

in the last class we looked at the concept of work done and kinetic energy today we will see what is called as the work energy theorem and the concept of potential energy and which leads to what we call as the principle of conservation of mechanical energy and times when this principle is valid times when we have to be careful when we use this principle so lets start

so we start with first what we call as the work energy theorem we have seen the concept of kinetic energy and at any point if a particle of mass  $m$  is moving with the speed  $v$  the kinetic energy of that particle is given by  $\frac{1}{2} m v^2$  now if a particle moves from position 1 to position 2 such that at position one its speed is  $v_i$  and at position two the speed is  $v_f$  then what we can see is the kinetic energy at position one will be equal to  $\frac{1}{2} m v_i^2$  the kinetic energy at position two is equal to  $\frac{1}{2} m v_f^2$  and the change in kinetic energy we can write it as  $\frac{1}{2} m v_f^2$  minus  $\frac{1}{2} m v_i^2$  this symbol  $\Delta$  which we use this means change in and this is always the final state quantity which we refer to minus the initial state and the work kinetic energy theorem or the work energy theorem tells us that the work done by forces when the particle moves from state 1 to state 2 is equal to the change in kinetic energy and this is simply the work energy theorem  $w$  is the work done by external forces acting on the particle as it moves from state 1 to state two or from state  $i$  to state  $f$

so the work done by external forces is equal to the change in kinetic energy and ah this work done by external forces will be the work done by net external forces or sum of external forces which are acting on the particle so this is external forces represent the net external forces or we can write them as sum of all the individual external forces which are acting on the particle

so we calculate the work done by each of them add up all these work done and this work done must be equal to the change in kinetic energy and we can very easily show this by two method let's start with the definition of kinetic energy kinetic energy is equal to  $\frac{1}{2} m v^2$  we differentiate this expression with respect to time

so we get  $\frac{dk}{dt}$  is equal to  $\frac{1}{2} m$  mass being constant times derivative of  $v^2$

so this will be equal to  $\frac{1}{2} m \cdot 2 v \cdot \frac{dv}{dt}$  note here  $v$  is the speed and

so this we can write it as  $m$  times  $\frac{dv}{dt}$  times  $v$  and this  $m$  times  $\frac{dv}{dt}$  this is nothing but the force acting on the body

so this will be equal to  $f$  times  $v$  and this is equal to  $\frac{dk}{dt}$  and  $v$  we can write as  $\frac{dx}{dt}$  where  $x$  is the direction of motion

so therefore what we get is  $\frac{dk}{dt}$  is equal to  $f$  times  $\frac{dx}{dt}$  and if we use the notation that  $\frac{dk}{dt}$  is  $\frac{\Delta k}{\Delta t}$  in the limit  $\Delta t$  goes to  $0$  and  $\frac{dx}{dt}$  is equal to  $\frac{\Delta x}{\Delta t}$  limit  $\Delta t$  going to  $0$  then  $\Delta t$  on both sides can go away and this will give us  $dk$  is equal to  $f dx$  and if we integrate this then we get integral from state  $i$  to state  $f$  of  $dk$  will be equal to integral from  $x_i$  to  $x_f$  of  $f dx$  and this integral  $dk$  from  $i$  to  $f$  will be nothing but change in kinetic energy and integral  $f dx$  from  $x_i$  to  $x_f$  is nothing but the work done by the force  $f$

so therefore what we get is we start basically if you see to get this expression we have used newton's second law we have used  $f$  is equal to  $ma$  we have used the expression  $f$  is equal to  $ma$  this derivation which has been done was for a one dimensional formulation which means that force is along this one direction let us say  $x$  and the movement of the particle is also along

