Engineering/Architectural Graphics – Part 1
Orthographic Projection
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Lecture – 26
Orthographic Projections
Introduction to Types of Solids

Good morning, welcome to week 6 of this online ongoing course on architectural graphics or engineering graphics here. I am your course instructor Dr. Avlokita Agrawal from IIT Roorkee, Department of Architecture and Planning. In this course, in the by gone 5 weeks, we have already covered understanding orthographic projections of points, lines and planes and we took different conditions related to these, the location of these points, lines and planes.

And prior to doing in that, we have also looked at the basics, the fundamentals of drawing, what are the different tools to use and we also learnt about the basic geometrical construction. Now, from today, which is the week 6, we will be starting to learn about the orthographic projections of solids. When I say solids, we are largely going to deal with regular solids and we are not going to concern ourselves with irregular solids.

However, if you learn thoroughly about the fundamentals of drawing orthographic projections for regular solids, you will be in a capacity to draw the orthographic projections of irregular solids as well. But before we go on to discuss about the orthographic projections of different types of solids, we must first understand what are the different types of solids that we are talking about.

And for each type of solid, the way in which we draw the orthographic projections might vary slightly. So, the first thing, we are going to do today is to understand about the different types of solids. So, broadly the regular solids are divided into 2 broad categories.

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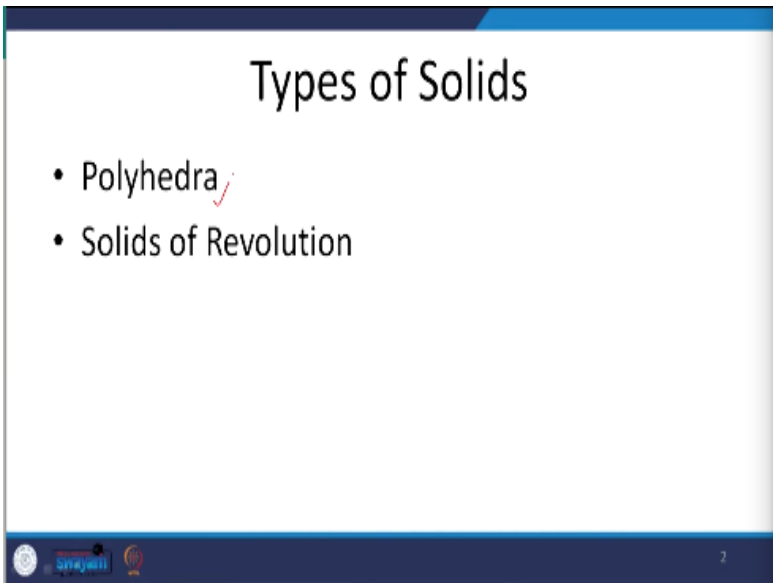

The first one is polyhedra and the other one is solids of revolution. Now, polyhedra is a group of solids or that solids, which have multiple different phases arranged in a certain fashion. So, there will be a rule; there will be a clause based on which the solid will be generated. So, it will just be combination of various faces, different faces put together, which makes these solids called polyhedral.

While the solids which are called which come under this category of solids of revolution, they are the solids which are formed by revolving any one shape about a central axis. So, we will see how what are the different types of solids which come into each of these categories today before we move on to orthographic projection.

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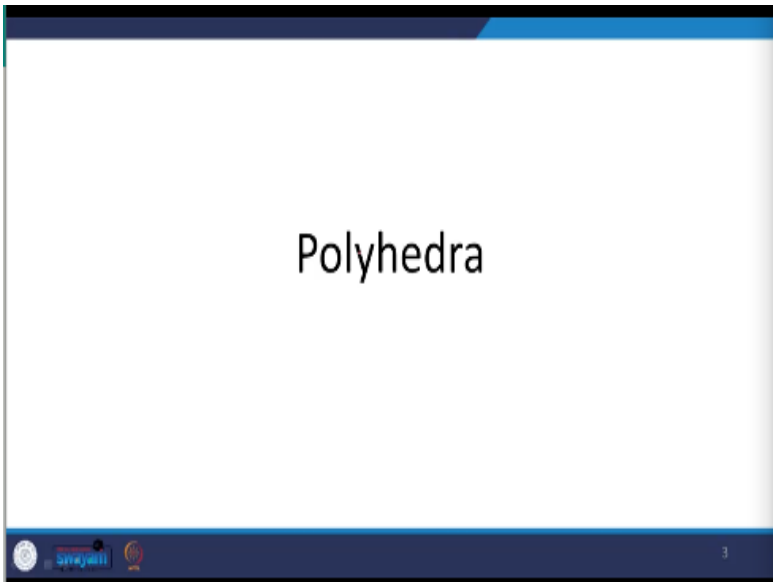

