So far we have studied how a particle moves and what we have described as dynamics is a description of motion today and in the next three or four series of lectures we will look at what the law of motion is and the question we will try to ask. The answer is what controls the motion of a body and the first thing we do to understand it is to introduce the concept of energy now.
 Will use some words for but if we look at it, what we can say is that force is a quantitative measure of the mechanical interactions of material bodies which means that if we have two bodies and they communicate with each other then they communicate with each other. Quantity and one of the things we understand that we observe in nature is that this ball may be in contact with the body or in some cases even if the bodies are not in C. The ball can be informed by distance if they are not attacking or they are not touching and we will see examples of all these things but just to explain if I touch the table and if I touch it I feel a ball in my hand and similarly a ball in my hand Is being applied to the table by and if I take an object and if I throw it the object is moving and the earth is applying a force on this object even though there is no contact between the earth and this object

so in both cases there is no contact or no contact If two bodies interact with each other in a situation then there may be a force between these two bodies and throughout our series when we talk about the laws of force and motion we will see how we can measure this kind of interaction between the bodies and we will see that Interactions have been measured by some laws and those laws we will study during the lectures in this series, let us try to identify some features. The rties of energy

so the first thing we understand is that the ball is an amount that has dimensions and it is clear from the fact that if I press the table lightly or if I press the table too hard I feel a different sensation in my hand. So in one case the force is less, in another case the force is more

so it has a dimension but not only a dimension, it also has a dimension and it also has a direction and as we have seen that quantities have one dimension as well as one dimension these quantities are referred to as vectors. And also what we described earlier when we talked about each of these quantities which has a dimension and direction does not need to be a vector but has some more properties for vectors. Converts according to the relationship and what we see is that the ball follows the rules of this law

so the ball is a vector quantity which means it will be ah if two balls are to be added then there will be two balls with different directions and the addition will follow Or you can use the addition triangle formula which is equivalent

so what we do is we represent the force by one. The length of the arrow is proportional to the dimension of the ball and the direction of the arrow indicates the direction of the ball and this particular statement which I have stated is that the length of the arrow is proportional to the dimension of the ball. More relevant when we talk about two different energies they will have their own dimensions and then length will represent the ratio of these two balls

so the ratio of length will represent this ratio

so how we present a force now is one thing that we observe and it is a very subtle thing. There is no evidence that what we perceive and it comes from observation and what we say is that the energy we see it is not dependent on the frame of reference where the force is being measured now we can say the same thing for all scalar or vector quantities So what I am saying now is that the reference frame as we have seen can be measured in the same amount in a frame that is fixed on the surface of the earth or let's say something moving.

The force we see depends on whether you are observing the force from a fixed frame of reference or from a frame that has constant velocity or constant acceleration or variable velocity. Whatever it is, there is an amount that does not depend on the reference frame which depends on the reference frame. Very clearly we have seen that when we look at the position vector position vector we fix a coordinate axis and we mark the position vector and it Obviously depends on the frame of reference and not on the position vector. We have also seen velocity and acceleration which we measure are frame dependent quantities

so let's just say position vector or velocity or acceleration as opposed to the reference frame where they are being measured and Again this observation that we emphasize that it is valid in the case of classical mechanics where we say that the speed we are talking about is much less than the speed of light

so in this chapter and at least throughout this argument we are going to talk about the mechanics part Classical mechanics says where we do not consider the effects

so the speed is much less than the speed of light

so now let us try to see that our second contact is a Hey there. Body means I have a body A and a body b and these two are touching

so it can be a body and it can be a body and there is a connection between these two bodies

so if you have a contact the contact between a and b is an energy Can give birth to and give examples of such forces. When we look at examples of such communication forces, let us explain these forces which we call as reaction force and among them these reaction forces include frictional force whenever an object slides on the surface. Then we see that there is a force that impedes the relative motion between the two surfaces and when we have this force in contact with two bodies or two solid bodies then we call it frictional force. Is doing, then in this case the air is in contact with the aircraft and the air will keep what we call the viscous force on the aircraft. So these balls like reaction force, friction ball, viscous balls are examples of forces that arise because there is a contact between two physical bodies. Another example of a contact force. Where we have a wall that is blocking the flow of water now here the water will apply when it touches the surface of the dam. We call the force hydrostatic force