x well this derivation has been done for a one dimensional motion but this is also valid for a general case and if it is a general three dimensional motion for a general case also the work energy theorem is valid and by general i mean 2d or 3d motion and here what we will use is if we have a general case then we will have to use  $K$  is equal to half  $m \mathbf{v} \cdot \mathbf{v}$  now we use the velocity vector and we write the kinetic energy in this form and now when we use  $dK$  by  $dt$  we will get this as half  $m$  times two times  $\mathbf{v} \cdot d\mathbf{v}$  by  $dt$  and then this two and this 2 will go away  $m$  can be taken with this so this will become equal to  $\mathbf{v} \cdot d\mathbf{v}$  by  $dt$  and  $m d\mathbf{v}$  by  $dt$  will be nothing but  $\mathbf{f}$  and what we will get is  $dK$  by  $dt$  is equal to  $\mathbf{f} \cdot d\mathbf{r}$  and for a particle  $\mathbf{v}$  can be written as  $d\mathbf{r}$  by  $dt$  where  $\mathbf{r}$  is the displacement vector for the particle

so this will come equal to  $\mathbf{f} \cdot d\mathbf{r}$  by  $dt$  and from here what we get is  $dK$  is equal to  $\mathbf{f} \cdot d\mathbf{r}$  and when we integrate this we get the same formulation for the kinetic energy even for a three dimensional case so this is the work kinetic energy theorem now we can also see that this is basically work kinetic energy theorem is in integrated form of newton's second law and this we can also see if we look at simple one dimensional motion if we look at  $\mathbf{f}$  is equal to  $m$  times  $d\mathbf{v}$  by  $dt$   $m$  times acceleration this is newton second law and this we can write it as  $m$  times  $d\mathbf{v}$  by  $dx$  into  $dx$  by  $dt$  using the chain rule and now here what we have then is this  $dx$  by  $dt$  we can write it as  $m$   $d\mathbf{v}$  by  $dx$  times  $\mathbf{v}$  and then we take the  $dx$  on the other side so we will get  $\mathbf{f} \cdot dx$  we take  $dx$  on the left hand side so we get  $\mathbf{f} \cdot dx$  is equal to  $m$  times  $\mathbf{v} \cdot d\mathbf{v}$  and when we integrate this we get the same thing because then  $\mathbf{v} \cdot d\mathbf{v}$  when we integrate this will become equal to  $m$  times  $\mathbf{v}^2$  by 2 from state  $i$  to state  $f$  so this becomes the change in kinetic energy and the integral of  $\mathbf{f}$  with respect to  $x$  will give us the work done

so therefore the work energy theorem is an integrated form of newton's second law now because we are using newton's second law

so therefore this is valid only if acceleration velocity displacements are being measured with respect to an inertial frame of reference

so for the work energy theorem to be valid the kinetic energy has to be measured with respect to an inertial frame and the displacement and the work done which you calculate also have to be measured with respect to the same inertial frame of reference otherwise the theorem will not be valid because  $\mathbf{f}$  is equal to  $m \mathbf{a}$  is valid only in an inertial frame of reference now the advantage of this work kinetic energy formulation is that in a lot of problem there are forces which act on a particle but do no work now how will this be possible suppose if a particle is moving along the  $x$  direction and if we have a force  $\mathbf{f}_1$  which is acting in the  $y$  direction now the work done by  $\mathbf{f}_1$  will be equal to  $\mathbf{f}_1 \cdot d\mathbf{r}$  integral of this with respect to  $\mathbf{r}$  and because  $d\mathbf{r}$  is in the  $i$  direction  $\mathbf{f}_1$  is in the  $j$  direction  $\mathbf{f}_1 \cdot d\mathbf{r}$  will be equal to zero and that is what we say that force certain forces do not do any work and therefore when we use the work energy theorem the such forces will not be accounted for and therefore they will if they are unknown forces then we don't have to bother about them now some examples of forces which do not do work well we have seen typically when we talk of normal reaction we have a block which is sliding up a plane or sliding down a plane then on this block when we draw the free body diagram the normal reaction acts perpendicular to the surface and this is the displacement direction and because  $\mathbf{n}$

