So now what you do is you try to have a compromise by reducing the weights of the sheet metal body which is around or reducing the weight of the material which is used such that the efficiency, mileage efficiency can be improved. And when you are doing so, if you go back and see, we do crash test. So in crash test, we try to do a little bit of optimization and try to generate an efficient design. What is problem solving framework? The core principle of engineering mechanics provides a structured approach to solve complex engineering problems.

You try to take a system. In that system, you try to divide several small subsystems. And each of the subsystem, you try to have a framework. And from that framework, you start working.



When we are looking at the definition in statics, a fundamental branch of engineering mechanics, meticulously investigates the behavior of rigid body at rest or in state of equilibrium. If you look at this tries to tell you a simple application or a simple system where in which a block, a wooden block or a stone block is there. So first you see when the stone block is at rest. You have a spring which is applied or you try to have a hydraulic system or a pneumatic system or a motor attached with a screw, whatever it is, you try to pull. So when you try to pull, you see the block is in stationary motion and the spring keeps on increasing the load.

After a certain point of load, the spring, so that means to say so much of weight is getting applied, this block starts moving. Once it starts moving, so from static friction to sliding friction it goes, you see there the load what you apply has reduced. So this is a simple example. This is very much used in any of the real time application where there is a moving body.

You can also understand that when you have a wooden rack wherein which it is loaded with books, it has a heavy mass. So now when you try to drag it, initially you will have so much of resistance, you keep on increasing your pushing force on it, at some point of time it slides. If your pushing force is instantaneously very large, the object is stationary, it topples. For example, I will try to draw a situation. So you have a rack, so you are trying to push, so the mass is here, weight is here.

You are trying to push with a force. Sometimes it can slide, sometimes it can topple. So how does it topple? The force is large. The bottom one which is holding the weight is resisting the force to help in movement.

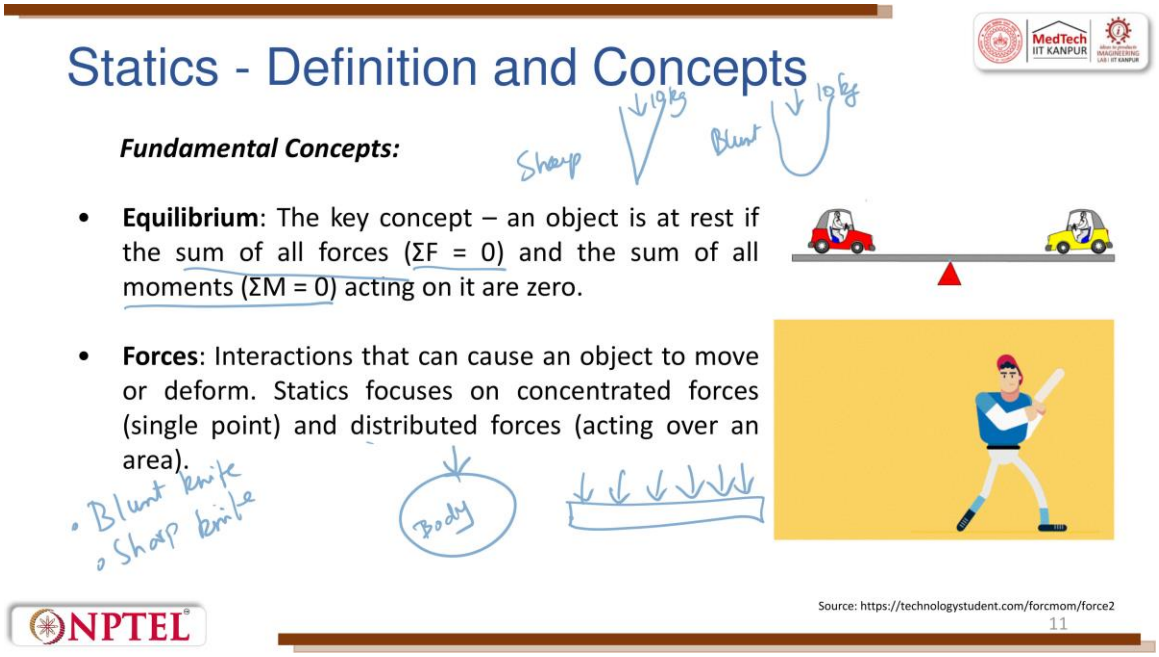
If the force keeps on increasing, it topples. See now you see it is a typical situation which you see in real time. In order to analyze that, we try to use this statics. So it is nothing but a foundational branch of engineering mechanics wherein which meticulous investigation are done on the behavior of rigid bodies at rest or in the state of equilibrium. Its primary focus lies in analyzing the intricate structure interplay of forces acting on a body and the conditions that ensures the forces perfectly counterbalance one another preventing any motion is statics.

And why do you want to do static? Because many a time, you are in motion. By doing static analysis, you can try to have a first-hand approximation to how the system will

react, what all has to be there in the system, what should be the weight of the system. All these things can be thought of. So there are two things which are there. Weight is there. The shape is also there.

We call it a system. So, weight is in, we will try to do everything in the statics and once it is done, when we have to improve the efficient design, we start playing with the shape factor. So you can see in the previous example, a man trying to push a block. So here is the force FA which is there. Here is a frictional force which is going against.

So why is that friction coming? No surface is flat. So you will have several interlockings on the floor and with the object. This tries to increase the friction.



The next fundamental concept is going to be equilibrium. The key concept is an object is at rest, if the sum of all the forces ($\sum F = 0$) and the sum of all the momentum ($\sum M = 0$). So it is something like this you have a car on one side, you have a car on one side of equal weight, so it is at equilibrium. So equilibrium means summation of all the forces and sum of all the moments acting on it must be 0. So, what we do is we always try to make a drawing system. With simple system, we convert a real time situation into a simple system, mass, force and other things.