so this is another example that comes due to contact but besides that there is some other force which we have seen which does not require any contact between the two bodies but again we realize there. The first example is the gravitational force and we see it in the sense that when a body is pulled towards the earth's surface, Newton also generalizes it to the universal law of gravitation if there are two masses. Applying a force on each other even though they are close to each other and here will be this gravitational force as we will see I am now talking very qualitatively this dependent ds on 1 over r The direction is also specified by the law of gravity and we will see this later but in addition to gravitational force two charges have a force due to ah if we have two charges one charge q one and one charge q q2 then there is a force between these two charges which we call electrostatic Ball and then we have in addition to it the electromagnetic force which is felt by a charge moving in a magnetic field now again There is no contact between these electrostatic and electromagnetic forces. These forces occur through distance. Now let us try to see what is the qualitative effect of a ball. So I think the easiest way we can describe a force now is that we will later see if a force pushes or pulls along its line of action , but if we see the effect of a ball from a point other than its line of action , We will also see that it revolves around a

point in a body which is not in the line of action but we will pause this discussion now when we talk about rotational speed and motion of inflexible bodies .

 A force that pushes or pulls a body is what it actually does with the body so the force that the force tries to do by pushing or pulling is an attempt to change the state of motion of a body So if I look at it in terms of dynamics, that's the effect. For example, let's see how the ball is in a body. This pen is lying on my hand. It is at rest. As the state of motion tends to change a body will have a tendency to start moving or vice versa if a body moves then we can apply a force to bring it to rest   and

so now it is a qualitative way to try to determine the amount of force. What we have said qualitatively about these statements is that in order to quantify these statements we will study by the law of motion how the laws of motion will measure the effect of energy on the state of motion of a body but before we do that let us explain some more basic concepts The thing we define is the concept of a particle and what we will say is that a particle is an entity of finite mass but infinite size means that the particle occupies only one point at a time in space

so if we talk in terms of coordinates what we can say is the particle xyz T is in spatial position at time

so this is how we idealize a particle now it is an idealization I use the term idealization because everything we know has a finite size

so when we want to consider the motion of a body its physical size is not important then we call it a particle And for example when we talk about the speed of a ball or the ball falling freely as we have seen in the projectiles. The ball is then assumed to be a particle and for at least the next few discourses we will assume that all the bodies we are applying the law of motion are particles and vice versa let's say there is a rod of length l and we have to study the motion of this rod Suppose I am applying a force at this point and if I apply a force at this point it is possible or another force is being applied somewhere else. And we'll see later we'll call it a rigid body. The body that will come much later, but at least I want you to get the idea of a rigid body. A rigid body is a set of particles

so that the distance between any two particles is always the same. Show but at least keep this definition in mind and now we will now just focus on the particle when we say we have a particle of mass m and the main thing is that when we talk about a particle the mass of a particle is finite it is not infinite and we move the particle from some frame Observe f what we find is that the particle has a velocity v has an acceleration and we will probably start it has a position vector r now what we find is that the mass of the particle is always constant and it comes again when we look at our classical mechanics We will always assume the mass of our individual particles to be constant and if we talk about two particles, their mass will be equal to m if that particle is a and b then ma plus mb is equal if both of them are combined then the mass of the new body will be equal to ma plus mb So v When the particles come together linearly, we now define that we see the mass of a particle which is constant and this mass does not depend on the frame of reference. And which is important for our law of motion and we define a quantity called Momentum. We use the p symbol with a vector in your textbook. Who defines the product of mass and velocity which means we are multiplying a scalar with a vector,

so the net result is also a vector,

so p is the sum of a vector and it is a product of ah mass and velocity. See we'll use it when we get on the wheel when we get to the law of motion. Now

what we notice is that if a body is at rest, it is moving. We need an energy to do this and similarly if a body is moving it needs an energy to bring it to rest but the next question we ask is to apply energy to start moving a resting body if you want to stop it then a The body is moving, a force must be applied to it but then the question arises if a body is in uniform motion then we have explained it before but let's try to understand it because we will use the term uniform motion again and again. Uniform motion means a body moving. Anything we can use at a constant speed along a straight line or straight line so if a body moves along a line and its motion is equal to v constant then we say it is at uniform speed and you can easily understand that it also means that body velocity is constant Velocity is constant or we say that it is moving in a straight line with constant speed. All three of these things are synonymous now. Running at a constant speed in a straight line do we need to apply a force on this body to maintain this state of motion and for a long time the time Aristotle the Greek philosopher who lived in 322 BC had the idea that a body needs a force to move at equal speeds and People have been following these ideas for a long time but it turns out that it was wrong