so if the displacement direction lets call it as  $\mathbf{r}$  because  $\mathbf{n}$  the normal reaction is perpendicular to  $\mathbf{r}$  therefore this will not do any work

so this may often happen then the second case which we see is if a particle moves on a circular path if it is moving on a circular path and let us say there is a string which is holding this particle we are slinging a stone tied by a string

so now if there's a tension which is acting on the particle the string force or the tension which we say and the particle is moving in a direction which is perpendicular to the string force

so here in case of circular motion work done by  $T$  or the string force is equal to zero and this could also be a case that there is a circular path on which a particle is moving in that case the normal reaction once again which is acting from the ground will be in a direction which will be perpendicular to the path

so that will also not do any work

so when we apply these ah the work energy theorem we will see this happen let us look at some simple cases the first case we will look at is a ball being thrown in air

so we are on the ground we take up we have a ball in our hand we throw it in air

so ah we give it a speed  $v_i$  i take a particle with the speed  $v_i$  throw it up in the air and it is in a free motion the particle moves up as it moves up so we throw the ball up in air from ground with the speed  $v_i$  now as the ball moves up gravity starts acting down gravity is acting in the downward direction

so the speed starts to reduce this is a retarding force eventually a point comes where the speed of the ball becomes equal to zero and at that point gravity is continuously acting down

so then it starts to come down and it comes back to the ground and if there are no there is no air friction then when the ball as we have seen when it comes down it will have a speed  $v_i$  again now if we look at it in terms of energy and work then what we have is at ground at this speed at ground when the ball is just left the kinetic energy is equal to  $\frac{1}{2}mv_i^2$  and as the ball moves up due to gravity the speed  $v$  comes down which means kinetic energy comes down and at the top position this is the highest position the ball will take the velocity becomes equal to zero which means the kinetic energy has become zero now gravity increases the speed and

so we increases or as the ball comes down by  $v_i$  mean the speed

so it increases as the ball comes down

so kinetic energy once again increases and as the ball comes to the ground level the kinetic energy restores its initial value now what is happening is gravity is doing work on the ball throughout now in the upward motion gravity the gravity force acts down the displacement is upwards

so therefore the work done by gravity is negative and that is why we have change in kinetic energy is equal to work done

so if work done by gravity is negative then the kinetic energy reduces and this happens till the ball reaches the top at the top position kinetic energy at the top position becomes zero now as the ball comes down in the downward motion gravity is acting down and the displacement vector is also down

so therefore now the work done is positive and change in kinetic energy which is equal to work done is also positive that means the kinetic energy starts to increase now what it gives us a feeling that is the work done by gravity can we look at this as in some sense as a stored energy that is as the ball moves up there is some form of energy which is related to the position of the ball vis-a-vis the vertical position which increases and as

