Engineering Graphics and Design
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Lecture 19
Polygons: Construction and Projections

Welcome back to week 4 of this NPTEL online course on engineering graphics and design. In the previous lecture we talking about how simple solids can be used to construct complex objects. In this lecture we will be looking at polygons because we know from polygons, we go to solids so once we know the construction of these polygons, we can use that information to build up solids and their projections. So, in this class we will learn both the construction of this polygons as well as how to project these polygons not just when they are in the simple or straight forward orientation. But even in the, if the orientation is at an angle.

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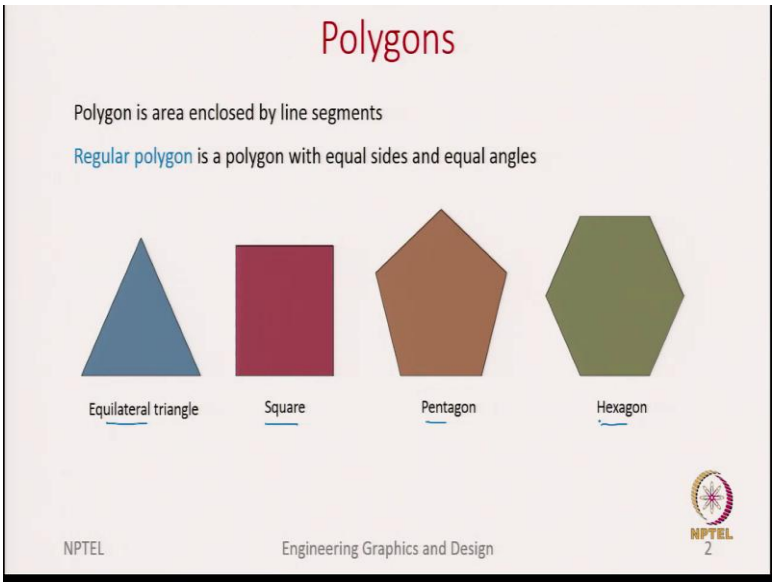

So, let us start with this very basic introduction to polygons which I guess most of us already know. But just for continuity as well as to keep everyone on the same page, we know that polygon is an area enclosed by line segments essentially if those line segments are all continuous and are closed then they enclose an area which we call it as polygon.

And within this class of polygons, we have this regular polygon where we say that they have equal sides and equal angles. What does that mean? For example, if you are talking about these equilateral triangles so we see that the three sides are of equal length and the angle between these sides is the same for all corners. The same thing goes with square, only difference is it is a polygon of four sides and a polygon of five sides is a pentagon, polygon of 6 sides is a hexagon. There is nothing new here but just to have everyone on the same page.

Now, let us look about how to construct these polygons. Again, I am sure most of us know how to draw an equilateral triangle and a square and most likely a hexagon.

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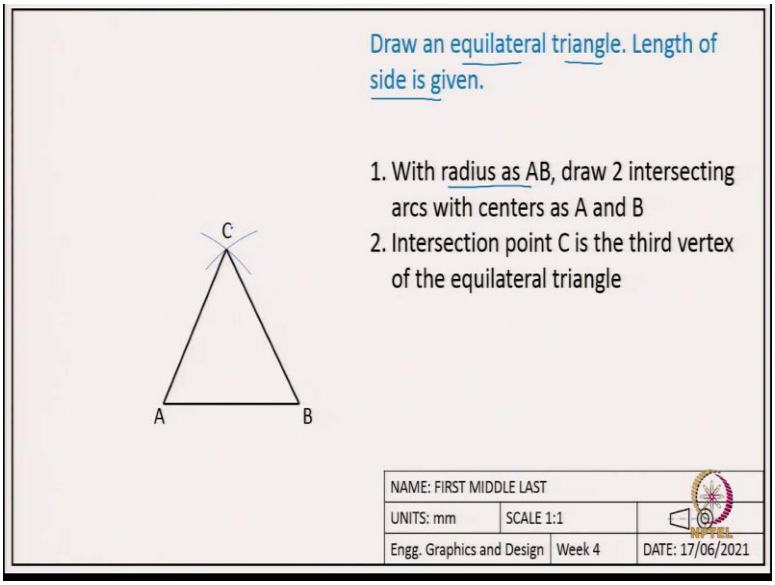

But let us say, if I ask you to draw a polygon of sides more than 6 then probably you may need some special techniques. We will discuss one in this class, but let us start with the simplest one which is to draw the equilateral triangle. Here we are saying that we already know what is the length of this side so we start with side AB, so with radius as AB we draw two intersecting arcs. So, I use a compass measure the length AB and then with center at A, I draw an arc. Again, with another arc with center at B, in both cases the radius is this length AB. So, that point of intersection is C which will define the triangle. So, we just need to connect the three points to get the equilateral triangle.