So, let us first learn about the first group of solids which is polyhedra and a large number of solids actually come under this group, this category called polyhedra. A lot of these solids you must be familiar with. Now, the first group of solids is this prism.

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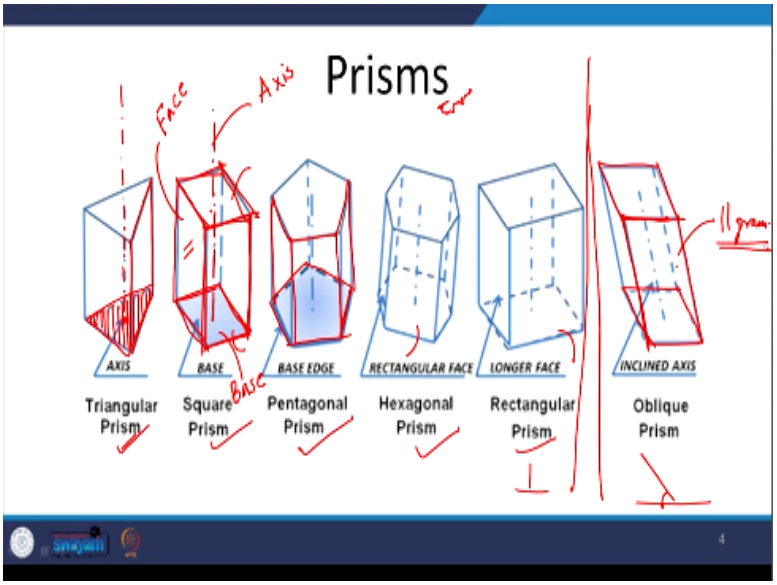

So, what is a prism? Prism is any solid which has a base and that base is extruded along an axis or vertical axis most likely it is a vertical axis and it is situated or it is originating from the centre of the base. So, if you look at the screen, we have different types of these prisms here. First one is this triangular prism. Now, what is a triangular prism? It has the base as a triangle. So, we have a triangular base here.

Now, on top of it from the centre of this base, which is the triangle, we have an axis if you remember we have this central actual line. So, this is the perpendicular, right now, in this case, it is perpendicular. So, this perpendicular is passing through the centre of the base and along this, each of this side is extruded to form a rectangular face. So, what we have? What are the different parts of a prism? We have a base.

So, we will basically have 2 bases. If you look at that and it could be any shape, it has an axis, which is in most likely cases perpendicular and then along the side of the base each side of the base, we have an extruded rectangle and the 2 bases are connected with the help of these faces. So, what we have here is we have face. We have a base. We have an axis. This is what we have for prism. So, what do we see here?

We have a triangular prism. Now, what does a triangular prism mean? It has a triangular base and it has 3 rectangular faces, because it is a triangular base and an axis. Square prism, which has a square as a base and then each of its faces is again rectangular and goes and meets another square in the top. A pentagon a prism will have a pentagon a base and then the faces which are rectangular only.

So, we again have rectangular faces. Hexagonal prism, the base changes to hexagon. Rectangular prism, the base changes to rectangle. All these are regular prisms with perpendicular axis. So, we have to within prisms, we will have 2 categories. So, one where the axis is perpendicular to the base and the other one, where the axis is making a certain angle with the base.