the ball comes down this energy decreases  
 so that there is a kinetic energy and there is an energy because of gravity  
 and some of these two may be constant  
 so this could be a way of looking at how the work done by gravity takes place  
 we will formalize this but before that let us try to also look at another  
 example where a similar thing happens when an external force acts like some  
 sort of stored energy let us now look at a second case of a block sliding on  
 a frictionless surface and encountering a spring  
 so we have a spring which is there and a block of mass  $m$  moving with the  
 velocity  $v$  comes is travelling in this direction and it and it moves and it  
 touches the spring  
 so now when the block touches the spring the block is moving forward  
 so this compresses the spring  
 so what happens is once the block is in touch with spring it continues to move  
 forward but the spring applies an opposite force on the block  
 so the speed of the block comes down  $v$  reduces because of the spring force  
 so once the block touches the spring the spring applies a force and we  
 know the spring force is given by  $k$  times  $x$  now what will happen is because  
 this velocity of the block decreases it touches the spring the spring keeps  
 on getting compressed eventually a time will come when the block will stop  
 and then the spring is applying a force in the opposite direction  
 so because of which the block will move now in the opposite direction and  
 so when the block stops its kinetic energy becomes equal to zero and then when  
 the spring applies the opposite motion the block moves again we could think of  
 this spring force can it be treated as some sort of an energy say we will  
 call it as symbol  $v$  now let us look at a third example where the work done by  
 the force  
 so now in the second case also the work done by spring we are treating this  
 can this be treated as a form of energy now let us look at a case third case  
 case three where we have again a block of mass  $m$  but now it slides on a  
 surface with friction  
 so it means let us say some force has been applied to the block because of  
 which at time  $t_0$  it has a velocity  $v_0$ . now at that time no external force is  
 being applied to the block it has already been removed because of the movement  
 of some because of the application of some force the block is now at this  
 stage it is moving with the velocity  $v_0$ . now what will happen is if if this  
 force if the ground is not frictionless there is a friction force then as  
 the block moves if you draw the free body diagram of the block its weight acts  
 downwards the normal reaction will act upwards and what we have is a force  
 of friction tries to stop the block and because of this force of friction the  
 velocity  $v_0$  will start going down and eventually a stage will come when the  
 block will stop let us say after moving a distance  $d$  and it comes to rest now  
 we have in this case if you look at it work which has been done by an any  
 external force on the block has been done by friction and what is what has  
 happened because of work done due to friction the kinetic energy of the block  
 from its state of  $\frac{1}{2} m v_0^2$  has become equal to zero  
 so that means the kinetic energy has become equal to  $0$  but and because of  
 the work done by friction but now if we want to bring the block back to its  
 original state then we have to apply that means if the block has stopped here  
 if i want to bring it back to its initial state i have to put some other  
 force and this force has to be applied again now you see the difference in the  
 previous two cases and this one in the previous case when the ball reached at  
 the top of its path and when its velocity or kinetic energy was zero then  
 because of the gravity force it again acquired a speed and it came down to the

ground and similarly when we had this block tied to the spring when the spring was compressed and the kinetic energy became zero then the spring energy in some sense pushed the block back and so that it came back to this state and then it went further so in both these cases the two cases earlier the work done by spring and the work done by gravity in some sense stored some energy whereas in the third case where we have the friction force which is acting the work done by friction we cannot get it back what happens to this this is some sort of an energy which gets dissipated so based on this we can say that there are certain type of forces where or whose work can be stored as energy and this energy due to these forces we will refer to this as potential energy the symbol which we will use for potential energy will be  $V$  now if we look at the work energy theorem the work energy theorem tells us work done by forces is equal to  $\Delta K$  now let us say on the system only those forces are acting let us look at simple case only gravity is acting or only spring force is acting then in that case if we have the work done by those forces can be specified as a potential energy then what we can say is change in kinetic energy plus change in potential energy is equal to zero and if we compare these two expressions then what we get is work done by those special forces or those external forces this can be written as minus the change in potential energy so if we have a force whose work can be stored as energy then work done by force would be written as minus the change in potential energy and this we can write it as minus  $\Delta V$  so what we say is if the system changes from configuration 1 to configuration 2 because of a force being applied then the change in potential energy will be given by minus the work done by that force but as we have seen not each force can be written in the form of change in potential energy so first let's see if we write so if we write the expression for potential energy  $V$  is equal to the change in potential energy is equal to minus the work done by that forces so that will become equal to minus of  $\int f dx$  where  $f$  is the force and this integral will go from  $x_i$  to  $x_f$   $x_i$  is state one  $x_f$  is state two so change in potential energy will be given by minus of  $\int f dx$  and this will be from state  $x_1$  to state  $x_2$  or  $x_i$  to state  $x_f$  now if the initial state  $x_i$  or  $x_f$  is the reference state and if we use the symbol  $\theta$  for the reference state then what we can say is potential energy at any  $x$  minus the potential energy at  $x_\theta$  this will be equal to minus the integral  $\int x dx$  with  $x$  going from  $x_\theta$  to  $x$  so this is how we can define the change in potential energy with respect to a reference state now one thing which we realize is when we use the potential energy formulation it is the change in potential energy which figures in our equation change in potential energy which means that because we are talking of the change in potential energy the reference value of  $V$  of  $x_\theta$  is not important we can assign it any arbitrary value we want and often what we will do is we will affine if we choose  $x_\theta$  as  $\theta$  then  $V$  of  $x_\theta$  is often taken as  $\theta$  and this will become clear when we once we do a couple of examples now potential energy this concept of potential energy is applicable only to those forces whose work is stored as energy this is how will qualitatively look at it right now when we quantitatively look at it in more details mathematically maybe when we do higher courses then we will have other ways of quantifying this but qualitatively we will say potential energy applicable to only those forces where work can be stored as energy and these forces whose