Then we will try to see whether the system is in equilibrium for which we always try to use this rule. $\sum F = 0$ or $\sum M = 0$ and both are to be used. Forces, interaction that can

cause an object to move or deform. Static focuses on concentrated forces and distributed forces acting over an area. So what we are trying to say is, in order to simplify the problem, we will always try to see, okay, there is a body.

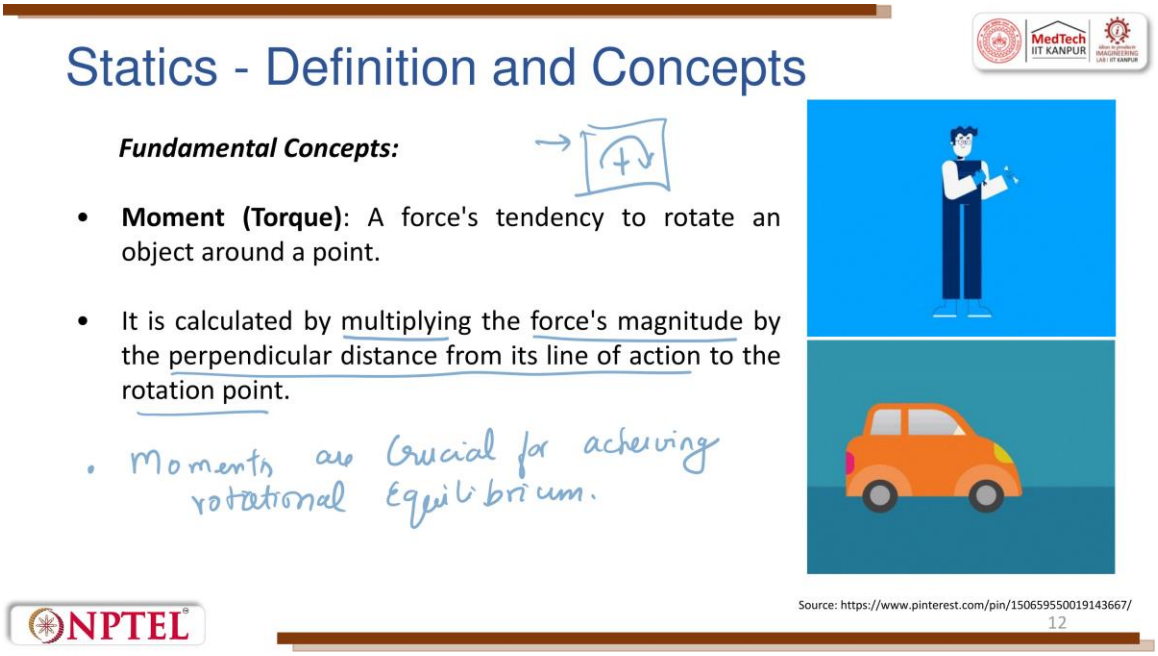
In this body, there is a concentrated load. So here what has happened? The load has been shifted to a single point. And this is a body. This can be a ball or whatever it is.

There is a body. There is a force, single point acting on it. So this can be thought of or you can try to have a body wherein which you try to apply it over an area. So let us take a simple example. You take a blunt knife and a sharp knife.

So why is the force always very high in a blunt knife as compared to that of a sharp knife? Why? Because the load which is applied gets distributed over an area. A sharp knife. A blunt knife. So now you apply a force of 10 kg.

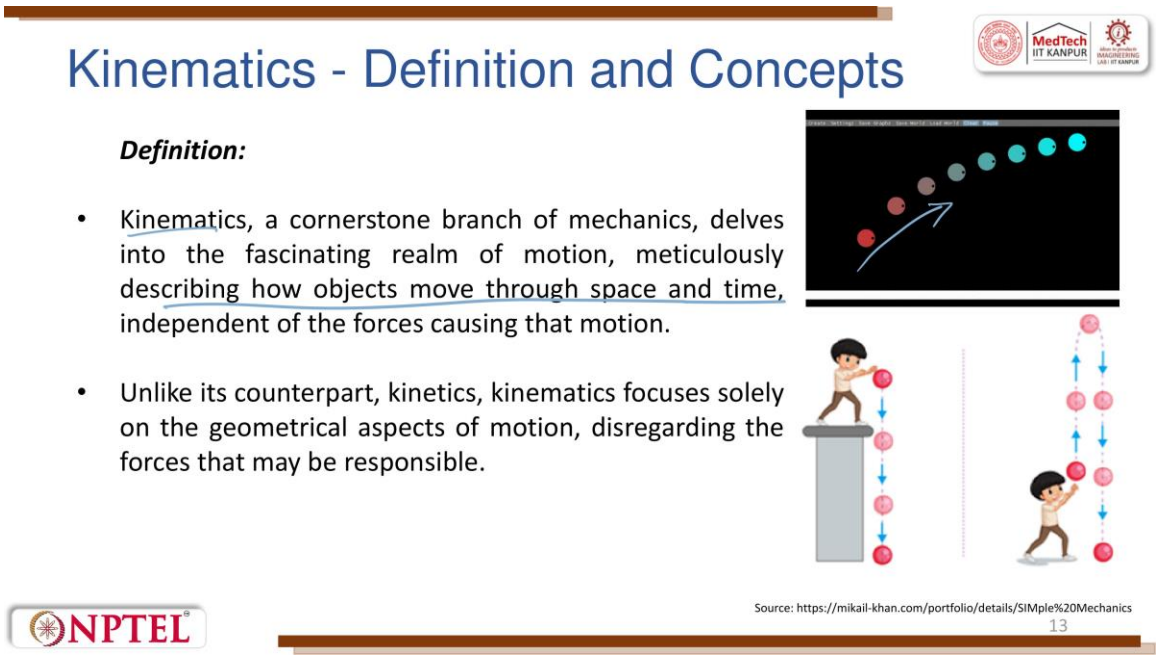
You apply a force of same 10 kg. So here it is getting distributed over an area. Moment it is distributed over an area, so then what happens? For cutting, you will always try to use a larger force. So this is what is the distribution of force effect which comes. Sharp and distribution. So single point and distributed over an area.