So, it is not perpendicular, however, each of it, so, the top and bottom will remain the square or whatever the base shape is and each of the face instead of becoming a rectangle, it will become a parallelogram. So, what we will have? The faces will not remain rectangular anymore, they will turn to parallelogram. So, that is what we are going to get here. This is the broad category of prism.

I must show you some of the prisms, some of the very simple prisms which so that you can relate what a prism would be. If you look at this solid, **(Video Starts: 07:30)** this is actually a prism. Now, what is the base? The base shape is actually octagon. So, we have this prism which is an octagonal prism and what do we get here, this is a vertical prism where the axis is perpendicular to the base.

Now, we have 2 bases, which are octagon and each of the face of this prism is a rectangle. So, whenever we will draw we have to know very clearly that in a perpendicular prism in a right angled prism not perpendicular, but a right angled prism, we will always get the faces as rectangles. So, depending upon the angle from which you will be looking at this prism, either you will be seeing an octagon or you will be seeing a rectangle.

And then there will be deformations of it depending upon how this prism is going to be placed with reference to the reference planes. So, this is what we know of as prism. It could be any type of prism depending upon the base shape. So, as I have shown from triangular to square **(Video Ends: 07:30)**, pentagon hexagon, now I have shown you an octagon. It could be any type of prism and it will remain to be called as a prism only.

So, these are the different types of prisms. But one thing here what would a cube be called? Is a cube of prism or cuboid, is it a prism? Yes, they are prisms, they are polyhedra. So, if we look at the cube here, **(Video Starts: 09:10)** what happens? That we have a square base, we have a top base, there is an axis which is perpendicular and each of this face is rectangle. But here in this case, the height of this prism is equal to the side of the base.

And in that case, when all the sides become equal, this rectangular prism becomes or square prism becomes a cube. If the height is more, than we get a cuboid. So, cuboid is also a type of rectangular prism. It is a rectangular prism. So, cube is a prism as well **(Video Ends: 09:53)**. The next set of solids that we have which is also commonly used is the pyramids.

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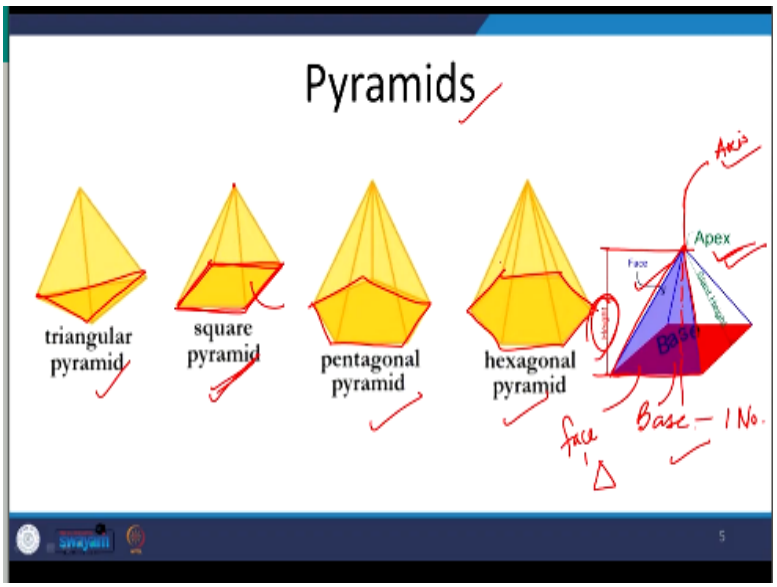

Now, if you remember or if you have heard of the pyramids of Egypt, then you know, you have a certain idea that okay what a pyramid is, but pyramid is not just a square based pyramid. So, what you see in Egypt or what you must have seen in pictures of Egyptian

pyramids is that they are all square pyramids. So, they have a square base and then they have a top point single point which is called the apex.

So, instead of the faces remaining rectangular, if the faces become triangular and they go and meet in one single point called apex. The shape which emerges is called a pyramid. Now, pyramids are also of various types. Again here the base, we have the base here exactly similar to that of a prism, we have an axis. So, we will have an axis here which we had in prism as well.

