In today's class we will continue our discussion on motion in a straight line, we will look at some examples of what we covered in the last class then we will look at the concept of relative velocity and some more examples
so what we will do in the last class Is running and has a uniform acceleration a and if it starts with a velocity of v 0 then the velocity at our end can be given in t by the expression v. v 0 is equal to plus where v is the distance covered at this distance is the velocity at the time we write by x minus x 0 it can be given by v 0 plus will be given in half a square and if we know the two velocities the initial velocity and the final velocity and if we Know the acceleration and distance but the relation between these goes by v square v zero square plus two times x minus x zero a few more relations can be formed v 0 can be given as half of plus v and
so the distance traveled will be half times v 0 plus v times t and similarly if we know the distance that we know the final velocity we do not know the initial velocity then the relation takes shape x minus x zero vt minus In all these formulas we now assume that the acceleration is now a half you should realize that the body is going through a negative acceleration which we call retardation and then you have to substitute a by subtracting r from r where r is the writ. The ordination is to calculate that sign as well and if somewhere you have a minus sign and it lags behind then its net will be a plus sign
so you have to take care of these kinds of things. Another thing we have to be aware of is that these formulas are valid only if acceleration. Is constant if the acceleration is not constant we can ot use these formulas and also what you notice in each of these formulas for example if we look at this formula we have two velocity acceleration and time missing in this formula
so if we look at our case then we have The final velocity is the initial velo. Velocity Acceleration Time and Displacement or Distance is x minus x zero These are our five variables and in each of these formulas you will see that these four variables come from a non- variable
so what is given and depending on what gives you a suitable formula The first three formulas are usually enough to use and the other two formulas fall directly from the first three formulas and we use these and sometimes x minus x zero. You can see the use of s symbol for displacement and
so people remember that these formulas are equal to s 0 v plus plus half an square. Now let us give an example. Standing in front of a high window, it takes 0.2 seconds for the ball to fall from the top of the window and then it touches the ground one second later and we need to find the height of the building and given that we can estimate the acceleration value of 10 meters per second due to gravity. Equals square, because we discussed in the last class that these problems where a body is falling under the influence of gravity freely which means that the acceleration it observes vertically is equal to g towards the ground, now let us solve this problem then what we have is This is a building from which the ball is falling, let's choose the direction of x downwards
so the acceleration is equal to g which will be 10 meters per second square now what we have now Given that the ball starts to fall where the ball starts to fall Let this position be zero Let the position above the window be indicated by position 2 below the b1 le t window and the ground position by 3. So now what we have been given is 1 to 2 This distance is given as 100 centimeters which is equal to 1. Meters and we also know that the duration between these times is 0.2 seconds
so now what we understand is that we know the distance we know the time and we know the acceleration but we don't know the initial velocity or the final velocity

so we use the formula that x minus x zero Equal v is zero t plus half square
so this is the formula
so now we use this formula from 1 to 2 distances .
 So now 1 to 2 x minus x 0 will be 1 meter starting velocity v 0 which we don't know it will be v 1 The time taken from 1 to 2 is 0.2 and then our plus half times the acceleration is g and the time taken from one to two is Now the zero point is two squares. This g we know it is ten
so the only unknown in this equation is v one and when we get the value of one is equal to zero point two v one plus five times zero point two square and hence we get the value of v one as four meters per second So once we know the value of v one. Then we need to find the total height of the building
so all we can do is divide it by we say it's s0 and let this residual height be s1
so that s1 includes the height of the window and from the bottom to the ground
so what we can do now is 1 The total time from 3 to the total time we know is 1 plus 0.2 is equal to 1.2 seconds
so we use the same formula again that x we use the total distance which is now equal to s 1 now we know the velocity 4 to 1.2 plus half wins 1.2 square
so it When we use this we get s one equal to four points eight plus seven points two
so it will be equal to 12 meters
so this is the height from the top of the window to the ground now we need to add s0 to it
so we go ahead with the calculation now. s zero is the height or distance from i but the height should be replaced by x above the window from the top of the building .
 The ball starts at rest
so we know the velocity of zero we know the velocity in one we know these two velocities but we don't know the time that we knew in other cases we did
so we use the formula that we know
so we know v we know v 0 and we Acceleration is known and
so we can use it to find x minus x 0 distance. So we use the formula v square is equal to v zero square plus two times x minus x zero is s zero now v square was given as four v was given four
so v square is sixteen it will be equal to two times ten times s plus zero
so here From what we get is s is equal to zero divided by sixteen. Twenty was equal to zero point eight meters
so we get the total height is equal to twelve pl. Our zero point is equal to eight twelve points is equal to eight meters .
 This distance could be divided by 2 to 3 because we know the time and velocity at 1 and the distance
so we could use it to find v2 and go from v2 to the ground. This remaining distance is added to the window height and is added as zero. And
so there are multiple ways to solve the same problem that you need to see is how you can optimize the variables and try to solve the problem in a minimal number of steps. Now let's look at another problem and what we have given here.
 That is, it travels from a train station, from a station b, it starts at rest, passes through the first part of the speed of a constant acceleration a1, and then it goes through constant obstruction until it rests at b , and l distance b a and b and assume that everything is in a straight line
so when we look closely at this problem the common mistakes that students make while doing this problem is the first part of the motion and somewhere they assume that it is the first half of the speed it is half the distance somewhere
The problem is not given that ah the distance from a to b is half the