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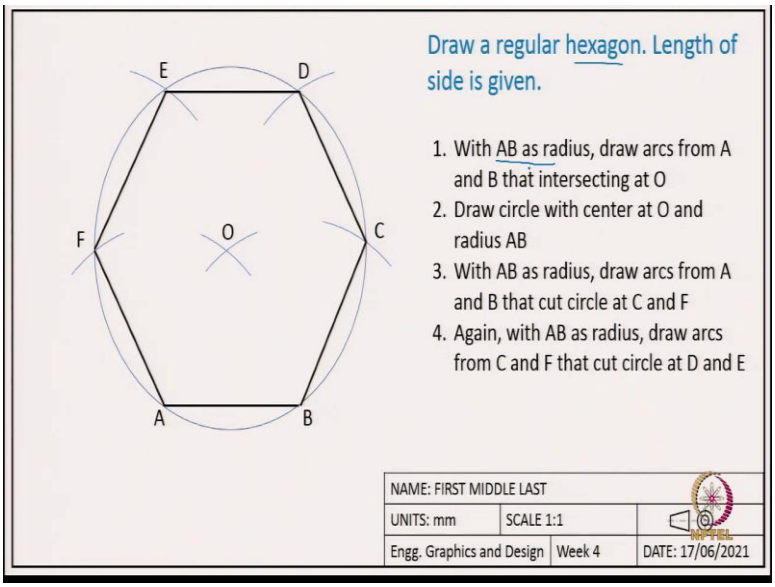

So, now let us move to the next one which is a regular hexagon, so I am skipping the square assuming that most of us know already how to draw a square, the same thing with hexagon, but since whatever we have discussed here will be used in the later slides, I thought I will once quickly go through. So, again here we are saying, we know the length of its sides so now what we will do is with radius as AB, we will draw a circle so you will first identify the center of the circle with the two arcs.

This procedure is similar to what we have done for an equilateral triangle in previous slide. But now with O as the center, we will draw a circle and the radius is AB. So, this is that circle, so after we get this circle, now we take this compass with distance AB and draw acres while we draw these acres, the radius of the arcs will be AB and the centers will be at points A and B. So, one arc from A and the other arc from B. So, we get this new where it is cutting the circles, the points F and C. So, we make two more arcs again with the same radius AB but now with the centers of F and C. So, from F we get this arc where it cuts at point E and then from point C we make an arc which cuts at point D.

So, now we identified the 6 points of the hexagon on this circle, we just need to connect those dots or the points to get the hexagon. So, here is the quick tutorial about how to draw this hexagon. But next what I will be discussing is how to draw a 'n' sided polygon but before I draw that, I need to discuss one technique. So, this is a technique used to divide a straight line into 'n' equal parts. So, first I will discuss that and then go to the drawing of 'n' sided polygon.

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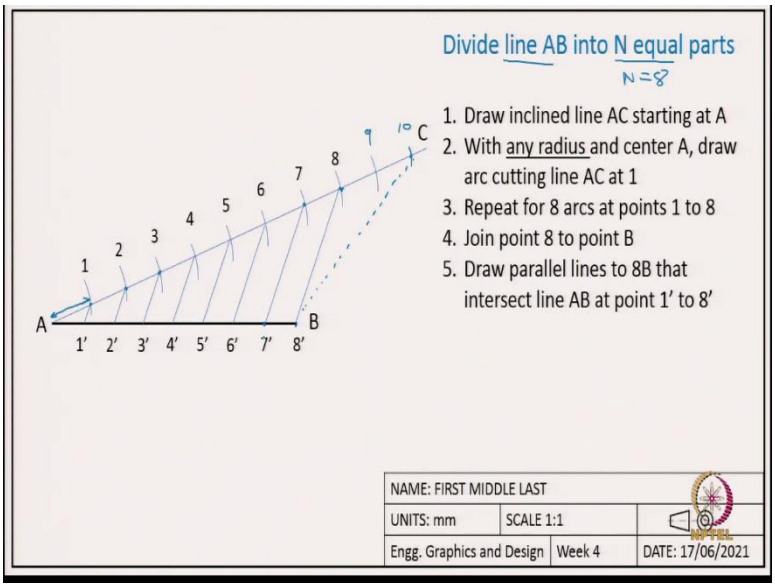

So, we are saying we want to divide this line AB into 'n' equal parts. In this slide I will be taking N= 8 for example but you can keep changing for any number. So, the first thing we do is we will draw an inclined line to AB starting at point A. So, this is inclined line AC starting at point A, I draw this inclined line.

So, the point to remember is, I simply said it as inclined line never mentioned what is the angle, what I meant by to free any angle you want. So, probably this is close to 20 or 30 degrees but you can have it at 45 or 60 it can vary. So, this technique is not fixed to a particular angle you are free to choose any angle.

Second, what we do is, any radius so with some arbitrary or random radius you take a compass with center as a draw an arc cutting this line AC at 1. So, what I am trying to say is this length, the length between A and 1 is arbitrary. So, you can choose any arbitrary length, we will stick to that length and draw multiple arcs. This time we will make the center at point 1 and draw another arc. So, now we get this point 2.