And the height of this is the height, we also had the height in prism. Prism and pyramid both have height, the only difference being that we only have one base here, while in prism, we had 2 bases and in this case, the top is one single point where all the lines converge. Now, what happens because of this? That each of the face is triangular. We will always get triangular faces for pyramids and also for regular solids for regular pyramids, we will get isosceles triangle.

In some cases, it may become depending upon what the height is. In some cases, we may get equilateral triangles also, but essentially, we will definitely get isosceles triangles in the pyramids. So, what do we get? We get one base, one axis one apex and some number of triangular faces that is what the pyramid will be formed of. So, if I say prism, it means that it is a rectangular cylinder like solid and if I say pyramid, it means I am talking about a cone like solid.

So, you must always have this difference in your mind when a question is given to you whenever, so, it will be a word problem, which you will have to draw. So, do not ever confuse between this prisms and pyramids. So, again, different types of pyramids are there, depending upon the shape of the base. So, we could have triangular pyramid where we have a triangular base. A square pyramid where we have a square base.

Pentagon pyramid have pentagonal base, hexagon pyramid are hexagon and base and so on. It could be again multiple types of pyramids. Let me show you some of these pyramids. So, that it becomes clearer to you how or what these pyramids are. So, what we have here **(Video**

Starts: 13:29), this one is an octogonal pyramid. So, what we have in the base is an octagon. So, if you look at this, it is an octagon.

And if you look at this, this is a right angled pyramid. So, the angle between the axis and the base is 90 degrees. It is perpendicular. And if you look at each of this face, each of the face is triangle. So, again, depending upon where you are going to be seeing this from this cone, this pyramid, we will be seeing either triangles or if you look at it from the top, we will actually be seeing an octagon shape with multiple triangles in it which is these edges.

So, these are the edges and these are the triangular surfaces. I have another pyramid for you. This one is a pentagonal pyramid here. So, what we have in base is a pentagon. And what we have here its axis is perpendicular to the face and we have these triangular faces here, which meet up in the apex. So, this is a pentagonal pyramid. Let us see which one is this well. This is again pentagonal pyramid.

So, we have a pentagon in the base and then we have these triangular faces and an apex at the top. So, any pyramid for that matter, we will get essentially triangular isosceles triangles or in some cases could be equilateral triangles depending upon the height of the cone. So, this is what our pyramid is **(Video Ends: 15:11)**.

The next set of solids is platonic solids. Now, what is a platonic solid? I am sure you must have at least read the definition of platonic solids in your schools.

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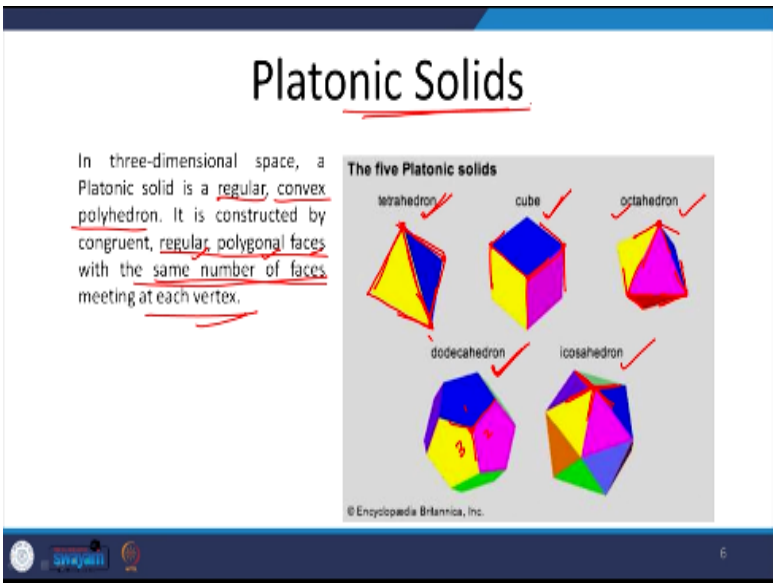

So, a platonic solid, it is a regular convex polyhedron and it is constructed by congruent regular polygonal faces. So, it is not essential that it has rectangular faces or triangular faces, it is regular polygonal faces with the same number of faces meeting at each vertex. So, at each vertex, there will be some given number of these polygonal faces and that we will be creating, that will be generating the solid, the polyhedron solid.