So statics focuses on concentrated force, single point or distributed area. The force acting also can be that, right. So force can be on a single point, force can be on an area.



Moment is nothing but a torque. A force's tendency to rotate an object around a point is called a torque.

The body which is mounted, so you are applying force, so it topples, so it is nothing but moment It is calculated by multiplying the force magnitude by the perpendicular distance from its line of action to the rotation point. That is moment. So the important terminologies are multiply force magnitude by perpendicular distance from its line of action to the rotation point. So this is important. So when we discuss more, moments are crucial for achieving rotational equilibrium. So, this is very important, you remember we were looking into $\sum F = 0, \sum M = 0$. So, this is for a equilibrium state.



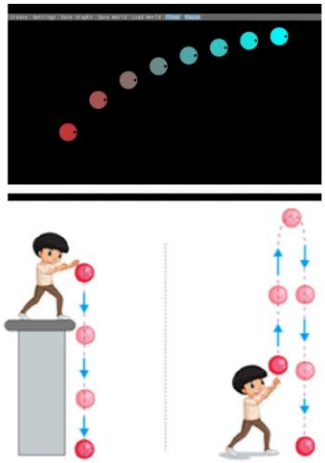
Let us see some of the definitions of kinematics. Kinematics is a cornerstone branch of mechanics. Deloves into the fascinating realm of motion meticulously describing how objects move through space and time. Independent of the forces causing that motion. So here we are more worried about how objects move through space and time. That is kinematics.

So, unlike its counterpart, kinetics, kinematics focuses solely on the geometrical aspects of motion, disregarding the forces that may be responsible. So, examples are a boy standing on a rooftop and playing or throwing a ball or a boy trying to throw a ball in the air and he sees how does the fall happens, a projectile motion.

Kinematics - Definition and Concepts

Distinction from Kinetics:

- While both kinematics and kinetics deal with motion, a crucial distinction exists.
- Kinematics is akin to a detailed map that meticulously charts the path and speed of an object, without explaining why the object takes that specific route or how fast it travels.
- Conversely, kinetics delves into the "why" aspect, analyzing the forces that cause the motion described in kinematics.



Source: https://mikail-khan.com/portfolio/details/SIMple%20Mechanics

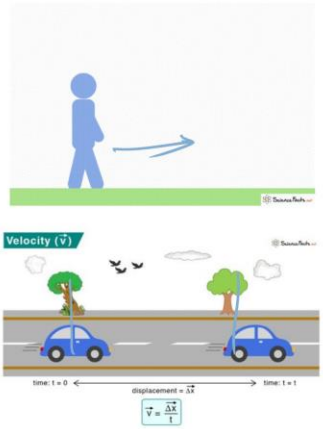
Distinction from kinetics is while both kinematics and kinetics deals with motion, a crucial distinction exists. In kinematics, akin to a detailed map that meticulously chart the path and the speed of an object without explaining why the object takes the specific route or how fast it travels. It only looks at the path and the speed of an object.

Conversely, kinetics delves into the y aspect analyzing the forces that causes the motion described in kinematics. So, you should clearly understand the distinction between kinetics and kinematics. Kinetics is y aspect is kinetics. Kinematics is path and speed of the object is discussed here.

Kinematics - Definition and Concepts

Key Concepts:

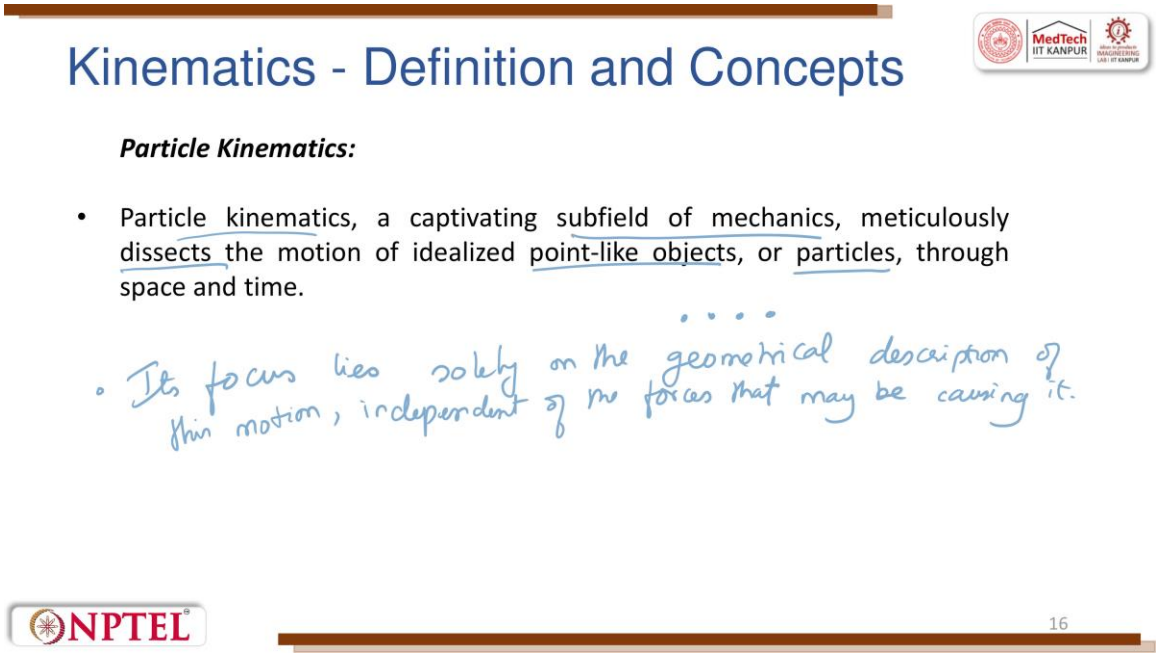
- Displacement (Δx) is the change in position of an object from its initial (x_0) to final (x_1) points, expressing both magnitude and direction ($\Delta x = x_1 - x_0$).
- Velocity (v) measures the rate of change of displacement over time, capturing both speed and direction ($v = \Delta x / \Delta t$).
- Acceleration (a) represents the rate of change of velocity over time, indicating whether an object is speeding up, slowing down, or changing direction ($a = \Delta v / \Delta t$).