And similarly, I will continue until the number of equal parts, I need to make this line AB. So, here I want to make it into 8 equal parts so I will make 8 arcs. So, each of these arcs will give me a point, so I got point from 1 to 8. Now what we do is, you connect this point 8 to the end of this line AB so which is point B.

So, we have joined this point 8 to point B. So, this is the final step we do where we need to draw parallel lines. So, you may be wondering how to draw parallel lines, most of the engineering drafters they are designed to draw parallel lines otherwise most people use a

roller scale, you can also use that to draw parallel lines but otherwise if you have just two set squares, actually, if you place one set square rigid and the other sliding on it, you also get parallel lines.

So, if not you can quickly look into YouTube and search for drawing parallel lines you will find a couple of videos to draw parallel lines just by using two set squares or a roller or a draft. If you are able to draw these parallel lines, what we need to do is, now draw lines parallel to this line B8.

So, first we draw this parallel line passing through this point 7, this will have a corresponding point 7 dash or 7 primes. Similarly, I keep repeating for points 1 to 8 and then I get these points 1 prime, 2 prime, 3 prime so on until 8 prime… So, these points equally divide this line AB into 8 equal parts.

So, I said here I have chosen it to be 8, you can choose it any number you want, only thing is you need to remember that the number of arcs should be equal to the number of parts you need to make. For example, if you want to make it 10 equal parts then you continue till 9 and 10 and then join this point 10 with B. So, for example, I am drawing it with a dotted line and then what you do is you draw lines parallel to this line B 10 and then you will be getting 10 equal parts of this line AB.

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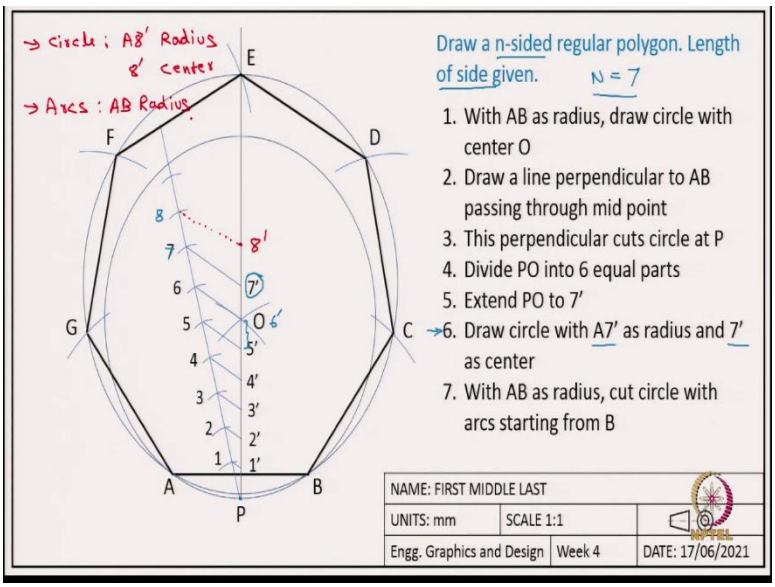

Now, what we have seen is how to divide a line into N equal parts, but now let us look at how to draw an N sided polygon. Here we are starting by knowing that, we know the length of the side so let us say one of the sides is already drawn here, which is AB. We need to draw the

rest of the sides for this N sided polygon. In this example, I will be using N=7 which means I am trying to draw a heptagon. So, let us see what is the first step we do? We draw a circle which passes through this points A and B and we name the center of the circle as O.

Now, second step is to draw a perpendicular line to this line AB which passes through the midpoint of A. So, let us say this is that line which passes to the midpoint of AB, this line intersects the circle at point P, let us name is as P. Now, what we do is, we divide this line PO into 6 equal parts. How do we divide line into 6 equal parts? That is exactly what we discussed in the previous class. So, I can draw an inclined line, 6 arcs and then join the point 6 with O, and then parallel lines, there we go. So, now we have successfully divided this line PO into 6 equal parts. But we said, we are drawing a polygon of sides 7, which means 5 dash and let us say this 0 is also 6 dash, I need another point 7 dash.

How do I get 7 dash which is equal distance like the same distance is repeated, I just need to draw one more arc after 6, so using the same arc length I am made this arc and name it 7 and then draw a parallel line? So, once you draw this parallel this intersects, this extended line PO at 7 prime. So, what we are now done is, we have 7 equal parts of this line 7 O, we have extended it for one extra unit to accommodate the seventh part.

So, now comes the final step, final two or three steps. Now we draw another circle with 7 prime as the center. And what is the radius? The radius is 7 primes to A. So, A 7 prime is the radius and the center is a 7 prime. So, this is the circle which we have drawn in step 6. So, once we have done this circle, the last step is, now taking the radius as AB, we need to make arcs to cut this bigger circle. Or the circle made with the center 7 dash.

