

in today's class we will see how to solve problems and in particular of problems where newton's second law f is equal to $m a$ is involved and in the last class we had already seen some problems while we were discussing newton's second law but let us recap the method which we should use when we want to solve problems using newton's second law now newton's second law says sum of forces acting on a particle is equal to mass times acceleration of the particle now keep in mind this acceleration a is as measured from an inertial reference frame the problems we will do today frame will not be an issue in most of these problems because it is very clear that the acceleration which we are measuring will be from the ground frame of reference now this equation has two sides obviously f on the left hand side $m a$ on the right hand side now what we have seen is that the information from the for the left hand side is going to come from the free body diagram which you will draw so the free body diagram will be a diagram where the particle or the body on which you whose acceleration you want to find you will isolate the body from the surroundings show all the forces acting on the body so this diagram where the body is shown notionally and all the external forces are shown on the body is what is referred to as the free body diagram and on the right hand side we have this must be equal to mass times the acceleration and in the order when you have to solve problems what you will get if all the forces are known you will be able to get the acceleration and when you do the analysis for the right hand side in some of the problems kinematics is what you will have to analyze because the problem may ask ah in the problem you may be asked what is the velocity of the particle after it has moved so much distance

so once you find the acceleration then you will have to use the relations for kinematics if the acceleration is constant then you will have relations like v_f^2 is equal to v_i^2 plus $2 a s$ where if everything is along the same direction or you take the acceleration along one component use this relation s will be the distance along that direction now if we have only one body in question that means there is a single particle then all this becomes relatively easy because you have forces acting on one body you have mass times acceleration the acceleration is of that same body where actually a lot of complexity comes when we have in the problem multiple bodies which means for example you could have a block one which is on a second block or you could have a case like this there is a pulley a string a mass one a mass two and this pulley itself there may be a mass three here and this top pulley may be fixed the bottom pulley this one may be moving

so you could have complex cases like this and in these type of problems you have more than one bodies there is body one body two in this one body one body two and body three

so now what happens is when you have more than one bodies then in general let us write this in general the accelerations of bodies one two and three may not be equal they may be different and you may have to find a relation between a_1 a_2 and a_3 in some cases they may be equal the directions may be different their magnitudes may be same and

so on

so this is one of the things which you will have to do you may have to find a relation between a_1 a_2 and a_3 . not only that also what you will find is that when you draw the free body diagrams of bodies 1 2 and 3 separately then what will happen is the force which body two applies on body one will now be external force in the free body diagram of one and similarly the force which body one applies on body two in the free body diagram of body two this force will be an external force but we know when we have this we should keep in

mind we have Newton's third law and this tells us that mutual forces applied by two bodies on each other are equal and opposite so this way when we draw the free body diagram of body one and body two the two forces which will come as a mutual pair of forces there could be for example a normal reaction between one and two a friction force between one and two then in the free body diagram of one end in the free body diagram of two these forces will be equal and opposite but their magnitudes will be related another case which comes into mind is when you have suppose bodies one and two and they are connected by a light rod and this case is slightly different than when they are connected by a string and we will see that also when they are connected by a light rod then what happens is if you try to draw the free body diagram of the rod then what you will have is this is the force which the body one will apply on the rod let us show it as f_1 in a general direction and the force which body 2 applies on this rod we show it in general as f_2 and let us assume that there is no other force acting on this light rod now when I apply my relation when I write Newton's law for the rod then what you will get is some of the forces on the rod must be equal to mass times the acceleration of the rod and because this rod is light that means we are assuming this mass is nearly zero so even if the rod is accelerating the sum of the forces on the rod must be equal to zero so therefore what it will give you is f_1 must be equal to minus of f_2 that means these two forces have to be equal and opposite and also we have not seen this but we know that because the rod is light so again even if it is rotating it cannot have any angular acceleration just as it cannot have the sum of moments therefore on the rod will be zero we have not talked about moments but what that will mean is that if this is the rod this is point one this is point two the force on one and two they have to pass through the same line so if this is f_1 then this will be f_2 or it could be the opposite case f_1 will be like this f_2 will be like this and the two magnitudes are equal