Source: https://www.sciencefacts.net/velocity.

So, the other key concepts are in kinematics are displacement. Displacement is Δx is the change in position of an object from its original x_0 to a final x_1 point expressing both magnitude and direction. So $\Delta x = x_1 - x_0$. Velocity measures the rate of change of displacement over time. So, velocity = $\Delta x / \Delta t$, displacement, velocity with respect to time. Then acceleration represents the rate of change of velocity over time indicating whether an object is speeding up, slowing down or changing direction is called as acceleration.

Please try to understand the difference between displacement, velocity and acceleration. It is rate of change of displacement is velocity, rate of change of velocity is acceleration. So in acceleration, you only say whether the car is speeding or slowing.



The next concept is Particle Kinematics. It is a subfield of mechanics wherein which it dissects the motion of idealized point-like objects.

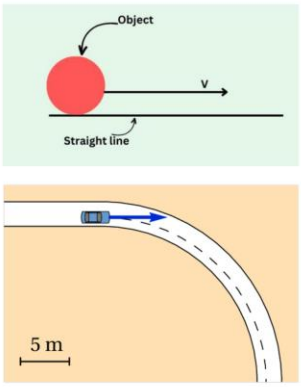
Point like objects or particles through a space and time. Its focus lies solely on the geometrical description of this motion independent of the forces that may be causing it. It is a very important statement. Its focus lies solely on the geometrical description of this motion independent of force that may cause it.

Kinematics - Definition and Concepts

Describing Particle Motion:

There are two main types of motion:

1. **Rectilinear (Straight Line):** Simpler description with scalar quantities (magnitude only) for displacement, velocity, and acceleration.
2. **Curvilinear (Curved Path):** Requires vector quantities (both magnitude and direction) for a complete description of displacement, velocity, and acceleration.



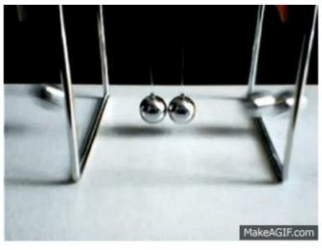
Source: https://villate.org/dynamics/curvilinear_motion.html

So there are two points, main types of motion, particle motion. One is Rectilinear, the second one is Curvilinear. Rectilinear means an object moving along a straight line. So its simpler description with scalar quantities is magnitude only for displacement, velocity and acceleration. When we talk about curvilinear, it requires vector quantity also with both magnitude and direction for a complete description of displacement, velocity or acceleration. The two things are very very important. Rectilinear and curvilinear. Rectilinear is predominantly is a scalar quantity. Curvilinear is a vector quantity.

Kinetics - Definition and Concepts

Definition:

- Kinetics, a cornerstone of mechanics, delves into the profound influence of forces on the motion of objects.
- It establishes a crucial link between the applied forces and the resulting changes in an object's state of motion.



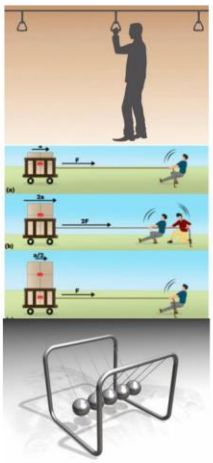
Source: https://makeagif.com/gif/kinetic-balls-I7buMz

So, when we see the definition of kinetics, it is a cornerstone of mechanics, dwells into the profound influence of forces on the motion of the object. It establishes crucial link between the applied forces and resulting changes in an object's state of motion. It establishes the object's state of change of motion.

Kinetics - Definition and Concepts

Newton's Laws of Motion:

- Newton's First Law of Motion: It states, "Every body continues in its state of rest or of uniform motion in a straight line, unless acted upon by some external force". This is also known as 'Law of Inertia'
- Newton's Second Law of Motion: It states, "The rate of change of momentum is directly proportional to the impressed force and takes place in the same direction in which the force acts".
- Newton's Third Law of Motion: It states, "To every action, there is always an equal and opposite reaction".



Source: https://www.teachengineering.org/lessons/view/uno_swing_lesson01

So now let us see some of the Newton's law of motion. Newton's first law of motion is It states that every body continues in its state of rest or of uniform motion in a straight line unless acted upon by some external force is Newton's first law of motion.

This is also known as law of inertia. The second law of motion, it states that the rate of change of momentum is directly proportion to the impressed force and takes place in the same direction in which the force acts. So this is the second law of motion, first law of motion. The third law of motion is to every action there is always an equal and opposite reaction.