So, here are those arcs, starting from B, first you make an arc and that cuts at C then point D, E, F, G. So, if you can notice these are the 7 points on the circle A, B, C, D, E, F, G and if you join them, we get the heptagon. So, I have given you a detail procedure about how to draw heptagon, but let us say if you want to draw an 8-sided polygon what should we do, we need to capture this point 8, let me change the color.

So, if we want 8-sided polygon, we first make an arc and name it A and then draw another parallel line to identify this point 8 prime and then what do we do? We draw a circle with what will be the radius? The radius will be 8 A prime is the radius and what will be the length of those arcs so center will be at… 8 prime will be the center.

So, we will first draw the circle with 8 prime as the center and the radius as A 8 prime and then draw the arcs, again for arcs, the radius will be AB and once we do this, we will get those 8 points lying on the circle and the last step will be to join all those 8 points to get the 8-sided polygon. So, what we have seen in the last few slides is to draw different polygons but our main idea is not just to learn about drawing polygons, the main reason is to see how to project these polygons, that is exactly what we are looking from now on.

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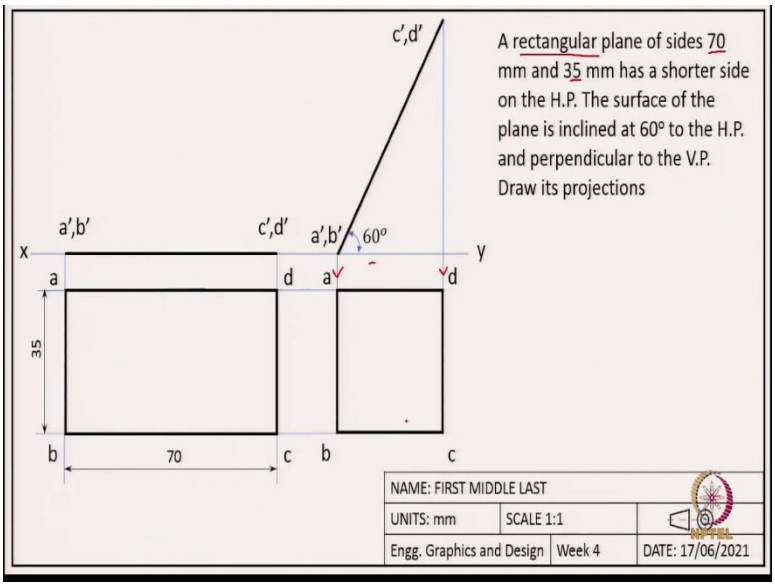

Now, we will be solving a few problems about projections of these polygons. So, here is the question we have, where it talks about rectangular plane with sides of 70 and 35. It says the shorter side is on the horizontal plane. The surface of the plane is inclined at 70 degrees to the horizontal plane. And it is also perpendicular to the vertical plane. First one needs to visualize how this plane looks like.

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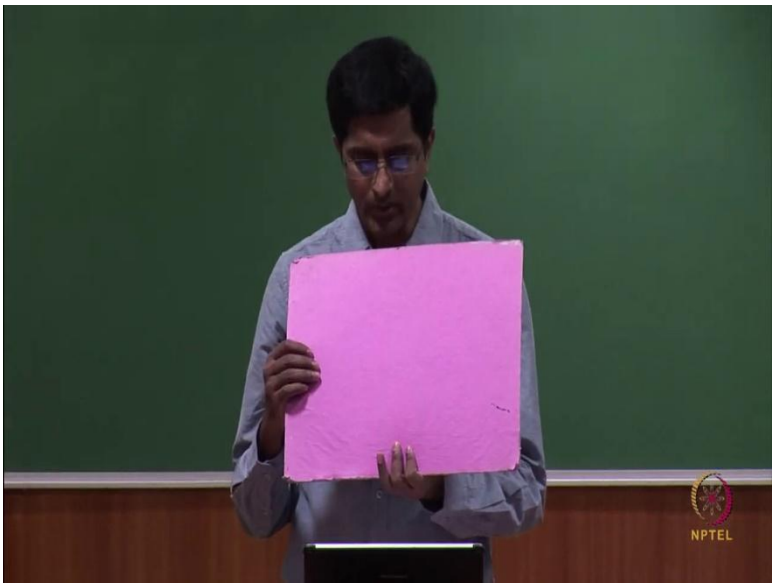

So, let us take the help of this rectangle plane, and then try to visualize. We said that, the longer side is 70 and the shorter side is 30. Now, it says the shorter side is on the horizontal plane, so let us say this is the horizontal plane and this is resting on it. What else do we know? The surface of the plane is inclined at 60 degrees to the horizontal plane so which means this plane makes an angle of 60 degrees.

So, this angle is 60 degrees, it also says, it is perpendicular to the vertical plane. So, this short edge, let us say now this is the vertical plane so this short edge is perpendicular to the vertical plane. So, this meets the description of the question saying that we want a rectangular plane which is at an angle of 60 degrees with the horizontal plane and the short edge perpendicular to the vertical plane.