acceleration and half the specific part where the obstruction is accelerated and the special part is not given to us when it is obstructed
so we have to keep this in mind when we deal with this problem. Let's solve this problem
so let's see the solution
so what we do here is tell us trains start from a and go to b if we see its speed
so it goes from a to b
so let's Li where it gives the point bc where it changes from acceleration to retardation
so if we look at the velocity drawn here the time curve here if we plot velocity as a function of time then what we get is that the velocity increases when the train goes from a to c and it Increases because its uniform acceleration will be a straight line and once it reaches c it the velocity decreases
so it has an acceleration of one minus eight
so it has an impedance of 2 which means the acceleration is minus 8 and the distance is a and There is somewhere between b where we do not know exactly where it lies
so we know that this is the total distance l
so now if we can write ac as s1 and cb as s2 which we know s plus one plus two is equal to what we know a The velocity at the point is zero and the velocity at the point b is zero
so let c be the velocity at bvc then if we work with what we know then vc square will be equal to va square plus 2 a 1 times s 1 and we also know that vb square will be equal to vc square minus 2 a 2 times s 2 So what we can get from here is that s 1 is now equal to als o o what we know That is va is 0 and we know vb is 0
so the first equation will give us s 1 equal to vc square 2 a 1 and the second equation will give us s 2 equal to vc square two a two we know this is the total distance. So l is equal to vc square over 2 a 1 plus vc square over 2 a 2 s 1 plus s 2 is l
so what we're doing here is we know l we know 1 and a 2 we have to get our answer
so from here we have Pi is equal to vc squared 1 over 2 a 1 plus 1 over 2 a 2 is equal to l
so we got vcl in terms of vc
so it gives us vc squared equal to l times two a one e divided by one plus two
so you When simplifying you will find that now we need to find out that the question is not to find VC if the question was to find VC then we got the answer now we have to find out the total time this was the problem
so to find the time once I know VC which I know VC Is equal to va plus one t one where t one is the time taken from a to ct is a to time c and we also know from here we can see that vb is equal to vc minus a2 t2
so a From khan again we know va is zero vb is zero
so what we have is t one what we get from here is t one is a1 over vc and t2 is equal to vc in notice a2 because we had constraint
so we have already subtracted here So now we need to find out the total time
so the total time is equal to t 1 plus t 2
so it will be equal to vc times 1 over 1 plus one on a to two and we already know that vc square is equal to vc is equal to l square root Divide one by one into two plus one by two
so we can substitute and simplify here and we get our final answer once we simplify we get t equal to square root by adding two la one by dividing one by

eight now like this The problem is you have to look at what has been given and what has been asked and act accordingly. Now we can do the same problem. There is a second method to solve this problem and that is we can solve it using graphical method. Now let's solve this problem using a graphical method. Let's try to plot and then see if we can find the amount of interest

so the problem is given to us that the train travels and its acceleration is given during its journey

so if I look at acceleration and plot it as a function of time then our Given that the train travels for the first part of its journey with an acceleration a1 and the second part of its journey with the acceleration of minus a2 because it is given that the obstacle is a2