work can be treated as some form of energy we call them as conservative forces and what we have is  $U(x) - U(x_0)$  is equal to minus the integral from  $x_0$  to  $x$  of  $f dx$  this is how we define the potential energy of those forces  $f$  is the force we integrate that with respect to  $x$  and that is how we get the potential energy we get another relation from here if we differentiate this expression then what we get is  $dU/dx$  is equal to minus  $f$  of  $x$

so this is in some sense an inverse relation if we know  $f$  of  $x$  this is equal to  $dU/dx$  the integral form of integral of  $f$  gives us the potential energy if we know the expression for potential energy and we differentiate that we will get the expression for minus of  $f$  now some points which we realize about potential energy when we talk of work done by a conservative force and so far at least we are presuming there are two conservative forces  $U(x)$  which  $U(x)$  at least the notion we have gravity and the spring force now we will show when they are conservative the spring force in particular is conservative only when we talk of linear springs but work done by a conservative force this depends only on the initial and the final position and not on the path taken and that is why we can define this work done as some sort of integral of the integral of that force work done we quantify it as some sort of a scalar which we call the potential energy

so the work done will not depend on the path for example if we have a body which is moved up from position one to position two we move it up at incline and so here the work done by gravity will be just a function of positions one and two and not the path and what we mean is even if the particle moves along a path a or path b or path c or let us say it takes first it travels horizontally then it travels vertically up any path which the particle takes the work done by a conservative force will be the same irrespective of the path which the particle takes and in case if the work done depends on the path then the force is not conservative and we cannot define a potential energy

so it has to be path independent secondly we look at the dimension of potential energy dimension of  $U$  this is the same as that of work done or energy which is  $m \times l^2 \times t^{-2}$  the third thing which is a corollary of the first one which we looked at is if suppose we have a body one it travels along some path and comes back to its original position

so a body travels a path and comes back to its original position now if a conservative force acts on the body during this position what will be the work done by the conservative force the work done by the conservative force as the body starts from position a and comes back to the same position which means it has followed a closed loop mind you the loop may not be circular it can be any arbitrary loop

so the body starts from here comes back after moving then the work done by a conservative force if it is acting all along this this interval when the body is moving the work done by conservative force will be equal to zero why because the work done can be written as change in potential energy and potential energy is only a function of this position

so  $U_f - U_i$  or  $U_i - U_f$  will be equal to potential energy at the final point minus potential energy at the position initial point will be equal to zero as position i is the same as position f

so the work done by a conservative force when the body moves in a closed loop is equal to zero

so in particular if we have two positions a and b and the particle moves

under the influence of a conservative force from a to b and comes back from b to a then the work done by the conservative force will be equal to zero so

in in this case what we can do is if work done from a to b plus the work done from b to a when the particle comes back this is equal to 0 if  $f$  is conservative and what this tells you is work done from a to b is equal to minus the work done from b to a if this is along for a conservative force now let us look at the potential energy and some conservative forces these are the typical conservative forces which will come in our problems when we solve which are common to day-to-day life and the first conservative force which we have seen very clearly is gravity due to earth surface when a body is moving near the earth near the surface why do we put this position because when a body is near the earth's surface