So, how do we draw the projections? So, let us say if I want to draw the front view and the top view, this is a simple problem because if you are looking at the front view, what do you see? What we see is simply a straight line and what is the length of the line? The length of the line will be the true length of this long side because this long side is parallel to the projection plane. In the front view what is the projection place, it is the vertical plane.

So, since this line or the side is parallel to the projection plane, we see the true view in the front view. So, once we capture the front view, now the question is what is the top view? So, will it look like the same rectangle which we have? No, because since it is inclined, we will see that the size of the rectangle is slightly different. But how do we calculate or how do we find the size of this new rectangle?

For that what we do is, yeah of course one can do the geometry and find it out but the idea of this course is to use geometrical tools to find out any dimensions. So, we are not using trigonometry to find the sides or making use of calculators to find the sides. We want to use the geometrical tools to find the dimensions. So, for this we have a simple way, the simple way is now let us say we assume that it is perfectly oriented which means the front view will be straight line and the top view will be a rectangle and the size of rectangle, we already know it is 35 by 70.

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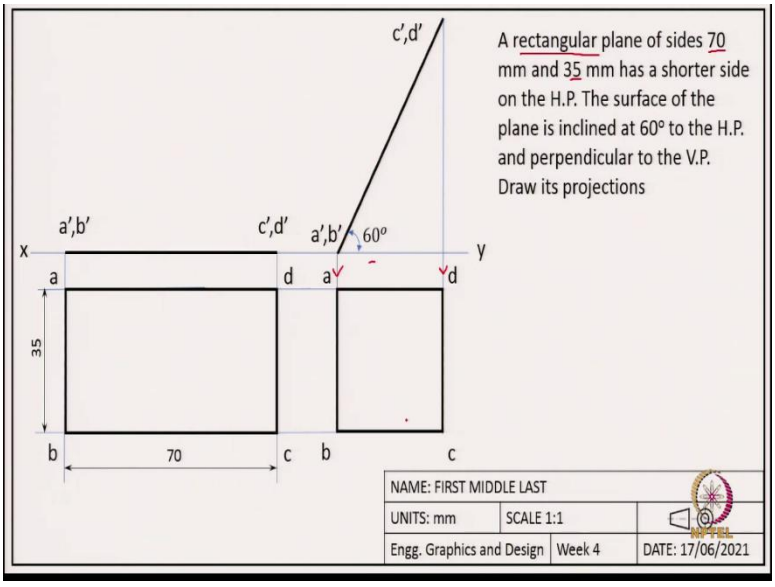

So, let us see how we first draw the views. So, first we start with the reference like x, y and then first capture the top view. Top view we know is a rectangle, so we have captured the rectangle and then we use projection lines to use the width of this rectangle which will help us to draw the top view.

So, since the rectangle is lying on the horizontal plane, you will notice that your front view is also in line with the reference line x, y and the naming of these corners of these plane A, B, C, D we have already discussed before saying that if you are looking in this direction, since your projector line first touches A, and then B, you should be writing in the same sequence, when you draw the front view, A prime, B prime. Similarly, so here I noticed a mistake, it should be D prime, C prime, please make the correction.

So, once we have these two views, we can use these two views to draw the actual question which is inclined plane. So, for inclined plane which one will we draw first? We said, in the inclined plane it is easy to start with the front view because we capture the true length. So, we draw a line which is inclined at 60 degrees and then since we know the length of these edge as 70, we draw this line A dash, B dash to C dash, D dash. And finally, what is left to capture the top view. To capture the top view, what we will do is, we will use information from the previous views as well as the current views.

So, we will use the front view, so first let us draw the projections from the front view and we will also get the projections from the top view from the previous step. So, we have broken this problem into a two step problem. In the first step, the plane is simply oriented, in the second step, it is inclined. So, we use the information from top view of the first step and front view of the second step. So, once we get these two projections, now we can easily draw the

top view. So, because these projections help us especially these projections help us to determine what is the width, when looking from the top view.

So, you might be wondering why we are following this very tedious procedure because this is a simple thing but later when we go to more sided polygons or when we go to more complex objects, you can use the same technique no matter how complex your object is. So, that is the whole point, it is not to say that even for simple thing like a rectangle we should follow this procedure but we are trying to demonstrate a new principle which can be applied for any complex object.

So, the idea being we will break down the procedure into two steps, in the first step you make the object in a very simple orientation where you can draw the front and top view very easily. And then use that information to develop the actual problem where the object is inclined.