so the acceleration vs. time curve looks like this is how we use the graphical method now We use the fact that the area below the acceleration curve gives us a change of velocity and the area under the velocity and time curve gives us displacement and Similarly the slope of velocity and time curve will give us acceleration when the acceleration constant n velocity and time curve will give a straight line along our slope which is equal to acceleration

so in this problem when we determine velocity and time curve the train starts at station a it b The point of stop c where it changes is acceleration

so it starts with a zero velocity and since the acceleration is constant from a to c it will travel velocity and the time curve will look like a straight line with positive slope and when it goes from c to b it will be Another straight line with a negative slope or

so here the slope of this curve will be one and the slope in the second part of the curve is equal to minus a2 and now let us see the problem we have been given if we want to find this total time from a to b. We say this time t1 if this time is t2 then we need to find the sum of this time which is t1 plus t2 and what we have been given is the total distance traveled. l Now the distance is also given as a field under velocity time curve

so if I look at this field now let's say velocity at this vertex is vc

so let's use this information if it is vc and we drop a perpendicular from here so that vt is below the curve Area it will be equal to half vc multiplied by t where t is equal to 1 plus t 2 total time and it is given to us it is equal to l

so this l is given t which we need to find out and now vc is unknown

so here we are Got a relation We want to find the second relation The slope of the line here a1 Now the slope of the line c will be divided by the velocity c vc minus 0 by t 1 and it is equal to a 1 It is the slope of the first line and the slope of the second line which is cb will be given as 0 Dividing velocity b by minus bc by t t2 is equal to subtraction of a2

so what we get from here is that when we write this we get t1 is equal to a1 on vc and we get t2 is vc- Is equal to a2 on top

so what we get from here is t1 plus t2 is equal to vc on a1 A2 on bng bc which we can write as vc one over one plus one a to a and now we use the second relation that we have that half divided by 2 of vc and l we got earlier

so what we get from here Is equal to t

so we substitute the value of vc here

so we get t is equal to l over 2 times 1 over 1 plus 1 plus 1 and now we can take the other side t means that t square is equal to l is equal to 2 of 1 Above 1 plus 1 and 2 and this is the answer we got earlier

so the graphical method can be effective if we both understand that the slope of the curve of velocity gives us acceleration during velocity and displacement of the area below the velocity time curve now let us consider the relative velocity Let us focus on and what we understand here is that the position of a

point depends on the reference frame from which it is being measured
so the position is a frame dependent quantity ty because it will vary with the
reference frame you are measuring and since the position is a frame. No. The
amount of velocity also refers to the velocity and acceleration of a point where
the derivative of the position and the velocity vector respectively become the
frame dependent quantity and this is what we noticed when we sit in a train we
are in the reference frame of the train and this is a common experience. That
we see the trees that are there and the telephone poles that they look like.
The movement of a point becomes a function of the frame from which you are
observing it when we are sitting on the train moving when the train is clearly
moving to a person on the ground and the telephone poles and trees are
stationary .
 The point means that the velocity we measure depends on the reference frame.
It cannot be that we cannot speak of any absolute velocity in that sense
so let us consider a point p. When we talk about motion with curved lines,
curves, etc. when we talk about those things
so here we are considering motion along a point p a straight line
so now we have an observer attached to frame a and an observer which means we
have a reference frame a. This observer is considering the movement of point p
from where and there is a point p
so the position of p is measured by frame a We mean that xba is
so xba is the position of p as observed by the observer
so let it be connected to a frame This is frame a. We also have a frame b and
the position of p has been observed by vectors such as frame b. Let us write
that xpb is therefore the position of p as connected to frame b Observed by
the observer and the position of frame b relative to frame a is indicated by
xba
so xba is the position of b as observed by the observer attached. All these
first points are a notice frame. There are two subscripts. The first one
represents the point that is moving or the point which is being observed by both
frames. The second one represents the frame from which the measurement is being
 taken. Is equal to
so we write here this xpa is equal to xpb plus xba now if we differentiate with
time then what we get is dt by dxp is equal to dt plus dxba by dt and we can
write that vpa is equal to vpb plus vb a Where vpa is the velocity of p as
observed from frame a and v pb is the velocity of p as observed from frame b
and vba is the velocity of frame b as observed from frame a now what often
happens in frame a Will be fixed and if it is clear that it is the same frame
then a can be omitted because when it is clear that frame a is fixed and a
clear frame then we do not write it and then the relation will become vp with
respect vp equal to b of b Plus v's This means that the velocity of the point
p observed from the ground is equal to the velocity of p which is observed from
the frame b plus the velocity of b observed from the ground
so this and what we understand from it gives us a relation to the velocity of
the p point observed from frame b B is equal to the velocity of p minus
velocity
so this is why we can write the velocity of p as the velocity of p observed by
frame b is equal to p minus velocity of b where nothing is said to mean that
they are now being measured relative to the ground if we assume Both frames a
and b move with constant velocity which means that the acceleration of a and
the acceleration of b are both 0 .
 We find that the acceleration of b differs in the expression of velocity and
because the acceleration of b will be equal to rm ab minus aa and since we get
0 from both the acceleration of p relative to a is equal to the acceleration of