so this is what will happen when we have a light rod connecting two bodies and this happens because the mass of the rod is negligible so forces and moments on the rod have to balance out so the forces will be like this a case like this we say the rod is in compression when we have a case like this we say the rod is in tension now the significance of this in the problem comes is that in the problem which we are solving when we draw the free body diagram of m_1 let us say it is a situation like this so now on the rod the force the rod is being pulled by body one so when I draw the free body diagram of m_1 I will get a force f_1 acting like this on body one because the rod is here and similarly when I draw the free body diagram of body 2 I will get a force f_2 which is now equal to f_1 these two magnitudes are equal they act in opposite directions on body two so this is the significance which I will get on the two bodies that the forces which will be acting will be equal and opposite in case if they are connected by a single light body so these sort of things we have to keep in mind another thing which we have to keep in mind when we have these problems are if there is a force of friction and this we have seen for example we have seen this in detail in the lecture if I have a body like this an external force f is being applied on this body then the force f tends to pull the body in the plus x direction or plus i direction

so therefore on this body when i draw the free body diagram of this body keep in mind when i draw the free body diagram i don't show the ground i only show the show the body i will have a force f acting like this and there will be a friction force which will tend to oppose this force f there will be a normal reaction from the ground and there will be the weight of the body if no other forces are acting this is the free body diagram of this block a which i have shown now in friction what we have to be careful about is if there is no slip then friction f is an unknown force it is a self-adjusting force so therefore if there is no slip means the body is not moving so you will get small f is equal to capital f so the value of friction will be just equal to capital f but if there is impending slip or actual slip then this friction force no longer remains an unknown it gets related to the normal force to the force which is acting on this in the perpendicular direction so in these cases friction is proportional to the normal force that means the perpendicular force and for the case of impending slip friction is equal to μ_s times n μ_s is the coefficient of static friction in case of actual slip friction is equal to μ_k times n so now when you have a problem involving friction in some of the problems maybe you first assume that there is no no slip so that means there is no movement when there is no movement acceleration of this body is zero so acceleration is zero so therefore you will be able to find the value of f and then once you find the value of f then you are supposed to check your assumption so therefore if you assume no slip so if there is no slip then acceleration of the body if it is slipping a case of simple sliding it will be equal to zero then you find the value of f from your equations $\sum f$ is equal to 0 and once you find the value of f the problem is not complete then you check is f less than $\mu_s n$ or is f less than μ_k times n and for that you will have to go to the y direction equations get the value of n and if f is less than $\mu_s n$ then assumption ok else you resolve the problem you assume slip now once you assume slip then you have to put f is equal to μ_k times n you have to put this value of f and then now what will happen is once you put in f a is an unknown earlier acceleration was known now acceleration will become that unknown and you will solve for a but what you have to do very carefully is put the right direction of f when you assume slip because you know the body is going to move in a particular direction the friction will oppose the relative slip on the body so that is how we solve problems involving friction now one class of problems where we do encounter a lot of difficulties especially when we are solving these problems for the first time are problems involving strings and pulleys and let us start with a very simple example i will start with a very simple example of problem of strings and pulleys what we have here is that there is a pulley p_1 which is fixed and there is a string the string which passes on the top of pulley and comes down one end of the string is tied to mass m one the other end to mass m two mass m two is free except by the string it is not touching the surface mass m one is touching the surface and here we will assume for the simplest problem first that the surface here is frictionless there is no force of friction on the surface also in the problems of pulleys and strings we will in most problems it is assumed that the pulleys are frictionless and light that means the acceleration of the pulleys when they are moving or the angular acceleration when it could be rotating is negligible so we do not have to account for that even they may rotate but because it is