Kinetics - Work and Energy

Work and Energy Principle:

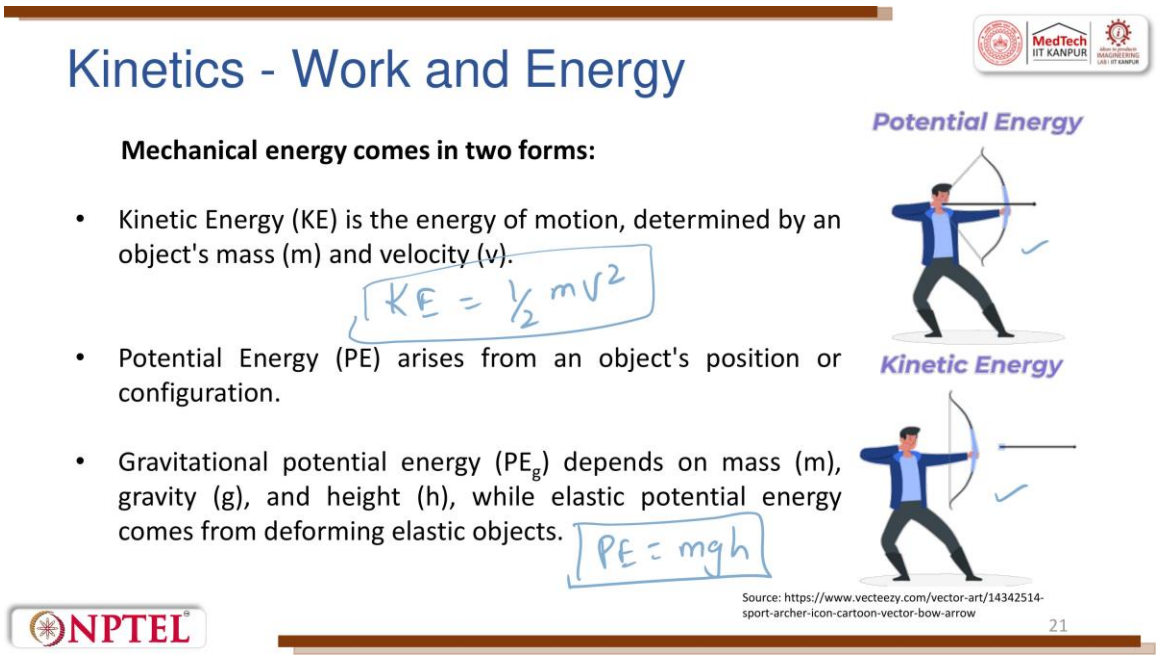
- This principle establishes a crucial link between the work done by a force and the change in an object's energy.
- In simpler terms, the work done on an object translates to a change in its energy.
- Mathematically, the work W done by a constant force F acting on an object undergoing a displacement d is expressed as W = Fd cos(θ), where θ is the angle between the force and displacement vectors.

Source: https://leverageedu.com/blog/work-energy-and-power/

Now let us see work and energy principles. So energy watts or it can be joules. Watts are joules per second, right. So energy can be heat energy as I told you. It can be energy what you consume in the house. Force, work is another thing. So, work and energy principles. This principle establishes a crucial link between the work done by a force and the change in an object's energy.

So, I am trying to push or I am trying to keep a ball. Hit it with a hammer. So, the work done by force and the changes in an object's energy. In simpler terms, the work done on an object translates to change in its energy. Mathematically, the work W done by a constant force F acting on an object undergoes a displacement d is expressed as $W = FdCos\theta$

Theta is the angle between the force and the displacement vector. So work, this is very important, work can be expressed as $W = FdCos\theta$. Theta is the angle between the force and the displacement vector.



So, the mechanical energy can come in two forms or it can come in maybe three forms I can say. But predominantly we talk about only two forms. So, what are they?

They are nothing but kinetic energy and potential energy. Kinetic energy is the energy of motion determined by an object's mass m and velocity. So, this is expressed as

$$KE = \frac{1}{2}mv^2$$

So potential energy is this. Kinetic energy is this. Potential energy means an arrow getting loaded to a string.

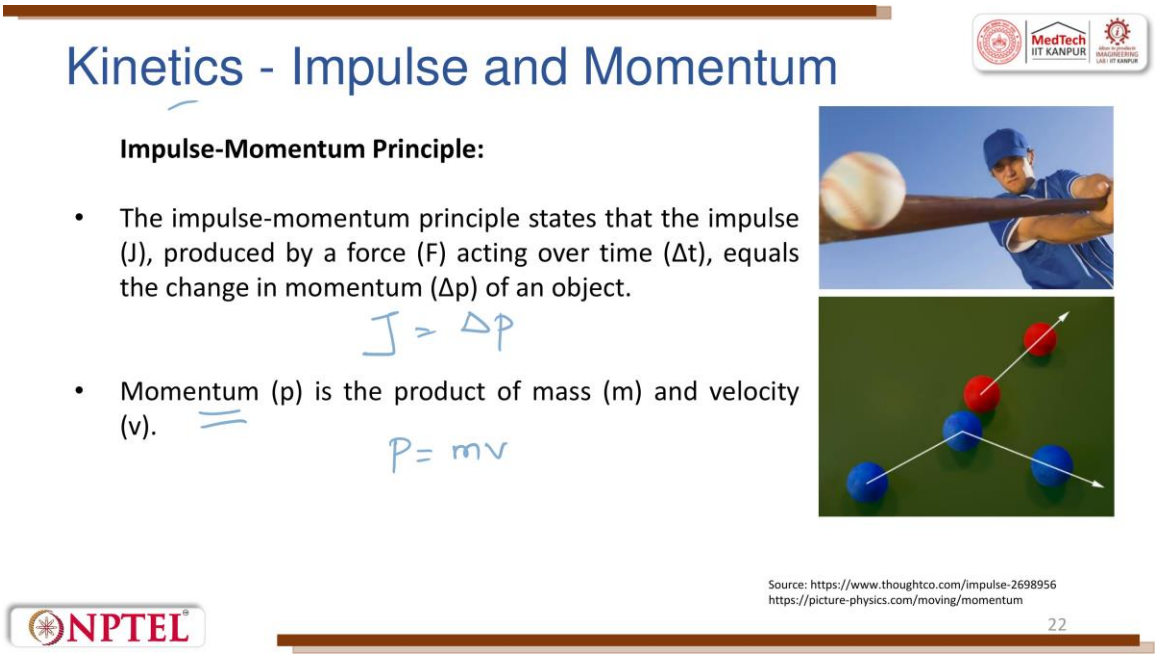
Or you are trying to pull a rubber band and then you keep a paper and release it. You see what is the projectile motion of the paper, whichever is used. This is release. And potential energy is the energy which is getting stored. Potential energy arises from an object's position or configuration.