Now, 5 solids qualify to be called as platonic solids. The first one we have a tetrahedron. What is a tetrahedron? It has 4 equilateral triangular faces. So, it has 4 faces, each of it being an equilateral triangle. So, what happens? That it each point as you read it, it has same number of faces meeting at each vertex. So, at this vertex, what we have? We will have 3 triangular faces. At this vertex also, we will have 3 triangular faces and likewise. This is tetrahedron.

What is the cube? Cube has 3 square faces meeting at each vertex. If you look at each vertex, we will have 3 square faces meeting, this is another platonic solid. What is an octahedron? Octahedron is formed by equilateral triangles, but there are a total of 8 equilateral triangles. And at each vertex, we have 4 equilateral triangles meeting at each vertex. So, if you look at this, we have 1, 2, 3 and 1 at the back here, if you say 1, 2, 3 and 1 towards the bottom. Similarly here 1, 2, 3 and 4 at the back. So, at each vertex, we have 4 equilateral triangles meeting in an octahedron.

We have another one, which is called dodecahedron. In dodecahedron, we have pentagon's meeting together. So, at each vertex, we have 3 pentagons coming together. So, it is always a convex solid. And then we have same number of faces meeting at each of the vertex. So, in a dodecahedron, we have regular pentagons and each vertex has 3 pentagons coming together, which is what is called a dodecahedron.

And the last one is an icosahedron. So, for icosahedron, we have 5 equilateral triangular surfaces meeting at each vertex and there are a total of 20 faces. So, only 5 solids actually qualify for being called as platonic solids. And the condition remains that at each vertex, it is the same number of faces meeting together and these are regular faces, regular planes.

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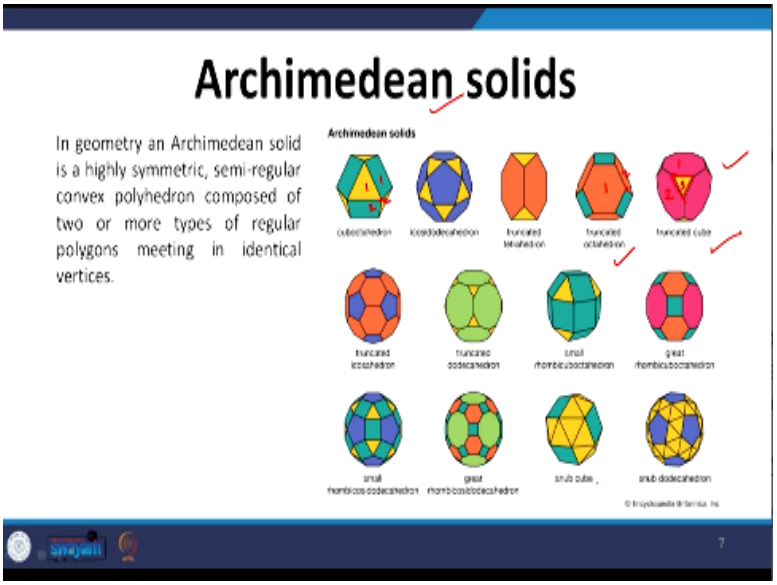

The next one within polyhedra is Archimedean solids and as the name suggests, these solids were defined or identified by Archimedes. So, there are 13 of such solids which are called as Archimedean solids and Archimedean solid is slightly different from platonic solid, what happens in Archimedean solids is that it is formed by combination of 2 or more regular solids.

And the condition remains that at each point, the number of faces joining again remains the same for all different types of faces, all different types of regular polygons that are coming together. So, for example, in this case, if you look what we will have, we will have 2

triangular, equilateral triangular faces and we will have 2 square faces coming together that will remain to be uniform throughout. And a solid formed by this is a cuboctahedron.