light it will not be needed to be accounted for
 so we have pulleys are frictionless and light and we assume that the string is
 inextensible which means the length of the string is constant in some of the
 more complex problems this assumption that the surface is frictionless will
 be broken you will maybe you will be given the coefficient of friction between
 these two surfaces but to start off with we are looking at this problem there
 are two masses m_1 and m_2 there is a pulley which is fixed to the ground and
 connect these masses are connected by a string which is tied to the pulley
 so now we want to find the acceleration of masses m_1 and m_2
 so we have to find acceleration a_1 and acceleration a_2 of masses m_1
 and m_2 that is what we have to know
 so to solve the problem what we do is let's start by drawing the free body
 diagram let us first draw the free body diagram of body two
 so this is the body two let us keep this picture in mind let us draw the free
 body diagram of body two
 so we have body two its weight which is $m_2 g$ which is acting down and
 there is a string force which we call the tension that is acting up these are
 the only two forces acting on the body and let us assume it is moving down
 with an acceleration a_2
 so see the free body diagram will only show the forces the acceleration you
 will show separately now when you apply newton's law to this what you will get
 is $m_2 g - T$ is equal to $m_2 a_2$
 so this is the free body diagram of body two now we draw the free body
 diagram of body one now when we have a string passing over a fixed pulley
 look at this we have the pulley here and we have a string which is passing over
 a fixed pulley in this case what is going to happen is because this pulley
 the two ends are connected this length of the string is the same
 so the magnitude of acceleration of these two bodies will be the same because
 if this goes down by a distance x this body here is going to travel right by
 distance x because the length of the string is constant
 so therefore the magnitude of the distances moved by bodies 1 and 2 will be
 the same if we differentiate that we will get the velocities are the same we
 differentiate again we will get the accelerations are the same
 so therefore the accelerations of bodies 1 and 2 in this case will be equal
 so that is the first conclusion which we get is if when a string passes over
 a fixed pulley then the accelerations and this let me say the magnitude of
 the bodies tied on the two ends are equal and the second thing which we
 get is that the tension in the string is equal that means we have this
 body here if I call this tension here as T_1 and this tension here is T_2 if I
 call this T_1 if I call this T_2 if this is a fixed pulley then these two
 tensions in the string are equal this is the free body diagram of the string
 if I draw the free body diagram of the body on body one I will have this force
 due to string coming here as T_1 on body two here I will have this force
 here as T_2 but from this diagram and this comes actually from moment
 balance which we have not seen T_1 must be equal to T_2
 so if the same string is passing over a fixed pulley then we will have the
 tensions are equal
 so therefore T_1 will be equal to T_2
 so coming back to the problem which we were solving we have drawn the free body
 diagram of body one we show the tension and we show the string now we draw the
 free body diagram of body two we had drawn now we draw the free body diagram
 of body one now body one is this one which is lying on the table now here
 firstly we have because these tensions are equal we get a force from the
 string which we call as T that is the same as the force which is acting on

body two in addition to this we will have the weight there is a normal reaction and that's it

so these are the forces on the body one which are acting this is body one the forces which are acting reaction from the ground there is no friction so there will be no friction force the weight acting down and the force because of the string and here now if we call this as the x direction this is the y direction

so when we apply sum of forces in the y direction the body is constrained to move on the horizontal surface there is no acceleration in the y direction so that will give us n_1 is equal to mg for this particular problem we do not need the value of n_1 but if friction between the ground was not ah zero then we would have needed n_1 to find the friction force and when we apply the newton's sec for second law in the x direction we will get t is equal to $m_1 a_1$ but we also know this is a string passing on a fixed pulley

so a_1 is equal to a_2

so we straight away now we can show the tension will be equal to when we write this equation this one tells us tension is equal to $m_2 g - a$ and the first equation tells us tension here when we write it this is equal to $m_1 a$ and this must be equal to $m_1 a$

so therefore when we equate these we get $m_1 a$ is equal to $m_2 g - a$ and we will get $m_1 + m_2$ times a is equal to $m_2 g$ and acceleration will be equal to $m_2 g$ over $m_1 + m_2$ now notice body one has an acceleration a which is in the plus x direction and body 2 has the same acceleration a but it is in the negative vertical direction you can if you call y as pointing up then this is in the minus i direction but the magnitudes are the same now to make this problem slightly more complicated if we add friction on the table for mass one then how will this become different again for mass two we will still have tension which is acting we have $m_2 g$ and we will have $m_2 g - t$ is equal to $m_2 a$ assuming that body is moving down