b relative to b That means if two frames are moving with constant velocity and you can see Acceleration of a point p which is moving with respect to this frame If the frames are moving with constant velocity then you will measure the same acceleration by these two frames. And the reason why acceleration and the measurement of this speed become important relative to the frame is that eventually we will use these relations of acceleration we will relate it to force and we will know Newton's second law for those of you who say that force is equal to mass acceleration and There we have to be very careful because when we say that the force mass is equal to the mass acceleration then the acceleration ca reference acceleration cannot be measured in terms of an arbitrary frame. Another word of caution when we come to acceleration is that when we use this relation vpa vpb plus v ba this relation is valid for low speed and to say low is what we mean. What we want is when v pb and vba are much less than each of them c where c is the speed of light if these velocities come close to the scale then the speed of light this relationship does not work and we have to use the theory of relativity to make it work because when we When it comes to the speed of light, the theory of relativity tells us that the speed of something cannot be greater than the speed of light. So we have to be careful. Next we will look at some examples of relative motion,
so the first example we have is a person walking up to a stagnant escalator
so there is an escalator and if a person walks from bottom to top he takes s time t1 now it is also given that If the escalator is running on a moving escalator and the person is standing there, it reaches from bottom to top in time 2. Now we need to find out the time if the person is moving at the speed we specified and the escalator is also moving .
 We want to figure this out
so we have the person here 1 time and the escalator itself sorry to go from top to bottom it takes two times to go from bottom to top and now we put if the person moves with his speed on the moving escalator then time T3 comes out and it is given to us that The length of the escalator
so let's do this , when the escalator is off let's first find the speed of the person
so that we know that the speed of the person is equal to the total length of the escalator Now the time he travels is divided by t1. Now when the person moves to the escalator, the velocity of this VP becomes the person related to the escalator and
so with a person running on the escalator, the person running on the escalator is equal to 1 l and the escalator. The velocity itself is given as l on t 2. Because the escalator itself takes a time t 2. So now when the person moves with the escalator speed of the person relative to the ground, it will be equal to the speed of the person with the escalator and equal to the speed of the escalator relative to the ground. This will be equal to l on t1 and it will be given as l on 2 and the velocity of the person on the ground will now be given as t 3 on l where t 3 is the final time taken by the moving person is the escalator
so what we get from here Is equal to 1 over t 3 is equal to 1 over t 1 plus 1 over t 2 and we can get t 3 equal to t 1 t 2 over t 1 plus t 2 and we can understand the final answer here is independent of l
so we Let's find the time taken by the person in the running escalator or now let's look at another problem, the two cities a and b are connected by a bus service where a bus is leaving in any direction within minutes. He saw a bus go. Passing it every 18 minutes towards its speed and every six minutes in reverse now it is given that the bus speed vb constant we need to find vb and t
so the bus speed ah given that constant we need to find the bus speed we have

in the bus We need to find out the duration given to us the speed of the cyclist

so let's see the speed of the cyclist it is known to us we also know the time T1 when the buses pass after this time is in the direction of the cyclist and time t 2 is the time when the buses pass the cyclist in opposite direction So t1 and t2 are the distances between consecutive bus passes

so let vb be the speed of the bus

so let us use this problem a method where we will analyze everything d reference frame

