Today we will now begin to discuss the motion of a plane to study motion or kinetics because we have found that the quantities that are relevant to us are positional displacement velocity and acceleration and what we saw until the last unit was a straight line of motion and when we are along a straight line When describing motion we would take care of the direction with a positive or negative sign if something is moving in one direction and if we call it positive if it comes back or opposite direction we call it positive we call the return direction negative but now we We will extend the discussion to two or three dimensional motion

so we will expand it to two or three dimensional motion and when we do this we will have to specify the direction. And this is what we do using quantities called vectors

so the first part of studying a plane of motion will actually be about vectors so before we describe what we will see here So we will see how to add vectors. We will see how to subtract vectors. We will see how to multiply a vector with a scalar. Now I do not have the word scalar. If we have a real number then how do we multiply the vector with real number now the question may come to you how do we multiply the vectors we can multiply them and we will refrain from answering this question in this unit then we will have two types of vectors We will talk about multiplication and it will follow after some time and after we vector we will see the motion of a body in a plane and when this motion of a body in a plane is performed with constant acceleration because it is a plane motion it will have multiple directions and if acceleration is constant Either way it takes us to a special kind of motion which we call projection motion and which we will explain and finally at the end of this unit we find the circular motion ah point chapter. We will not do that which is moving and as it moves it marks a circular path

so these are the things that we will study in this unit so we will start to discuss this unit with scalar and vector A scalar is a quantity which has a dimension Represents a scalar and a scalar has no direction

so it is basically a scalar quantity determined by a single number in a specific set of units

so it is always any quantity unless it is dimensionless but a scalar quantity will be specified with the unit For example when we talk about the mass of an object we say mass is one kilogram or two kilograms or thousand grams 500 grams etc. ,

so when we talk about mass we have no idea of direction which scalars are temperature objects when we measure temperature Let's say we say when we measure someone's body temperature we say 37 degrees Celsius or 98.6 degrees Fahrenheit is normal for the human body. When we talk about speed again, even when we talk about speed, there is no sense. At a point then if we look at the quantity we call distance or length of path it was the total distance of a point when it goes from a to b and when we measure the distance no direction is involved

so this quantity is also a scalar and scalars. Scalars can be added by following the general or general rules of algebra. Addition Addition Subtraction Multiplication and Divide Now Addition and Subtraction We have seen that we can take two scalars and we can add or subtract them when adding or subtracting. The scalar then the units have to be identical

so for example if you have two masses you can add two masses but if I have mass and a body temperature then you know these two things scalar ad ding mass at a temperature will not give me anything meaningful

so it can be done No. When we have addition and subtraction the units have to

be identical but when we multiply and divide the scalars

so now suppose I am multiplying a scalar with a scalar b now a scalar a can have a scalar b unit b will now have a unit Multiplication When I write it as multiplied by b, the unit of product will be the product of two dimensions of a and b

so we can do this as we saw when we multiply a and b the unit of product will be the unit of product of these two units and similarly we Now we can make a division of a scalar a by b. When we divide these, these quantities can be different units of a and b, and the quotient we get is the division of these two units, and let us see, for example, the density is equal to the mass when divided by the volume. Now if the unit of mass is ar e in kilograms and if the unit of volume is in cubic meters then the unit of density will be kilograms per cubic meter

so we have this and sometimes let's think let's take an example let's say we have a rectangle a and b here when we are on this side So if we look at the circumference of this rectangle we see that the times are equal to two times one plus b

so we are adding two scales here two lengths a and b

so the circumference is two times one plus b If we see the area then the area is equal to b and here if a And if b is in meters then the circumference is also in meters but if you look at the area b times then the unit of area will be meters times meters. Which meter square Now let's talk about vector A vector is a quantity that first we will talk about it has a dimension and it also has a dimension

so the vector will have both dimension and direction and then there is a second property associated with the vector which is very important and that is It adheres to a specific rule of addition which I will describe and we can call this law of addition as a triangle law that we can express it in that term or we can call it as parallel logarithm of addition

so a quantity has a dimension in its direction. The first is necessary and the second is that when we add these two quantities to this quantity they have to follow a certain rule. Because it has two properties it has a dimension and it has a direction

so a vector is specified by its dimensions and direction and it There are many ways to do this that we will now show you usually use a bold letter notation to represent a vector in a textbook

so in printed text you will see the vector marked by a bold letter notation but when we write it we use the letter with an arrow above. So for the former, if I write v with the up arrow, it represents the vector v and the magnitude of this vector v. It is represented only by the letter v without the arrow, or sometimes we show it between two parallel bars with a vector v

so we select the vector. Start the dimension of the vector as indicated by v This is now one of the vectors we have already seen except that we will write with v or v and let's write this Suppose the position of the vector is a point p is moving along a path