Archimedean solids are arrived by, there are several ways, but largely by truncating regular solids. Some of these are derived by truncating a cube. For example, this one this is a truncated cube. Now, if the corners of the cube are cut, so, in this case what we have at each vertex, we will have an octagon. So, we will have 2 octagons coming together and we will have an equilateral triangle. This is what we derived out of a truncated cube.

A truncated octahedron will have one hexagonal face sorry 2 hexagonal faces and one square face coming together. These are 13. So, if you go and look at it in detail, we will have 13 different types of Archimedean solids. We are not going to cover this part in our projections of solids, but, it is very interesting to read and as you are going to become engineers, you might be using some of these very interesting shapes in designing.

So, go ahead and read about each of these shapes of these Archimedean solids. So, these were the different types of polyhedra, different types of solids, which are formed by putting together different types of faces in a very organised manner in a fixed with a rule manner.

The next types of solids are called the solids of revolution.

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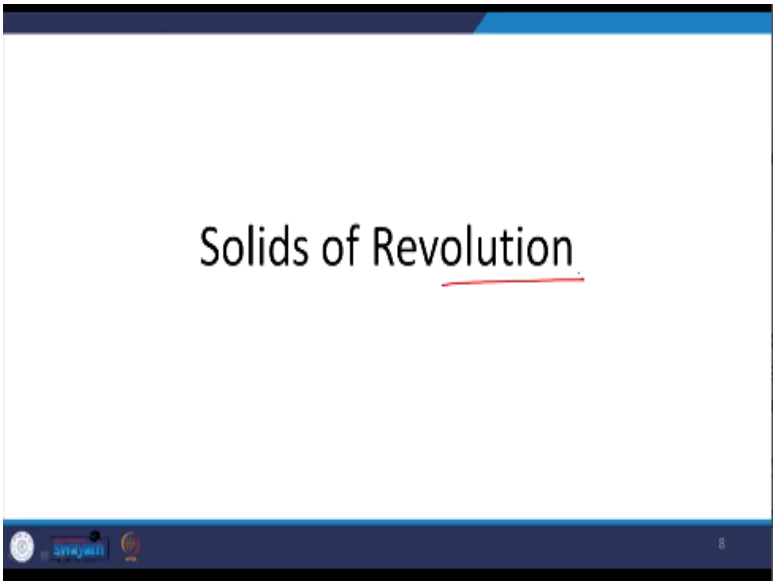

As the name suggests, these solids are derived by revolving a particular shape any given shape along an axis and hence the solid is produced. So, the first one that we know of which is the simplest is a cylinder.

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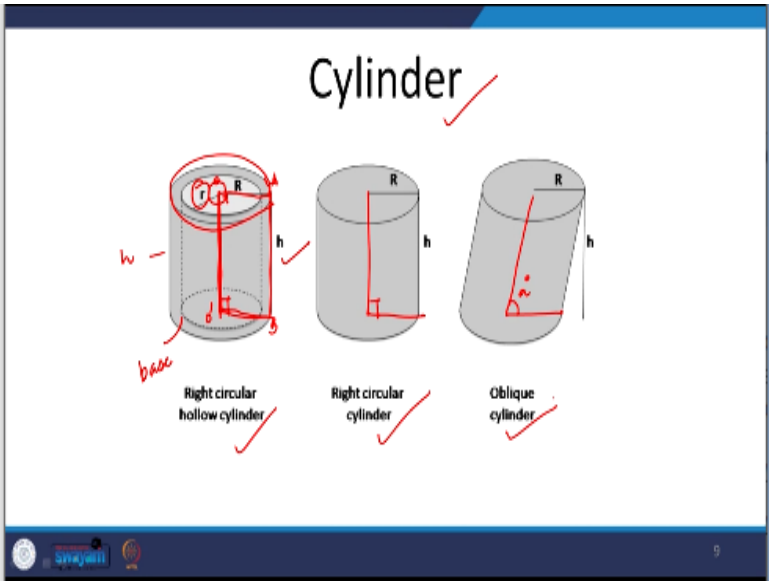

What is a cylinder? A cylinder is a solid of revolution which is formed by rotating a rectangle. So, if you rotate this rectangle, which is say O, A, B, O dash by 360 degrees like this, so, we fix this side which is O O dash and we rotate this, we revolve this around by a complete 360 degree. We will get a cylinder. So, in a cylinder, what do we have? We have a base; we have height, which is edge; we will have a radius.