Gravitational potential energy depends on mass, gravity and height. While elastic potential energy comes from deforming elastic objects. So, PE = mgh. So, this is for kinetic energy and this is for potential energy. In many of the manufacturing problems, we will try to use potential energy and kinetic energy.

For example, what is the load required to split a material by water? So now where is the application? It is water jet or I will put it this way. There is a waterfall which comes. The waterfall, what is the energy required

To erode the rock from the particular place right. So now what is the force required to break the rock. So that depends on a waterfall. So, in waterfall, you try to change the, increase the potential energy. When you try to increase the potential energy, what happens is you try to play with the hedge.

So, what is the height from where the water falls and what is the mass of it, then what is the gravity. So, all these things try to play for potential energy and then it tries to hit at the object its kinetic energy.



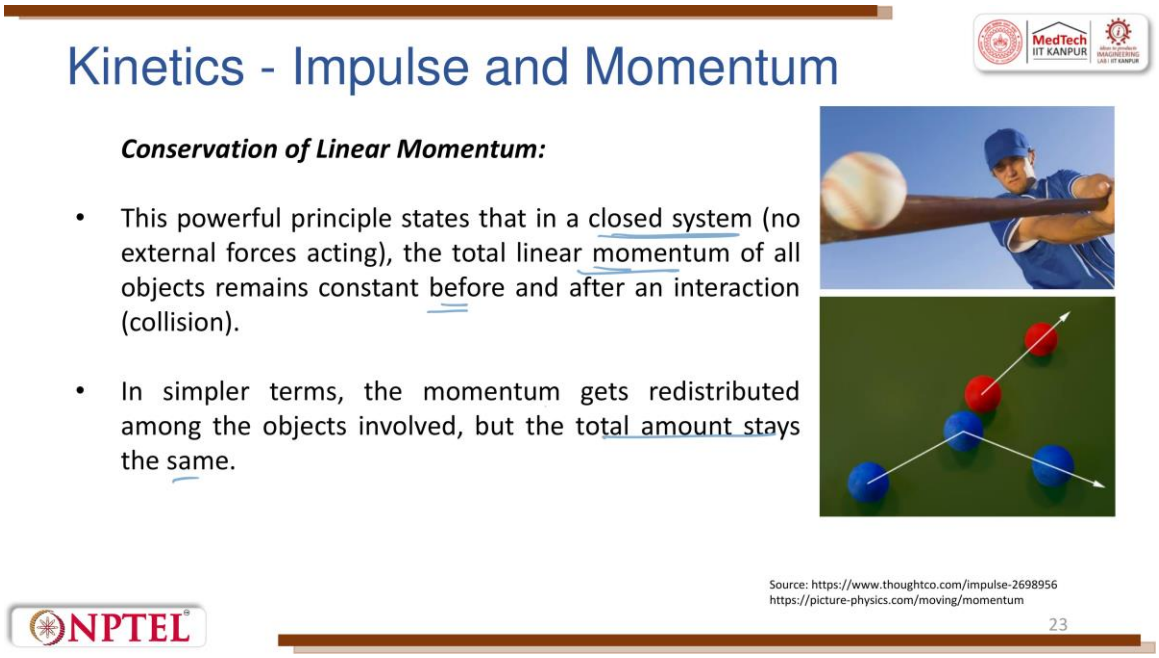
So next is impulse momentum principle which is part of kinetics. So, the impulse momentum principle states that the impulse J produced by a force F acting over a time Δt equals the change of momentum Δp of an object. So, this is nothing but $J = \Delta p$.

The principle states that the impulse J, you use a baseball or you use a football or you use a cricket or you throw a basketball. So impulse J produced by a force F acting over a time period Δt equals the change of momentum Δp of an object. So, $P = mv$. This is momentum.

$$F = ma$$

$$P = mv$$

So, when you are trying to play a carrom board or when you are trying to play a billiards, so you can see the striking ball hitting the other ball and then moving.



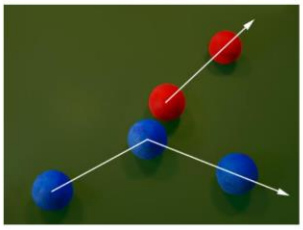
So, what is conservation of linear momentum? The conservation of linear momentum is a powerful principle which states that in a closed system, no external force acting, the total linear momentum of an object remains constant before and after an interaction. In simpler terms, the momentum gets redistributed around the object itself but the total amount stays the same. The amount whatever you apply in your closed system, that the total linear momentum of an object remains constant before and after an interaction.

So, the moment gets redistributed among the objects involved, but the total amount stay is the same.