so at this instantaneous point p here at the next moment it is pp. Is in prime point

so this means that the particle at position t is in t prime at p prime it is in p prime

so all we do is choose a coordinate axis to find its position. Let's say we choose two mutually perpendicular directions. We call them x and y. The Cartesian axis is represented by the intersection of o. And the intersection of y is called origin

so we will draw it again we have xy here it is o is p now line from o to p If

I draw it then along this direction it is called r position p vector of point
so we can write it as vector r Hall is equal to op and since we are going from
o to p along a certain direction we are presenting it as a vector sign which is
the position vector of p at t. Now if it is p prime then I can draw a line from
o to p prime and I can call it position vector r prime it is op prime it is the
position vector of p at t and actually if I add p to p prime it is p it p
prime if I join them with a straight line pp prime this is what we call the
displacement vector of p
so the distance of this straight line from p to p prime which has a definite
direction from p to p is prime displacement vector and we can see that the
particle Traveling either way from p to p Prime it is traveling this way or
this way from p to p prime the displacement vector will always be independent
of the same path and from this it is clear that the displacement vector will
be less than or equal to the length of the path
so now define Suppose if we have two vectors a and b then the equality of
vectors means that if we say vector a is equal to vector b then it means that
the dimension of a is equal to the dimension of b it is one thing but because it
is a vector quantity and it has two dimensions dimension and direction So this
 The sides of t a and a must be equal to the direction of b
so to make sure if we have a vector we denote by op and there is another
vector we denote by qr
so now if a is equal to b then you To do this, we shift b to check whether it
is equal to ab.
We move the vectors parallel to either of the two vectors a or b .
Vector until the two tails touch each other
so we move b to a and o to q. Move and then we see that if p and r coincide,
if the points p and r coincide, then we say two vectors are equal, if they do
not coincide, then the vectors will not be equal,
so touch up to two tails, if two heads coincide , we say vector a Equal to
vector b Now it is possible that sometimes the dimensions of a and b can be
equal and we will write this as equal to a b because the measure of a is the
dimension of b without the vector mark but vector a may not be equal to vector
b and it Suppose we have a vector like this and a vector b whose denominator
The length is the same but a different direction
so now when you move the tail of b to a you will see that the two tails will be
at the same point but the two heads will not meet
so vector a will not be equal to vector b
so this is how we define the equality of two vectors. Multiply a vector by
a. A real number by a real number and let's say we're not just a real number.
Make it a positive. First we'll take a case of a positive real number. A
positive real number and we see the lambda bar aa scalar multiplied by a vector
so now what we get is it will be a vector
so this product to us this product is a vector whose direction is equal to the
direction of one but the dimension is a lambda product of a dimension Let's
look at this with an example. Suppose I have a vector a and I mean I want to
write 2a
so 2a will be a vector which is twice the length of a on the same side. Now it
will be equal to 2a lambda. If 1 is greater then the product dimension is
greater and if Lambda is less than one then the dimension is smaller and if I
see it then the new vector allows to write this r since the product is equal to
Lambda a If I take the dimension of r which is equal to r it will be equal to
the dimension of lambda a and we can write it as lambda property equal to the
dimension of a or equal to the lambda property. Now here we are talking about
positive lambda. It is in the same line opposite to direction one but it is in

opposite direction

so for example if we have a vector on the opposite side we write a vector of the same length as minus one

so and if I want to have a vector which is twice the length of the opposite side which is now Subtraction will be equal to 2a

so we are talking about lambda time a lambda can have its own dimension and lambda a dimension can have lambda dimension and dimension of a and will actually be the product of the way we described it if we have a scalar if a scalar There is a beta that divides a vector which means you want to write by dividing by beta but this is only a special case of a scalar multiplication where one over beta lambda

so the vectors are scalar This rule, which can be multiplied or divided by, comes with the next basic rule which we have described in the properties of a vector and it is the addition of two vectors because we said that one quantity or two is one quantity if a vector now follows the addition rule of vectors as we say this addition. We can describe by two methods by which we get the same answer, the first of which we call the addition triangle formula

so we have a vector and there is a vector b and we want to find the vector r which is equal to a plus b

so here we select its a plus b We select vector a. We draw a vector

so we will draw a vector. Now we will draw a vector on the head of a at the end of a which means at the end of which we draw a vector b with its tail on the head of a

so we have a vector. Draw

so we have a vector here a it b

so now the third side of the triangle is seen in reverse order see we are going to a to b now the third side of the triangle is this direction and what I mean by reverse order is if I move from a to b So if I follow the arrows I will take this line I will take in reverse order and this third one gives me this direction r which is equal to a plus b