so we have this acceleration a down and if i draw the free body diagram of this body what i will get is there is a normal reaction n_1 there is $m_1 g$ there is t but now there is this force of friction

so what i will get is n_1 is equal to $m_1 g$ and t minus the force of friction is equal to $m_1 a$

so we are assuming this is moving like this now if the body is moving then what you will have to do is this force of friction will be equal to μ_k times n_1 and

so you put in the value of μ_k times n_1 and you will be able to get a but it is possible that this mass m_2 which is there is small enough

so that the body will not move

so if you have to do an analysis like that you first assume a is equal to 0 then you will get if you put a is equal to 0 you will get t_2 t is equal to $m_2 g$ and you put a is equal to this t must also be equal to f

so you will calculate the value of f assuming there is no slip and this value of f will come out to be equal to $m_2 g$ and then you check if this force of friction is less than μ_s times n_1 if or actually it should be μ_s if it is static

so you check if t if this is less than friction is less than μ_s times n_1 and if this is less then assumption is ok there is no acceleration but if you get friction is exceeded μ_s times n_1 then you have to come back to the problem and do it like this

so this is how in a nutshell you will complete this problem now a slightly

more complex version of this problem we could take let us have a look at this we have a case again a single pulley p_1 which is fixed in all these problems of physics you should try to see and analyze if the pulley is fixed or not in a fixed pulley life is very easy why because at the two ends the magnitude of accelerations will be equal and the tension will be the same throughout the string

so now here what we have is an incline there is connection at both and once again if we assume frictionless contacts at the slope as well as at the table then what you will get is if you now this angle is given to be θ if you draw the free body diagram of body one this is body one you have its weight $m_1 g$ there is normal reaction n_1 and then there is the string force t so we have these are the three forces acting and we will assume the acceleration like this

so these are the this is the free body diagram now in the free body diagram of body two we have an incline on which the body two is placed and you should familiarize yourself how to draw free body diagrams of bodies like this now here we realize the acceleration we are taking is down the incline if that is the case now if i draw the free body diagram notice this is not the free body diagram why is this not the free body diagram because i am also showing the incline

so in the free body diagram i will only show the body then what i will have is there is a normal reaction n_2 there is its weight $m_2 g$ and there is string tension t these are the forces acting on the body so now when we write this the first equation will give me n_1 is equal to $m_1 g$ t is equal to $m_1 a$ there are two unknowns only one equation then we go to the second equation now whenever we have things like this that means the forces are acting at an angles at angles to each other not right angle but some other angle then you have to decide along which direction you will resolve now here because our acceleration is down the incline maybe we take this as the x direction for this particular free body diagram the perpendicular direction has the v

so now if we have to do it like this then what we have to do is this weight $m_2 g$ is acting vertically down

so now what we will have to do is if we choose our directions like this we have to resolve $m_2 g$ along x and y how do we do this now what we realize is the angle between this direction y and $m_2 g$ is θ this a geometry will tell you there is θ between horizontal and the incline so now when i go perpendicular to the incline and the perpendicular direction to the incline a h and the force which is in that direction

so we will get the angle between these two will also be θ

so therefore this $m_2 g$ which i have acting here when i write this it will have this angle is θ

so this will become $m_2 g \cos \theta$ and this will become $m_2 g \sin \theta$

so therefore let us do it properly let us do it again this is $m_2 g$ these are the two perpendicular directions this angle is θ

so the component along this will be $m_2 g \cos \theta$ and this component of $m_2 g$ will be $m_2 g \sin \theta$

so once we do this then we have our weight like this

so we have n_2 acting here we have t acting here and then what i can do is i can write this as $m_2 g \cos \theta$ i can write this as $m_2 g \sin \theta$ and final acceleration is here

so therefore what what i will get from here is n_2 will be equal to $m_2 g \cos \theta$ because the incline this block is sliding only along the incline so no component along the vertical direction and then we will have $m_2 g$