so let's see when the cyclist is in a position and a bus passes him Then the bus number one passes him and the cyclist is equal to zero. Now the next bus which is the number two bus one is behind the bus number one. The distance of vb time capital t at this moment because after all bus time passing is equal to vc to t1. And the distance traveled by bus number two at the same time will be equal to vb times t plus vc times t1 and this total distance is also equal to the distance traveled by bus number two

so let's write this distance traveled by bus two when it is from t When the cyclist crosses it will be equal to zero then the time observed will be equal to vb times t plus vc times one and how much time this bus has traveled at this time this bus has traveled for one time is equal to vb times t one

so we are here We get a relation from. This is a relation and we now analyze the other side. Now if we look at this relation we have two unknown vb and t vc is given to t1

so we have an equation about this but two unknown

so we need one more equation. And for that we look at the buses traveling in the opposite direction

so now let's say here a bus equal to t 0 has just passed the number 3 cyclist and there is a bus number 4 it will be a vb times distance cyclist in the number three bus behind t This is how it is now What will happen is that after two times the bus number four will pass the cyclist. Now the distance this distance traveled by the cyclist is equal to vc times t2 and the distance traveled by bus here is vb times t 2 and the total distance is vb times t

so we Pi is the second relation that gives us vb times t is equal to vc times t2 plus vb times t2

so now again if we calculate we have the same unknown vb and t2 unknown vc familiar to us t 2 familiar to us vb same unknown

so when we find it When we work we have two equations and two unknowns and we can solve it and we get our answer

so there is a way to solve it and you can now omit

so for to solve it for example in this case what we have if you solve this equation The number one gives us vbt is equal to vb minus vc times t one and the equation number two gives us vbt is equal to vb plus vc times t two. will give the value of vb because we know vc t1 and t2 and its Then we can now find the same question. When you work with numbers we can figure out the numbers. Please note that your unit should be consistent if you express the time in hours. Time is given to m inutes

so it is better to convert everything if you speak in our terms we should convert minutes to hours When the bus and the cyclist travel in the same direction

so this bus is traveling it is vb and the cyclist is traveling in the same direction which is given by bc

so we will keep the way the cyclist saw the speed of the bus as vb relative to c it will be vb minus vc Equal and in this frame we look at it when the cyclist is riding towards it. The cyclist bus travels the distance between

two consecutive buses when it overtakes him

so the distance to the cyclist's frame is vb bar t and if you have any difficulty in trying to understand it you will assume that the cyclist is at rest if the cyclist is at rest VC is equal to zero and Then when he sees a bus passing him I will say bus number one then when bus number two will pass this bus number two VBT is far away

so he will vbt before the distance this bus has crossed it and the same thing will continue. When the cyclist is running and

so now the distance traveled in this reference frame is vbt and time taken is not one

so we have bus speed as seen by multiplying the cyclist frame by time it will be equal to the distance traveled by the bus shown in the cyclist frame and it will be vbt The product will be equal to t

so we have vb minus vc times t is equal to a vbt and this relationship is the same as we observed earlier in equation number one now let us look at the opposite direction of motion The cyclist is moving like this. The bus is going in the opposite direction. So now the bus speed in the ground frame is equal to minus vb minus the nus mark because we are taking it as a positive x direction.   So it will be equal to minus vb and the speed of the cyclist as seen from the ground is plus vc from the side

so with the minus sign it becomes vb times minus vc and it is equal to minus vb plus bc

so it is the bus speed cyclist now The cyclist observes in the reference frame that the bus minimizes VBT before it passes him and when it passes the first bus number three it is equal to zero when we start and it is bus number four

so the cyclist observes the distance traveled by bus number four before it reaches him will be minus vb t the minus sign comes because the bus is traveling in the opposite direction

so now that we again use the fact that velocity of the bus with respect to the cyclist this t ime taken is t2 and this will be equal to minus vbt and velocity of bus as seen from the cyclist we have already worked this out this is minus of vb plus vc times t2 is equal to minus vbt and this is the same as relation number two which we have obtained earlier

so you with when we observe things in a relative frame we can also solve the same problem with this method

so we have seen this concept of relative motion and with this will end up our lectures on motion in one dimension in the next class we will talk of motion in a plane where we look at position displacement velocity when a body is traveling in a plane but to understand that will also need a crash course on vectors

so we will start with vectors and then we will talk of motion in a plane you