so we add vectors from triangle formula

so it is called triangle formula that we have two vectors equal Drawing sequentially we complete the third arm of the triangle. The triangle in reverse order gives us the sum of vectors a and b. Now let's see what we see is a plus b. Let's reverse the order of addition

so we see vector b plus a with these two vectors. I will draw and then draw vector a on the tail of vector bi

so it was b it a and then I look at the third in reverse order it gives me vector r 1 which is equal to b plus a now what we understand is vector r 1 vector r Not like this is at b plus a is equal to a plus b and we call it the commutative law of vector addition and we therefore call it the commutative law of vector addition and we see with the scalars that the sum of an addition b is equal to the sum of b plus a if If we add three vectors together then we have a third property

so now let us add three vectors ab and c and this way you can see that we can generalize it to add more vectors and sometimes you can see it as a polygon of addition. The formula is called

so let's see here They have a vector

so we add vector b and

so now what we see is a plus b and we add c

so a plus b if we look at it it will be given by this dotted line and now the third vector c which is a plus b has to be added it has to be placed on the tail of b and now when we see that if I add a b complete the triangle from b to ci and when I look at it in the opposite sense it is a plus b

so this vector here gives me a plus b plus c So we make a polygon of all the vectors there and the last side that completes it will give the sum of all our vectors. Now let's see how it relates. b and c add vectors

so if i add b and c vectors then i get this dotted line and I have to take it in reverse sense

so   abc

so i see this line this is vector b plus vector c and when i add it to ai again We get a plus b plus c

so what we get is vector a pla Adding b plus plus c will be equal to a vector a plus b and c and this property is called associative property

so we can add vectors in any order. Let's add that we try to do this

so now put a vector a vector at the head of this i which is minus a which means I come back to the same point

so the sum of these two will now be a vector which we call as 0 vector

so add itself to a subtraction. The result is a 0 vector

so what we get is a and we can subtract a plus from here. The zero vector gives us a lambda multiplication. At any scalar the zero vector will give us the zero vector itself and a zero scalar multiplied by a vector gives us a. Will give a zero vector

so we have defined a zero vector in this way and just like we have the addition of vectors if we try to see the subtraction of vectors but if this means we are talking about a subtraction b then it is a special case of addition which We can write this as the addition and subtraction of b which means we take a vector and we add it to the subtraction of v which means we will get an addition minus b opposite to v and now as we have discussed we have seen addition using triangle formula now a There is a second way and what is called the formula of parallel circle of addition of vectors and what we do in parallelogram formula is that if we first arrange the vectors a and b with the tail joined at the same point you remember we first put vector b at the head of a and a with its tail Now what we will do here is I have a vector a I want to add it to the vector b

so I will keep the vector a and vector b with the tail at the same point now these are two arms or rather two adjacent arms

so if these two adjacent arms We see them as adjacent sides of a parallelogram

so we complete the parallelogram which means we draw a vector a to b and from this step we draw another vector which is equivalent to b

so it is a parallelogram then parallelogram The diagonal starts from the tail The diagonal starts from the common point of these two vectors is equal to vector r which is equal to the sum of a plus b Why do we sometimes use sine r because often the sum of these is called result

so So here the angle of parallelogram gives us the sum of vectors a and b and this wha t is called pad. Thus we use vector addition using formulas of parallel circles of vectors and if you look at the second you will see that it is a Parallel,

so this aspect is nothing but vector b and hence the diagonal that we have. Got here nothing more than the third arm of the triangle if a and b are placed sequentially and

so we see that the parallelogram formula is nothing but the same result as the addition triangle formula and if we ever say we want to see a minus b

so if We have a vector a and it is b b vector we want to find a minus b then from this point b if I draw a vector against which it is subtracted and I complete this triangle