$\sin \theta - t$ is equal to $m_2 a$

so we know the values of m_2 and θ

so there are two unknowns t and a one equation comes from body one the other comes from body two and we can solve this problem now you see here that when we have solving these problems we had multiple bodies we had two bodies in these problems but what we did was the forces which were acting on these two bodies which was there was a common force the tension

so that we related was equal on both the bodies and we worked out the direction and also we realized there is a relation between the acceleration of these two bodies which were equal

so therefore that is how we were able to solve these equations now one thing we have seen is that one take home we can say which can be taken from this is that accelerations of blocks connected to the ends of the same string i have written this but let us write this in a more crisp form accelerations of blocks connected to the ends of same string passing over a fixed pulley have the same magnitude now about the forces what we can say is if there is a pulley if this is fixed or moving if the forces on the if and there is the same string if on left hand side the force is T_1 the other side it is T_2 if we have a fixed or a moving pulley as long as the pulley is light and frictionless for light and frictionless pulley whether it is fixed or moving T_1 is equal to T_2

so if the same string passes on the pulley then these two forces in the strings will be equal whereas for acceleration this relation will be valid only if we are have a same string passing over a fixed pulley now let us have a look at a problem where the pulley is not fixed

so in problems with multiple accelerating pulleys and strings we have to set up equations which relate or equations relating accelerations of various blocks or bodies which are connected by the strings and this is done by relating coordinates of the moving blocks and pulleys to the length of the string which is fixed because even if the pulley is moving what we know is the total length of the string which is there that is fixed so we write the coordinates of different points and then we use the relation that the length of the string is fixed and using this consideration that the length of the string is fixed we can find the accelerations and relations between them

so we will be able to find a relation between various accelerations by using the fact that length is fixed once again the for these problems pulleys and strings will be considered as massless and the string will be considered to be of constant length

so let us have a look at an example of a problem of where a multiple pulley where a moving pulley is involved

so let us have a look we have a mass m_1 which is on the ground it passes over there is a thread which passes over a pulley the other end of the pulley this thread is connected to the fixed point here but the pulley itself can move the center of the pulley through another string is connected to a mass m_2 and mass m_2 on mass m_2 a force F is being applied and its being pulled to the right

so this pulley which we have here in this example this pulley is not fixed you do not see this pulley being connected to the ground

so this is a movable pulley now here if m_1 , m_2 and F are given we are asked to find the accelerations a_1 and a_2 and once again in addition to the pulley being frictionless and light will also assume that these contacts between m_1 and m_2 and ground are frictionless if it is not all we have to do is also add the force of friction the equation becomes slightly

more complex but in principle it stays the same what we want to learn here is how do we find these accelerations a_1 and a_2 and how do we find the relation between them now to do this what we will do is we will write the coordinates of either the pulley or the masses and we will write

so let us write the coordinate of mass m_1 now when we write the coordinates we should keep in mind that the reference should be a fixed reference

so that means for example if i look at this mass m_1 if this is the position i could either take it from the pulley or i could take it from the vertical wall but if i take it from the pulley or the center of the pulley the center of the pulley is moving

so i do not take the coordinate reference from the center of the pulley so what i am going to do is i am going to choose for m_1 i am going to choose this as the reference and let me call this as x_1 and similarly i look at the center of the pulley and i call this from the same reference point as x_2 now i do not have to take the references from the same point for different bodies in this particular problem i have taken them from the same point what i have to ensure is that this the wherever i am measuring the coordinate from the origin or the reference point cannot be moving if it is moving it can still be done but it becomes more involved then you have to take the movement of that point also into question

so in this case what we have done is x_1 is the coordinate of mass m_1 and x_2 is the coordinate of the center of the pulley

so x_1 let us write this down x_1 is the distance coordinate of m_1 and x_2 is the coordinate of the center of the pulley

so now what one can see is what is the length of the string which is going on the pulley let me just show this

so what we want to now now write down is what is the length of the string going on the pulley there are two strings we are talking of this string what is the total length of this string and this we want to express in terms of x_1 and x_2