Kinetics - Impulse and Momentum

Applications in Collisions

- The impulse-momentum principle is essential for analyzing collisions.
- It helps to predict post-collision velocities by considering the impulse from forces and changes in momentum.
- This knowledge aids in designing safety features like car airbags and understanding phenomena like planetary collisions.



Source: https://www.thoughtco.com/impulse-2698956
https://picture-physics.com/moving/momentum

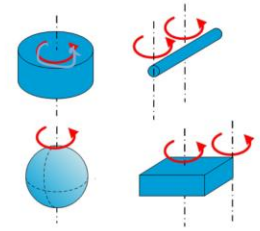
So, applications of collusions we will see. The impulse momentum principle is essentially used for analyzing collusions. Collusion means a ball hitting a ball, a carrom board coining hitting another carrom board coin, a bat hitting a ball, a tennis racket hitting a tennis ball. It helps to predict post-collusion velocity by considering impulse from the force and changes in momentum.

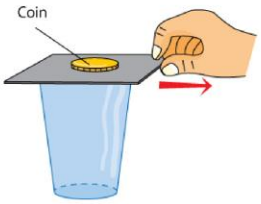
This knowledge helps in aiding safety features like car, airbags and understanding phenomena like planetary collusions. So everywhere we use the application in collusion.

Kinetics - Moment of Inertia

Moment of Inertia

- The moment of inertia (I) emerges as a crucial concept analogous to mass in linear motion.
- It quantifies an object's resistance to change in its rotational state.
- Just like a heavier mass is harder to accelerate linearly, a larger moment of inertia signifies greater resistance to rotational acceleration.

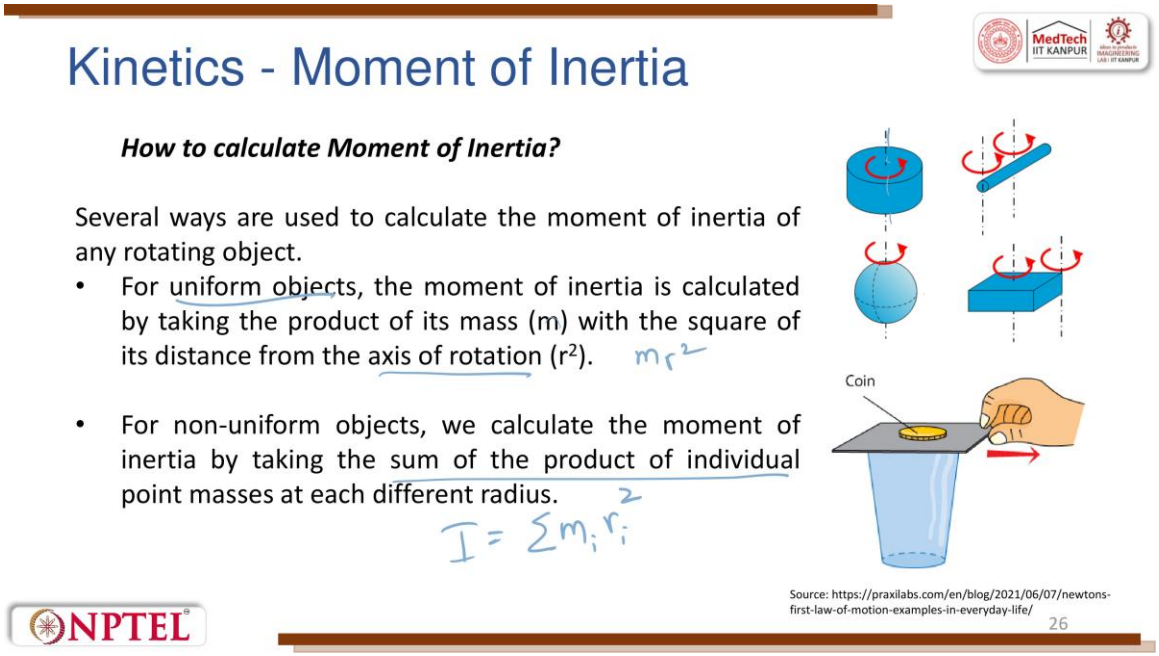




Source: https://praxilabs.com/en/blog/2021/06/07/newtons-first-law-of-motion-examples-in-everyday-life/

Moment of inertia emerges as a crucial concept analogous to mass in linear motion. So, mass in linear. So, you can see here this is I, moment of inertia.

The quantities an object resists to change in its rotational state is moment of inertia. Just like a heavier mass is harder to accelerate linearly, a large amount of inertia signifies greater resistance to the rotational acceleration. You keep a coin, you keep a paper, you pull the paper in such a way such that the coin slips inside the glass tumbler or inside a closed volume, right. So, moment of inertia is very important, in later part of the course, we will use this concept of moment of inertia which is it quantifies an object's resistance to change in its rotational state. So, when you have a pen, when you have to spin the pen, its moment of inertia is there.