so this vector a will be equal to vector a minus vector b And it was a and b

so we can fix the subtraction and now what you can understand here is that a

subtraction is not equal to b. Add two
so that I complete this triangle. I do this
so it will actually fall on the same line. This vector will be equal to b minus
a. In fact, it will become b minus a .
 Lambed If a sum is multiplied by the sum of b it will be equal to the lambda
property and the lambda property will be equal to b and it can be verified later
we see what we call as resolution. Suppose we have two vectors a and b which
are zero vectors of different directions in a plane and we have a third
vector a in the same plane.
 You can say this is a vector
so we have a vector aa vector b they are in different directions they don't
need to be perpendicular to each other they are just two different directions
and we have a third vector
so we have three things ab and a now what can we say vector a Who can be
expressed as two sums of vectors? Now what are the characteristics of these two
vectors? Let the first of these be multiplied by a real number .
 That is to say we can express a as lambda times small a plus mu times small b
so we can do this and the way to do this to understand it is to make vector ab
equal to op
so this vector a which we mean by op after o We are drawing a line parallel to
a
so if real vector a is like this then we draw a line through o which is
parallel to a and if real vector b is like this then we draw a line parallel to
b through p
so now b is on this side Was we are drawing a line parallel to b
so now it will be a lambda multiplication a it is a second vector it will be
mu multiplication b because it is parallel to b
so whatever the length this factor will come to mu the length magnification
factor will come to lambda
so plus lambda a plus mu b can be written as vector a and what we say
so we do it once we say vector a has been solved along two elements two
elements vector lambda a and mu b along a and b can now normally have a and b
no adaptation but they Cannot be parallel to each other
so a Now let's say the resolution of a dead vector. Now the resolution of a
vector becomes more general if the a and b vectors are perpendicular to each
other. It has a directional meaning but its dimensions are always the same and
so we generally refer to a unit vector. Whenever we talk about it we use a
symbol hat and whenever we use a hat we mean a vector whose dimension is one
and we have one. Let's say a single vector
so now let's look at our Cartesian system our Cartesian system and here we will
now extend it to three dimensions
so le t we point a vector a with three dimensions
so we have for example x axis y axis and z axis a common. There is a point p
whose coordinate is xyz and if we take the vector from o to p then let it be
called as vector. a is now equal to op if we drop a perpendicular from p to xz
plane and hit it in the right plane at p prime now if we join op prime then it
is very clear op prime plus p prime p now equal to op we have point p prime If
we look at its coordinates then they will be equal to x 0 z. It is a point on
the plane of z
so the y coordinate of the point p will be x 0 z of 0 and what we do is if we
draw a prime from the point p we get perpendicular to the x axis and
perpendicular to the z axis from the p prime. So now here this distance will be
z and here this distance will be x and this x will be called x will be x will
be x component of vector opz will be z component of vector op and similarly p

prime p is equal to y
so it will be vector op's The y component is also what we see. Suppose if this vector op x makes an angle alpha with the axis then the vector op x makes an angle alpha with the axis. Creates the beta and makes it an angle I will use a third color pen to draw an angle with the z axis If we create, then what we have is that the x component will be equal to the magnitude of op cosine alpha y component will be the magnitude of op cosine beta and z component will be equal to op cosine gamma magnitude
so we call these xy
so it is the x component of vector op it The y component of op and this is the z component of op Now what we do is we write unit vectors along the xy and z axes now this x has a certain direction
so we will use the symbol i for a unit vector along the x axis Very common for unit vectors along the z axis. Use the j symbol for unit vectors. We use the k symbol which means if these are xy and a vector of length xx is a length along the x axis. will be j and will be a vector of length 1 along the z axis k and if I want to find the measure of i of j and the measure of k think about it obviously all of them have to be one and suppose if I have a vector on the sub-common side The single vector along a is a vector of dimensions The length of the word I should use is the length of the word I should say 1 dimension along the direction of a we call it as a single vector of a either we use a n sign for it or sometimes we use e sub a with cap and in many cases a The unit vector represents the notation of a and a is a and with the hat tells us that it is a unit vector
so a single vector along any general direction can be written like this and if so what you can understand is if the vector a is this Is a single vector along n but vector a can be written as n times or dimension of t imes n
so we will have a single vector and now let us take the resolution of a vector along the x and y axes
so let us see a planar case now we have a vector There is the x axis which is the y axis which is the angle between the x axis and the ab theater. Drop let it be point py then it is very sp Oh that a is equal to op vector it is nothing else o times px plus o oopx plus opy sorry it can't start vector a will be equal to op equal to opy equal to opy where px and py point x and y axis and someone on opx A subx can be multiplied by i which is the dimension of opx which is the x component of a time unit vector along the x direction which is i and this I can write it as ay bar j
so what we have here is that I add the axis of vector a as ayj Ax and ay are called x and y elements of a
so ax and ay is the x and y element of the vector. Now if we also want to find, we have vector a. So we can see that there are two ways to write a vector a in a plane the first way we use the dimension of a and we specify the angle theta which is formed by an x axis we specify these two things and it gives our vector a and The second way is that we calculate x and y the elements ax and ay and then we add the axis as equal to ayj. Write the factor and from the figure which makes it quite clear if it is a vector then it makes an angle theta with the x axis this axis this ay then what we have is the square of ax plus ay square will actually be equal to ax a cos theta ay will be equal to a sin theta
so ax square and ay square is equal to a square cos square theta plus a square sin square theta which will be equal to a square And we can write as tan theta is equal to ay on ay if you see this figure this height is ay it is ax
so tan theta is equal to ay on dx and then you can understand ax and ay can be positive or negative

so how do we work Let's do this thing. Now in the next class we will go a little further on vectors. We will look at the analytical method of adding vectors in terms of unit vectors and then we will move on to the description of a plane motion using vectors. Thank you.