so if this is earth and a ball let's say is thrown up it is nearby then gravity force pulls it down and this gravity is constant if the distance from the surface of the earth is not too much we know otherwise we have newton's universal gravitational law which takes care which tells us that gravity is a function of distance but if we are near the surface of the earth we can assume that gravity is constant and this gravity is essentially it is a conservative force and the potential energy due to gravity can be written as  $mgh$  where  $h$  is positive when we are going upwards upwards means opposite to gravity

so if we are let's say this position let's say it's on ground we call this as zero position if we are at a height  $h$  then at this position the potential energy we can call it as  $mgh$  basically the difference of potential energy we should put it as  $v_b$  minus  $v_a$  is equal to  $mgh$  where gravity is acting downwards  $h$  is the height distance the vertical distance between point a and point b so this is how we calculate the potential energy due to gravity force on earth now what can be done is we can choose the reference level as 0 at any point that means if at the surface of the earth we say potential energy is zero so we can choose  $v_a$  is equal to zero then we get  $v_b$  is equal to  $mgh$  in another problem we can choose  $v_b$  as zero if we choose  $v_b = 0$  then  $v_a$  will be equal to minus  $mgh$  and you will see it won't make a difference because when we solve problems we talk of change in potential energy

so if we are talking of  $v_b$  minus  $v_a$  will be equal to 0 minus minus  $mgh$  which is plus  $mgh$  and even when we take potential energy at a as 0 then we get  $v_b$  minus  $v_a$  is equal to  $mgh$

so therefore this is

so it is up to us to choose the reference level here and if we move down let us say if we are moving down if this is position and if this is  $h_1$  this is a this is b then we have we will look at if  $v_a$  is equal to 0 then  $v_b$  will be minus  $mg$  times  $h_1$  and if suppose the two points a and b are like this and this is the direction of gravity then what we have to do is when we calculate  $v_b$  is equal to  $v_a$  plus  $mg$  times  $\Delta$  where  $\Delta$  is the vertical distance between b and a and you see the simplification which comes because of this formulation is that what we are bothered about is only the change in potential energy to calculate the work done by gravity see our original equation of integrated form of newton's law is  $w$  is equal to minus  $k$  now if in a problem there is only gravity acting then what we have shown is the work done by gravity can be written as minus the change in potential energy and to calculate  $v$  due to gravity all we need is the vertical height of the body so whether the body is moving along a curved path inclined path it does not matter at the position of interest we need to find the vertical height with respect to some reference position

so the calculation of work done becomes quite easy when a conservative force acts because we use instead of  $w$  we use the minus the change in potential energy and we don't need to then bother about the path the body actually takes when it moves from position 1 to position 2. the second case of energy which we have

so the second case of conservative force is when we have a spring which acts or which applies a force which is given by Hooke's law where the force spring is equal to minus  $kx$  if the spring is such that the force is proportional to the displacement of the spring then such a spring force is conservative and we can define a  $v$  associated with this spring force and how do we do that suppose if let me destroy it again we have a block connected to a spring and let us assume that this surface is frictionless then what we do is we count start with  $x$  is equal to  $0$  is the unstretched position of the spring now if if the spring is compressed by distance  $x$  then the work done by the spring force this will be equal to integral from  $0$  to the current position let us call it as  $x$  m it has been displaced up to this position this will be equal to integral  $f \cdot dx$  and this force due to spring we have seen this is equal to minus the  $k \cdot x \cdot dx$   $x$  going from zero to  $x$  m so this becomes equal to minus  $k$  times  $x$  m square by two minus zero so therefore the work done by spring is equal to minus  $k$  times  $x$  m square by two and work done by spring is equal to minus the change in potential energy so the potential energy change in potential energy can be written as  $k$  times  $x$  m square by 2