so now if i look at this from here this total length of the string can be written as $2x_2$ twice of this length minus x_1 $2x_2$ minus x_1 will give me the length of the string going on the pulley of course on this there is some extra length which is going on the top diameter of the pulley but that always stays constant

so i could say that plus πr or something like that but we do not need to do that because that is a constant length

so this total length which i have got is $2x_2$ minus x_1 . now this length is constant

so therefore if i differentiate this what i am going to get is

so differentiate this with respect to time

so i will get $2\dot{x}_2$ minus \dot{x}_1 is equal to zero and we differentiate second time and this will give me zero is equal to $2\ddot{x}_2$ minus \ddot{x}_1

so now what we get is ah a relation between $2\ddot{x}_2$ and \ddot{x}_1 \ddot{x}_1 is the distance

so what we have from here is \ddot{x}_1 is equal to $2\ddot{x}_2$

so this x_2 is the distance which the pulley moves and also the pulley is connected to mass m_2 through a string

so the distance moved by mass m_2 is also the relative distance will be x_2

so what we have here is \ddot{x}_1 is equal to \ddot{x}_2 which means

a_1 is equal to 2 times a_2

so this is the relation which i get between acceleration of body one and acceleration of body two a_1 acceleration of this is equal to twice the acceleration of body two and this comes from the fact that the length of the string must be the same ok

so once we have this relation where i get a_1 is equal to $2 a_2$ and in fact we can generalize this let's first generalize this relation if one end of a string passing over a moving pulley is fixed

so if one end of the string which is passing on over a moving pulley this end is fixed then the acceleration of the other end other end was one

acceleration of the other end is twice the acceleration of the pulley

so if we have a moving pulley such that one end of the string is fixed ah to of is connected to a fixed point then the acceleration of the second end is equal to ah twice the acceleration of the pulley and that will come because the length of the string has to be constant

so once we have this then in this particular problem this was the major thing finding a relation between a_1 and a_2 now if i draw the free body diagram

of this body then what you will see is on body two you will have force f let us say there is tension i will call it as t_2 there is n_2 there is $m_2 g$ and our relation will be f minus t_2 is equal to m_2 times a_2 now once again there is there are two unknowns t_2 and a_2 and there is only one equation

so then we move to the free body diagram of body one when i draw the free body diagram of body one i show the body one i have n_1 i have $m_1 g$ and i

have t_1 and here what this one will tell me is t_1 is equal to m_1 times a_1 . i have a relation between a_1 and a_2 but what do i do between t_1 and t_2

and to find the relation between t_1 and t_2 what i will have to do is i have

to draw the free body diagram of the pulley i draw the free body diagram of

the pulley and what i have is on this side the tension is t_2 on this side

the tension is t_1 notice these are in opposite direction because of action and

reaction we are drawing here the free body diagram of body one here we are

drawing the free body diagram of the string of the pulley i have somewhere cut

this string and i have the pulley and the string is shown i have cut the string

so i am showing the forces on the string which will be opposite to the forces acting on the block

so now because this pulley is light once again we will have sum of forces must be equal to 0

so this gives me twice of t_1 is equal to t_2

so now i have enough equations f minus t_2 is equal to $m_2 a_2$ t_1 is equal to $m_1 a_1$ $2 t_1$ is equal to t_2 and i had already got the equation a_1 is

equal to $2 a_2$

so using all this when i work out what i get is

so we have a relation t_1 is equal to $m_1 a_1$ this comes from free body diagram of one free body diagram of two gives us f minus t_2 is equal to