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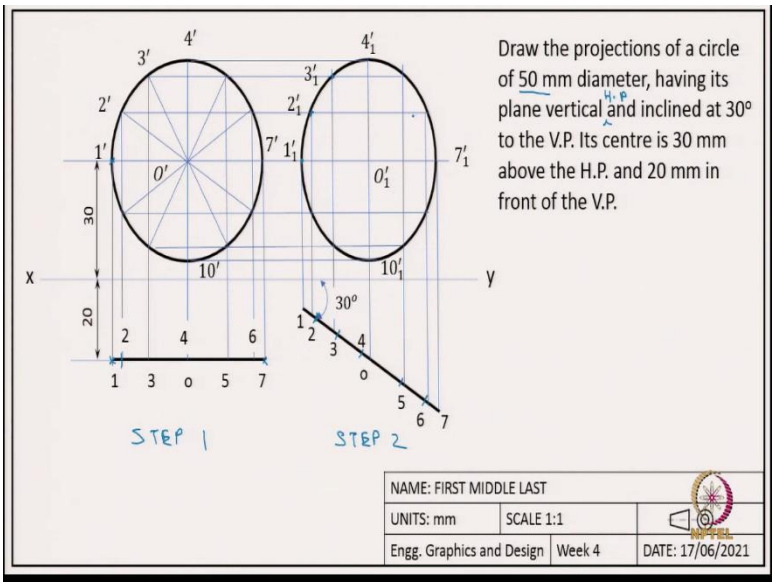

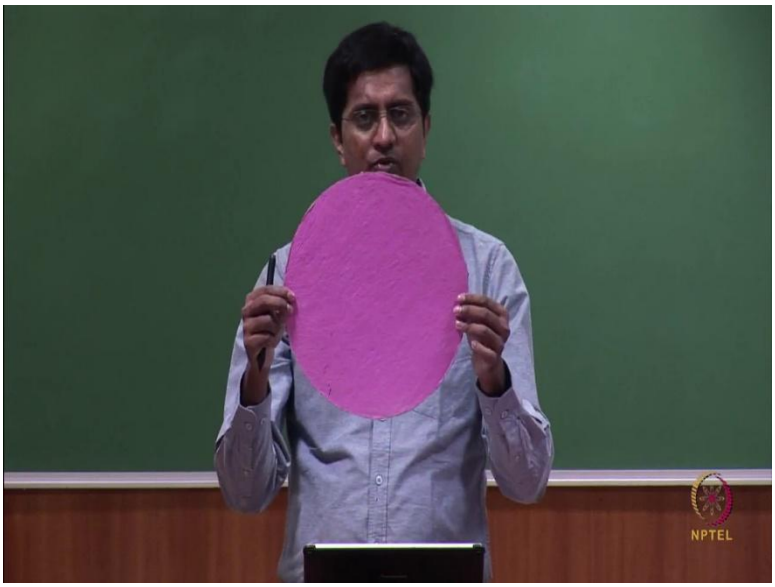

So, to demonstrate, we will again follow another example, this time for a circle. So, we will use the same procedure but you will notice in a circle there is something new to learn. So, first let us read the question and understand what it is, so we are asked to draw the projection of a circle diameter of 50mm, having its plane vertical and inclined at 30 degrees to the vertical plane. Its center is 30mm above the horizontal plane and 20mm in the vertical plane.

So, here is the circle, we will follow the instructions saying that the diameter is 50mm, let us say 50 units because it is much bigger than 50mm. And we also have this plane vertical and inclined, probably what is missing is it is vertical to horizontal plane, and inclined at 30 degrees to the vertical plane. So, let us say this is the vertical plane, probably this is what they meant by inclined it 30 degrees to the vertical plane and this plane is also perpendicular to the horizontal plane.

So, one might say, there is two possibilities for this question because you can either orient it in this way and say, that this is at an angle of 30 degrees with the vertical plane or you may also chose this direction because again this plane makes an angle of 30 degrees with the vertical plane so it does not matter with this question, but of course when the object is known, then you should follow more rigorous way of defining the orientation in position.

So, for the moment let us assume that it is oriented in this fashion, so again what I wanted to demonstrate here is, if you look at the front view, it is a circle but the moment I change the orientation, will you still see it as a circle? Will you see the true shape of a circle? No, the answer is at this angle, if you are looking from the front what you notice is an ellipse so now you need to know how to draw an ellipse on an engineering drawing sheet because you want to make sure that the ellipse looks very smooth.

So, how to draw it is, they are probably there are many methods to draw it, in this class we will be looking at one simple method, where you can draw the ellipse with some free hand sketching but with the help of some projection's lines. So, the front view is the circle and top view is a line, a straight line, the length of the line will be the diameter because you will be looking from this edge to this edge. So, the length of this line will be the diameter of this circle.

So, once done with the first step, we have few more things to do at this step because for us to draw the ellipse we want to divide the circle into 12 equal parts. It need not be 12, it can be 24 or 8 or some other number. But 12 is something like a balance of not too many or not too less. So, let us divide the circle into 12 equal parts, and let us also name it.

So, we are naming starting from here 1, 2, 3, 4. I am not naming each and everything. Otherwise, 7, 10 and so, now we have divided the circle into 12 equal parts, so let us look at the projection of these points on the top view. So, the projection of 1 will be here, projection of 7 will be here, similarly, projection of these lines like 2 will be somewhere there.