so what we have is if a spring is compressed by amount  $\Delta$  the potential energy for the spring can be written as half  $k \Delta^2$  and what we will realize is even if the spring is extended by an amount  $\Delta$  once again the potential energy of the spring will become equal to half  $k \Delta^2$  and for that all we have is this will again be because spring force is acting in the opposite direction the same thing will happen minus  $k \cdot x$  m square by two so therefore the potential energy

so what we can say is if we have a spring we can call it as a linear spring by linear spring we mean force due to the spring is equal to minus  $kx$  then the potential energy corresponding to the spring we can write it as half  $k \Delta^2$  where  $\Delta$  is the displacement of the spring with respect to its unstretched length

so now we have seen two forces which have for which we can write the potential energy force due to gravity and the force due to a linear spring there is a third type of force for which potential energy can be defined and this would be potential energy due to force of gravity between two bodies and this we are talking of the universal law of gravitation where we will have this force if we have a body  $m_1$  another  $m_2$  and if this distance between these is  $r$  then we have the gravitational force is equal to minus  $G \frac{m_1 m_2}{r^2}$  upon  $r^2$  in the direction if we call this as the  $r$  direction then force on body one will be minus  $G \frac{m_1 m_2}{r^2}$  in the opposite direction

so  $m_2$

so  $m_2$  will exert a force on  $m_1$  it will pull

so force on  $m_1$  will be in this direction force on  $m_2$  will be towards  $m_1$  and this is given as  $G \frac{m_1 m_2}{r^2}$

so because if we choose if we talk of force on body one then  $m_2$  is here

so  $r$  direction will be in uh direction from  $m_1$  to  $m_2$  and the gravitational force will pull will be on  $m_1$  will be towards  $m_2$

so therefore we have these the minus sign comes

so we have the universal law of gravitation which is there and but this we

will see once we complete this there is a separate chapter on universal law of gravitation

so

now we can generalize this law of we have looked at this ah the work energy theorem what we have shown is that we have change in kinetic energy is equal to work done now work done will be due to several forces in general when a body is moving many forces act on it now some of these forces we can divide them some of these forces will be conservative forces others will be non conservative

so what we can say is change in kinetic energy will be work done by conservative forces plus work done by non-conservative forces now the work done by conservative forces we can write it as change in potential energy corresponding to each of these forces

so this term can be taken on the other side then what we get is  $\Delta K$  plus  $\Delta V$  will be equal to work done by non conservative forces now if there are no non conservative forces and this happened when we took the first two examples of a block sliding on a frictionless ground and hitting a spring or a ball being thrown up into air then what we have is if there are no non-conservative forces then the work theorem becomes change in kinetic energy plus change in potential energy is equal to zero and this is what we call as the principle of conservation of mechanical energy but for this principle to be valid keep in mind the non-conservative forces which are acting on the body do not do any work and the work done by conservative forces is accounted for in the change of potential energy

so therefore only in a system where non conservative forces are not acting or they do not do any work change in kinetic energy plus change in potential energy is equal to zero otherwise this change is equal to work done by non-conservative forces now we can slightly generalize this and if we say that the work done by non-conservative forces is equal to minus the change in internal energy and this would mean that there is some sort of dissipation which has taken place

so this goes to adding the temperature of the body or change in internal energy which gets dissipated as heat or some other form and then what we can get is change in kinetic energy plus change in potential energy due to conservative forces plus the change in internal energy is equal to zero and this then can be seen as a generalized form of ah law of conservation of energy and in the change in other forms of energy there could be energy could change in other forms not just mechanical energy there could be electrical chemical or nuclear then all these would also be added like  $\Delta U$  here and this would then become the generalized form of conservation of energy so today we have seen the concept of potential energy and the work energy theorem and in the next class we will look at one or two simple problems where we will see how work energy theorem helps us to solve things in an easy way ah and then we will look at the principle of conservation of linear momentum which again is an integrated form of newton's second law thank you you