$m_2 a_2$ but now we know a_1 is equal to $2 a_2$

so therefore t_1 is equal to m_1 times a_1

so it becomes equal to 2 times m_1 times a_2 and we get f minus t_1

ah t_2 is equal to $2 t_1$

so f minus 2 times 2 times $m_1 a_2$ is equal to $m_2 a_2$ and this

gives us f is equal to $4 m_1$ plus m_2 times a_2 and

so we can find a_2 and hence we can find a_1 next let us look at another

problem which is slightly more involved in this case what we have is a mass m_1 which is connected to a pulley and this pulley is ah through a string

connected to a second pulley p2 pulley p1 is fixed pulley p2 is moving and on one end of the pulley p2 we have a mass m2 on the other end of the pulley p2 we have a mass m three but now pulley p2 is moving and the problem we have to find a1 a2 and a3 and once again we assume frictionless surface frictionless pulleys and light pulley and constant length string all this is assumed

so now given this we have to find the acceleration a1 assume a1 is like this assume a2 is like this a2 and a3 are assumed to be downwards a1 is on the right well if there is anything other than this we will get a minus sign so we have to find these accelerations

so now if we have to solve this problem first we draw free body diagram of bodies two and three

so when i draw the free body diagram of body two i have got m two g detention t two i draw free body diagram of body three we have m three g and now once again this tension is equal to t2 and we have this acceleration is a3 this acceleration is a2 a2 is not equal to a3 because the pulley p2 is moving so we have these two relations and from here we can directly get m two g minus t two is equal to m two a two m three g minus t two is equal to m three a three

so these are two relations but then we have another unknown t two

so next what we do is

so we have started from the bottom of the problem now we draw the free body diagram of the pulley two

so if i draw the free body diagram i have t two t two and let this force here be termed as t one

so clearly from here we get t one is equal to two times t two next we will draw the free body diagram

so we have drawn this

so we have found a relation between t1 and t2 then we draw the free body diagram of m1 when i draw the free body diagram of this what i get is n one m one g and t one and this free body diagram and this t one i can write it as two t two

so this free body diagram directly tells me two t two is equal to m one times a one

so now i have this is my third equation now if you look at the unknowns a two a one a three three acceleration and one tension t one we have already got rid of by writing this equation

so now still we need one more equation

so we have a one a two a three and t two we have four unknowns and we have three equations

so now what we will do is we will find a relation between the accelerations

so we have this mass like this there is a pulley here this pulley is fixed this is moving this is p1 this is p2 and what we have here

so now what we do is let us say this is block one let us call this coordinate from here going to the left as x one this is block mass one is fixed here

so the distance from this fixed point x one is the distance of mass one from the right from a fixed point now what we do is this is block 2 this is block 3

so we choose the center of this pulley this pulley is fixed this is central point i choose this distance from here to block 2 as x 2 and here 2 3 as x 3 and let me call this as x p the distance of the center of the pulley from this point i call it as x p

so x two is the distance of block two but notice this has to be taken from a fixed reference point not with respect to pulley 2 center because that itself

is moving

so i choose x_2 and x_3 from a fixed reference point now from this figure if i look at it let's see first thing what we know is x_1 plus x_p this is equal to l_1 x_1 plus x_p is equal to the length of the first string now the length of the second string is also constant so now let us see what is the length of this string this distance is x_2 minus x_p x_2 minus x_p is this distance and x_3 minus x_p is this distance so what i get is x_2 minus x_p plus x_3 minus x_p is equal to l_2 x_2 minus l_1 plus x_2 minus x_p plus x_3 minus x_p is this so therefore from here what i get is x_2 plus x_3 minus two x_p is equal to l_2 and for x_p i can put as l_1 minus x_1 so x_2 plus x_3 minus two times l_1 minus x_1 is equal to l_2 so this gives me x_2 plus x_3 plus two x_1 is equal to l_2 plus two l_1 this is a constant now when i differentiate this i will get my cancel now one thing we have to note here the way we have defined this x_1 is in the left whereas a_1 is defined like this so therefore x_1 double dot will be equal to minus of a_1 so what we do is we differentiate this 2 times and this is going to give us a 2 plus a 3 minus 2 times a 1 is equal to 0 so this is the fourth relation which we are going to get and using this we can solve our problem we have four equations and four unknowns where the tension can then be eliminated and we can get the values of a_1 a_2 and a_3 so these are the this is the way in which we solve problems when we have multiple bodies we try to relate the forces on the bodies and we try to relate the accelerations of these bodies write equations for them and then we solve these problems thank you you