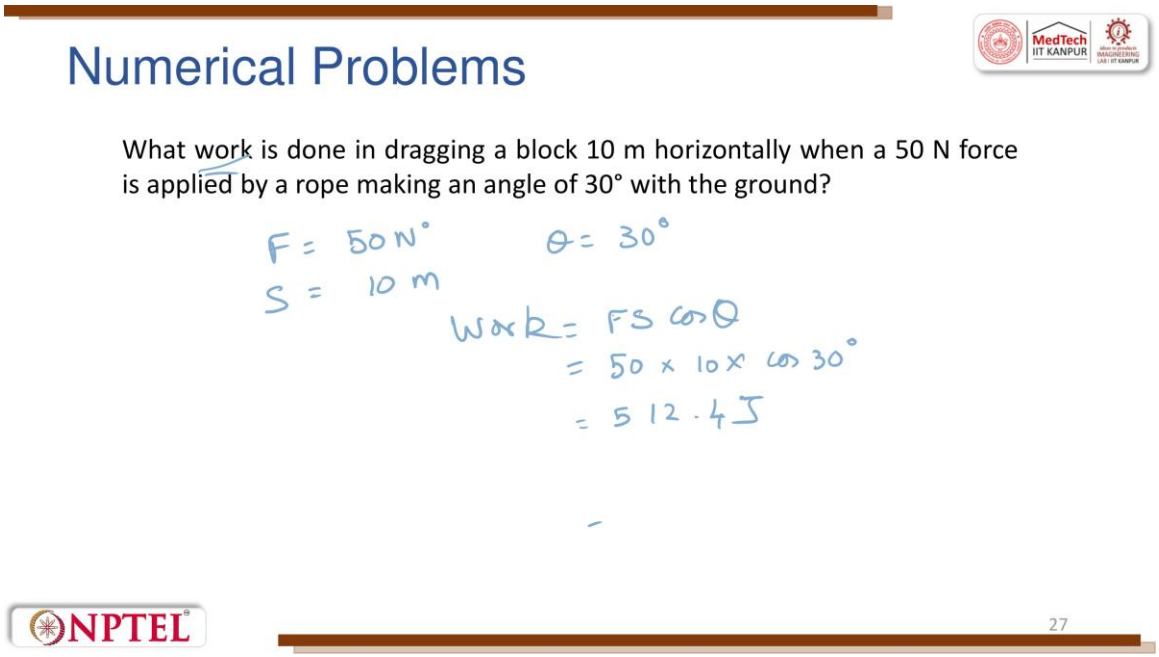
How to calculate the moment of inertia? Several ways are used to calculate the moment of inertia of a rotating object.

They are for uniform objects; the moment of inertia is calculated by taking the product of mass with the square of its distance from the axis of rotation. So, it is mr^2. This is how they calculate for a uniform object. What is a uniform object? Axi-symmetry part. Uniform objects, the moment of inertia is calculated by taking the product of the mass with its square of the distance from the axis of rotation.

For a non-uniform object, we calculate the moment of inertia by taking the sum of the products of individual point masses at each different radius. So, this is written as

$$I = \sum m_i r_i^2$$

It is mi is nothing but summation of $m_i r_i$ square. So, it is the sum of the product of individual point masses.



Now, let us try to solve a simple problem and use the concepts whatever we have gone through. In the tutorials, you will have minimum 10 problems in each lecture. We will try to post the problem and you will have to solve it. Then we will release the solution also. What work is done in dragging a block 10 meters horizontally when a 50 Newton force is applied by a rope making an angle of 30 degrees with the ground? So, how do you solve the problem?

What is the force available? 50 Newton. What is the horizontal distance it has to drag? 10 meters. What is the theta which it makes? 30 degrees. So, what do you have to find out? What is the work done? So, what is the formula for work?

$$W = FsCos\theta$$

$$50 * 10 * Cos30° = 512.4\, J$$

Numerical Problems

How large a torque is needed to accelerate a wheel, for which I = 2 kg m^2, from rest to 30 r.p.s in 20 seconds?

Moment of Inertia (I) = 2 kg m^2

R.P.S after 20 sec, n = 30

Intial velocity, $\omega_1 = 0$

Final velocity $\omega_2 = 2 \times \pi \times 30 = 188.4$ rad/sec

Angular acceleration $= \frac{\omega_2 - \omega_1}{t} = \frac{188.4 - 0}{20} = 9.43$ rad/sec^2

Now torque : $\tau = I \times \alpha$

$= 2\ kg\ m^2 \times 9.43\ rad/sec^2 = 18.86$ Nm or J

Now, let us see one more problem. How large a torque is needed to accelerate a wheel, that means to say in a car wheel, for which I = 2 kg meter square from rest to 30 rotations per second in 20 seconds. How large a torque is needed to accelerate a wheel for which I equal to 2 kg m^2 from rest to 30 rps in 20 seconds. So, moment of inertia they are asking.

$$Moment\ of\ inertia\ (I) = 2\ kg\ m^2$$

$$RPS\ after\ 20\ seconds\ n = 30.$$

$$Initial\ velocity, \omega_1 = 0$$

$$Final\ velocity, \omega_2 = 2 * \pi * 30 = 188.4\ rad/sec$$

What is angular acceleration?

$$Angular\ acceleration = \frac{\omega_2 - \omega_1}{t} = \frac{188.4 - 0}{20} = 9.43\ rad/sec$$

So now, if you want to find out what is torque,

$$Torque = I * \alpha = 2\ kg\ m^2 * 9.43 rad/sec = 18.86\ Nm\ or\ J$$

To Recapitulate

- What is statics? What are its fundamental concepts?
- What is kinematics?
- How kinematics is distinct from kinetics?
- State Particle Kinematics with its types.
- Explain the definition and concepts of Kinetics.
- Elaborate the principle of Work and Energy.
- What is Impulse-Momentum Principle?
- What is momentum? State its application in collisions.
- Explain in brief Moment of Inertia.

So, friends, to recap what we went through in this lecture, we saw what is statics, what are some of the fundamental concepts, then kinematics, then how kinematics is distinct from kinetics, state principle, particle kinematics with its properties. Types then explaining the definition and concepts of kinetics, then elaborate the principles of work and energy.

Then we studied about impulse momentum principle, what is momentum and its application in collusion and finally we saw a brief moment of inertia introduction and we solved two problems here are the references which we have used for this lecture.

Thank you very much