And similarly, we name these points on the top view 1, 2, 3, 4, 0 because the center is also following the corresponding to point 4, 5, 6, 7. So, of course here I am ignoring the other points 8, 9, 10, 11, 12, but you can understand because they overlap with the points on the top of the circle.

So, the reason why we are looking at these 12 points is we will trace these 12 points on the circle to the ellipse then it becomes easy for us to draw the ellipse because we just need to connect those 12 points to draw something looking close to an ellipse. So, in step two, what we said is, we need to rotate it, let us say I rotate it in this fashion. So, will the front view or the top view retain the true length? Front view change from circle to ellipse, so let us ignore that, but the top view initially was a diameter, straight line length of diameter and even after rotation., it will be a straight line and the length will remain the same which is the diameter. So, let us first start with the top view.

So, once the top view is done, again I copied these distances from 1 to 2 by arcs so I can measure the arc length from 1 to 2 in my step 1 and copy the same thing in step 2. Similarly, by using those arcs, I will identify these points. So, identify these points 1 to 7 on this inclined line, then I just need to draw the projectors so I will draw the projectors from top view of step 2, so let us say this is step 2 and this is step 1. So, the intersection of these

projectors from both these front view or step 1 and top view of step 2 will give us the 12 points. So, let us say these are the 12 points.

So, finally we just need to connect those points with the help of free hand to get these ellipses. So, what we are shown in this slide is, how to draw an ellipse when we know what is the angle by which we rotate this circle. To put it simply, we are just placing 12 points on this circle and then tracing those 12 points in the up coming projections. So, once we know the 12 points, now we joining these adjacent points with free hand curves.

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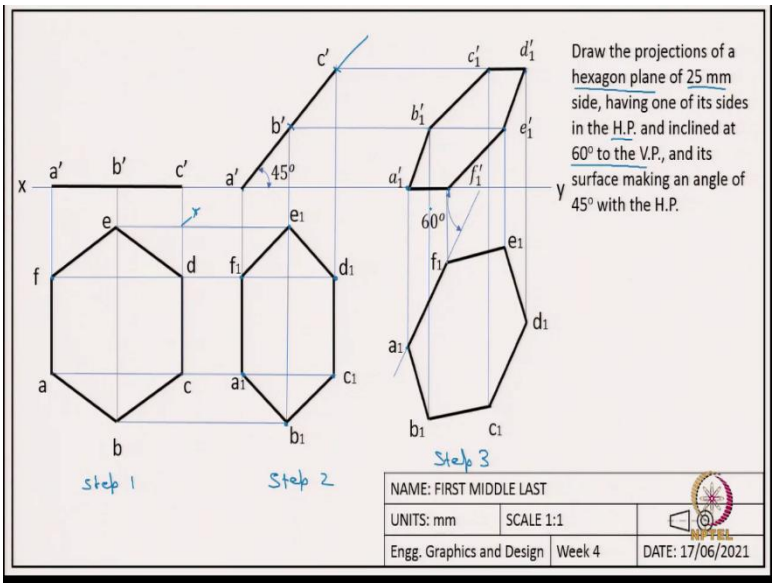

So, finally this is the last example, which we will be looking at this lecture where have a projection of the hexagon plane. So, here we know that the sides are 25mm having one of its

sides in the horizontal plane and inclined at 60 degrees to the vertical plane. And its surface making an angle of 45 degrees with the horizontal plane.

As you can see, this is more complicated inclination because it is inclined to both the horizontal and the vertical plane. So, no matter whether it is inclined to horizontal and vertical we will simplify the process. We will say, we will start with the hexagon, which is properly aligned with the projection planes. So, we will start by saying that, let us say, the top view you have the hexagon, so once you are looking from the top, you can draw the hexagon very easily by the regular methods which we have already discussed to draw the hexagon.

So, once we draw the top view of the hexagon, then it will be easy for me to draw the front view then I know what is the width of this hexagon. So, using this projection lines I can now draw the front view of this hexagon. Now, what I will do is, instead of inclining this hexagon with both the horizontal and vertical plane, I will only make it incline to one single plane. So, let us say, I will first incline it with the, let us assume that this is the hexagon we are talking about, initially it was lying on the horizontal plane, now I will tilt it such that it makes an angle of 45 degree with the horizontal plane.

So, what I have done is, I have just rotated it such that, it makes an angle 45 with the horizontal plane, but still perpendicular with the vertical plane. Since it is perpendicular to the vertical plane, you notice that the front view is easy to capture because before rotation and after rotation, the front view shape looks the same. The only difference is, it is at an angle.

So, we first start with the front view in this case. Once we know it is at 45 degrees so we will draw a straight line at 45 and depending on the lengths of points B and C, we make arcs and identify those points. So, these lengths we are getting from the previous front. So, once we know this, how do we draw the top view of the hexagon? So, again the point is, it is very simple, you just need to trace the points, so for example, this point F, you need to draw a projection line which is a horizontal line and the similar point F which is somewhere here, you need to draw another projection.