so let me do Aristotle. It said that there is a need for energy. Was and basically it was not Aristotle's fault that he realized if you look at this practical thing that if there is something that is going on. g And if there is a body, you give it a push and let it go, it comes to rest,

so it is necessary to apply the uniform velocity of the balls to maintain its motion, but what Aristotle did not consider is because this body is in touch. In this case with the second part of the body the lower arm of my hand applies frictional force and this is what stops the body and it was not considered by Aristotle

so there is a force of friction which occurs when two solid objects are in contact or a viscous force trying to resist relative motion But it was not considered then Galileo who was between fifteen and sixteen forty two from Italy was the first to observe it and he refuted Aristotle's idea and what he said is that an external force is required for a body to maintain its uniform motion No, and how Galileo got it. Let's try to see if there were some very nice insights that Galileo could make these observations if we look at a motion with two curved planes and what we see is if a body tells us that there is a ball that bends. Rolled down we take this example because when a ball is rolling on a bend the friction ball is very small

so when it is not bent Che rolls Gravitational acceleration When it goes down it increases the speed of the positive ball but when it goes up the curve the acceleration is negative

so if the same ball starts at some speed here and it goes over the curve then there is a negative acceleration

so now if We try to reduce the angle slowly and we come to a state where there is a flat surface

so if there is positive acceleration then what will happen here if there is negative acceleration then in case of a flat surface it will be very intuitive that in this case acceleration will be zero This means that if the ball continues to move with the acceleration of a on a flat surface, then its acceleration will be zero,

so it will continue to move. No force is being applied on G. Take and you put the two curves together as we did there. Of course we look at the motion separately if this ball comes here and let's say this angle is theta this angle is alpha it is a distance d not the first curve. Che goes and after coming here it starts to go up and the distance it crosses till it bends is d2 then what is observed if theta is equal to alpha then d1 is equal to d2 then what

are you and what you observe if Angle is greater than alpha theater but
distance d is less than two d one means if it is more steep it goes up a short
distance
so we first take alpha which is bigger than theta we see this distance is less
then we subtract alpha equal to alpha we see This distance is equal
so now when we reduce it we take alpha less. From the theta then we find d 2
is greater than d 1 and then suppose if alpha 0 is created then what if we
continue to look the same then what we get is we expect this distance to go to
infinity d2 which would mean if it Angle alpha zero, then once the ball comes
here it moves on this surface which says that no external force is required
so what Galileo said was that if a body is in such a state then what was
Galileo's observation if a body is in a state of rest or uniform motion   ,
Both of these conditions are equal and no energy is required to maintain these
conditions which means whether the body is at rest or at the same speed the
body maintains its own condition and this property .
 We refer   to this feature of the body as maintaining a state of rest or
constant motion .
We call it a special name. It is called inertia,
so basically what we can say is that a body does not change its state of rest or
constant motion unless and without external energy. This is applied and it is
also referred to as Newton's first law of motion. Historically it happened.
Newton was a British scientist and Newton was born in 1642, the year Galileo
died. And what we call the three laws of motion, and the first law of motion
was originally stated by Galileo, but since Newton compiled all the laws, we
refer to it as the first law of motion, or Newton's first law of motion, which
is valid for a particle, and That is to say, and the first statement in
Newton's terminology is that every body moves at rest or at the same speed
unless some external force is forced to act, otherwise what we have here now
means that what we are assuming is if a body is at the same speed. There is no
external force at work and we should probably make this statement somewhat
worthy because when we have no external force it gives a feeling that no force
is working on a body but what we understand is that it is possible that two
forces are one. The body is working and the net result of these two forces is
zero which is equivalent to saying that no net force acts on a body,
so we should say that instead of saying that any force x can be the correct way
to say the word Ray will be that no net ball is working on any body or
external object. If the force acting on a body is zero then the body will be in
its ah rest or uniform motion
so different energies of 0 net ball can work on a body instead of individual
energy but if the result is 0 then this law will be valid and other things we
can understand. That when the body is at rest or at the same speed there are
some general kinetic quantities that define these two conditions: a body at
rest or a body at the same speed and the general kinematic quantities that we
can see are whether the body is at rest or the body is at the same speed. In
that case the acceleration would be zero
so what we can assume is that if the net external force of a body is equal to
zero then its acceleration is equal to zero and it could be another way or
quantitative way of looking at the first law of motion
so now we have two types of situations there There are two types of situations
 we can handle. The first is that if we know that some of the external forces
at work are equal to zero on a body then we can say that its acceleration is
zero but it is normal. It may not be
so obvious to find out if some external energy in life is zero but what we can
easily see from the point of view of measurement or measurement is that we know