So, we use projection lines from both the front view of step 2, let me write this, step 2, step 1… so we will use the top view of step 1 and front view of step 2. Once we have these projection lines, then the intersection of these projection lines will give us the points which we are looking at on the polygons. So, once we connect these 6 points, we get the hexagon in the rotated view.

So, in step 2 we only rotated this hexagon, it is now making an angle with one particular plane. But the question asks for inclination with two different planes, then what we do is, this is step 1, lying on the horizontal planes, step 2 inclined. Now, what we do is, we just rotate it. So, basically what we are doing is, these 45 degrees with horizontal plane remains. The only thing you are doing is, you are now rotating, which means let us say this is the line which connects to the point which is resting on the horizontal line. This line will rotate, such that this line will now make an angle with vertical plane.

So, again let us follow, this line which is now parallel to the vertical plane will be rotated such that it will now make an angle with the vertical plane. So, this angle is given in this problem as 60 degrees. So, then what we need to understand is should we start with the front view or the top view. So, the question to be remembered is where do you capture the true shape? Before and after rotation, the top view shape remains the same, you just need to visualize because it is rotating about the vertical axis so the top view shape remains the same.

So, let us first capture the top view, now we draw this 60-degree line and based on that we copy the shape. So, this is step 3 and in step 3 what we have done is, we have noticed that the shape will remain the same as in step 2 only difference is now it will be at different angle. So, once we have captured this top view, then it will be easy for us to capture the front view because we just need to follow the points. So, point A1 is here, we need to have a vertical projector which connects with the front view A from the previous step. So, here are the projection lines and the intersection defines the points we are looking for.

So, once we join these points, we get the front view after rotation so what we have done is after rotation so what we have done is, first step it is simply lying on a horizontal plane. Second step, it is at an angle to the horizontal plane. Third step, we rotate this such that it makes an angle with the vertical plane. And that angle here is given as 60 degrees.

So, what we are trying to accomplish with these 3 steps is to say that, any polygon we can get front view and the top view just by simplifying the views. How do we simplify the views? We simplify the views by making sure it is either parallel or perpendicular to one of the planes. Because once it is either parallel or perpendicular, it captures the true shape of the object. So, in step 1, top view is a true shape of the hexagon, in step 2, the true shape is captured by the straight line. And in step 3, the true shape is captured by the top view.

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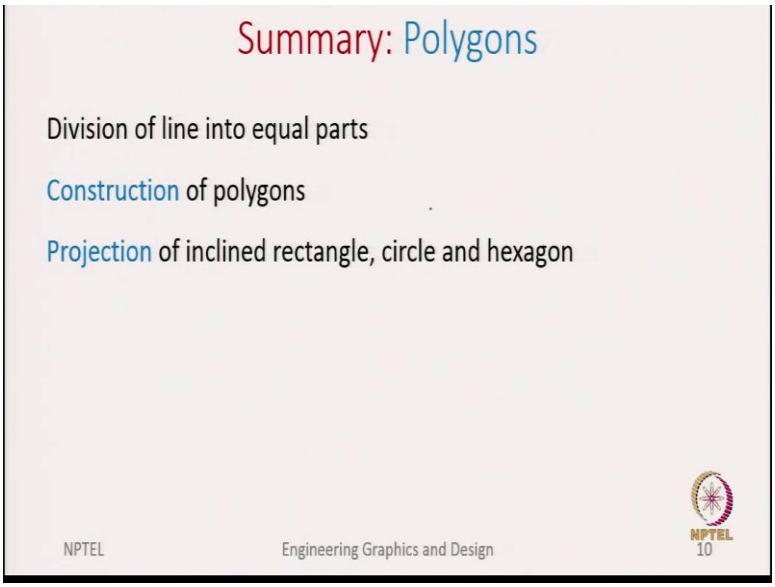

So, in summary what we have been discussing in this lecture is, first we looked at some techniques how to divide a line into N equal parts. We also looked at how to construct polygons, mainly how to draw a N sided polygon. And lastly, we also looked at three examples of projection of simple polygons, we started by projecting a rectangle and then a circle and then a hexagon. So, I presented you three step methods where even if your polygon is inclined with both horizontal and vertical planes, you can simplify the question by first making sure either it is parallel or perpendicular to one of the planes and then gradually increase the complexity or introduce angular orientations.

So, in the next lecture we will be looking at the projection of solids where we will be looking or using the concepts that we learnt in this lecture about drawing polygons. Because once you draw polygons, drawing solids becomes very easy because you just need to draw the top base and the bottom base for example for prisms, and once you draw the top and bottom base, you just need to connect with straight lines to get a solid.

And for example, for a pyramid, you just need to capture the base of the pyramid in different orientation. After you capture the base, the other thing you need to specify is where the apex lies because once the base and apex are defined, the rest of the solid is getting developed by joining these lines. So, you join lines from the apex to the different corners of the polygon to get the solid. Thank you for your attention, we will meet again in the next lecture.