that if the acceleration of a body can be measured because we have seen such dynamics All we have to do is give us the rate of change of position which gives us the rate of change of velocity gives us acceleration and we do not know all the energy acting on the body

so in this case what we say is that from the first law we can say that if acceleration is 0 then the sum of energy Or something will be clear that the external force acting on a body must be zero

so let's give an example of this. Suppose I look at a sphere lying on the ground then all I know is that the sphere has a force due to the force of gravity which I call. Let it be as weight and let me write it as m times g and when we get into this we get to see more of it but we write it this way and

so this is a force being applied to the sphere the earth now we see has a contact with the ground And there is contact in the ground. We do n't know what it is. Let's say we are represented by a reaction force. Now in this case because we know that the acceleration of the sphere is 0. So now it is sometimes referred to as the body of equilibrium and when the bodies are in equilibrium they do not move and the sum of the external forces acting on a body is equal to zero is actually a branch of mechanics which we refer to as statics We are talking about bodies that are not moving at all and we are analyzing them. Let's look at the first formula of the most important speed. Let's look at some more places where the first law can actually be used to explain some facts. And let's look at some examples. Acceleration It is seen that the body falls backwards and a reverse observation is felt when we get on the bus or car again and the brakes are broken applied to the car and we see that the passenger's body falls in front

so how can we explain this In both cases what we understand is that the feet of the bus or car are in contact with the floor and stops when the speed of the car slows down and what we find is that the feet constantly touch the floor and there is no relative motion between the foot and the bus or car due to friction So the acceleration of the legs is the same but when we look at the human body the human body is not a single rigid body and when the upper part of the body or the upper parts of the body start living it maintains its resting state .

So that when it is attached to the foot it does not come in contact with the ground

so it maintains its resting position where the legs move forward when the bus starts moving then the legs move forward then the body maintains its resting position and

so the body must fall backwards. Keeps the trend. As soon as it starts to fall back a muscular force acts on the body which brings it forward and it comes to the same state of rest in case of bus but the initial reaction is that the body falls backwards and an adverse effect occurs when a break is applied when a When the break is applied there is a decay and the legs feel the same decay

so when the leg feels the same decay they stop but the body is still in motion so that it maintains the state of motion

so when a sudden break is applied it falls forward Goes and then the muscle forces work on the body and in case of car it brings it to rest

so now we try to focus on what we have seen. At this point I have mentioned again that the state of rest as far as the first law goes is the state of rest and the state of uniform motion ah again uniform speed means constant motion in the same direction because it is very important e once change of direction we know that the body has an element of acceleration Perpendicular to the path we saw earlier

so now when the body is at rest or in steady motion the same motion is equivalent to these two states as far as the force effect is concerned , as far as the force is concerned the body is at rest or it is moving they are identical and what we do is Ah

so if this is the same then what we can say is that the frame of reference because the state of reference or the state of uniform motion will be determined in the case of a reference frame

so the frames of reference that are either at rest or if they move with each other at constant speed which means uniform speed. The type of frames is equivalent which means if I say there is a frame that is at rest

so I put a coordinate system to target x and yx frames. There is a frame B at rest which is constant with v which is constant

so those two frames are the kind of frames that I have described that they are either at rest relative to each other or moving at constant speed and these two frames are equivalent to the effect of energy and a Named Frames These are called Galilean Invariant Frames This is just a name given to it and you can see it

so we're going to give it a go now we see what causes a body to move Now what we want to know is when we want to measure a body How fast it moves or how a particular force is applied to a body but what will be the acceleration and this measurement will come to Newton's second law of motion in the next class when we discuss Newton's second law of motion which will refer to when external force on the body Is not zero and what effect does a non-zero force have on the acceleration of the body ?