This is what will define a cylinder which is formed by revolving a rectangle about one of its side which is also called the axis. So, we could have different types of cylinders. We could have hollow cylinders; we could have right circular cylinders. Now, in both the cases the axis is again perpendicular to the base and in case, the axis is making certain angle with the base, it is called an oblique cylinder as it is slightly inclined.

So, this is the simple shape of cylinder and I do not really **(Video Starts: 23:37)** have to show it to you but that cylinder is this which has 2 circular faces and there is one face which is connecting these 2 circular faces. So, there is no rectangular face; there is no **(Video Ends: 23:54)** triangular face, which forms the cylinder. The next solid of revolution is cone, which is again very simple.

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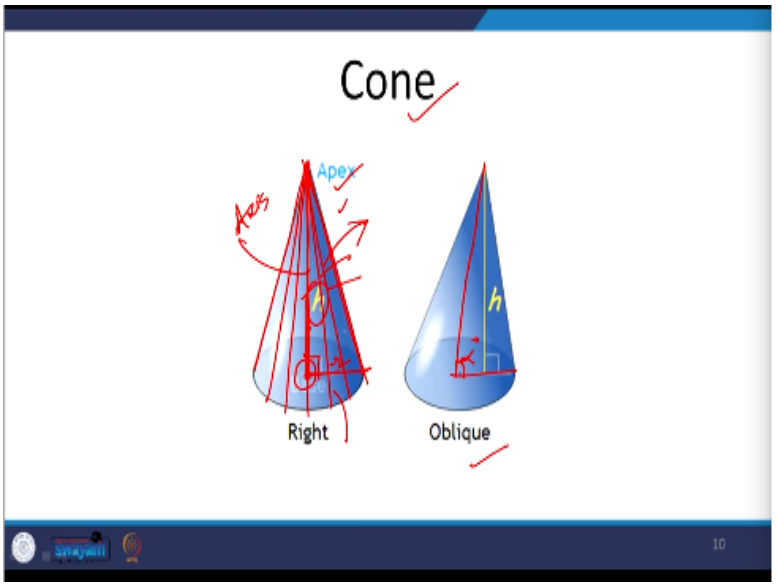

How do we arrive at cone? The core is formed by rotating a right angled triangle about its perpendicular side. So, if we by 360 degrees, so if we rotate if we revolve this triangle, the right angle triangle about its perpendicular side, then we will get a cone. In the cone again, cone is a type of pyramid. So, what we have? Base is a circle. The apex, we have. We have an axis of height 'h' and there will be a radius to the base which is the definition of its size, the base radius.

In case, the axis is not perpendicular; in case, the axis makes an angle with the base, it is called an oblique cone. Again, we have been using and seeing cones, you must be familiar with the various formula of deriving the area, surface area, the volume of the cones, but, remember that cone is again a solid of revolution and we do not have any rectangular or triangular face to it, we just have a base face which is which is circle in this case.

And the rest is a continuous shape and the shape of this surface which is the face of the cone and it is formed or it is defined by these generators which connect the apex to any point on the centre. The shape of this in case, we want to open it up; in case, we want to construct the cone depends upon the height and the radius, height of the cone and the radius of the base. So, you must have already **(Video Starts: 26:08)** seen and you must be familiar with what cone is.

And we have already read about the conic sections as part of the geometric construction, the basic geometric construction, but this is what a cone is simple apex base at a continuous surface **(Video Ends: 26:24)** around it. The last one of these solids of revolution is a sphere.

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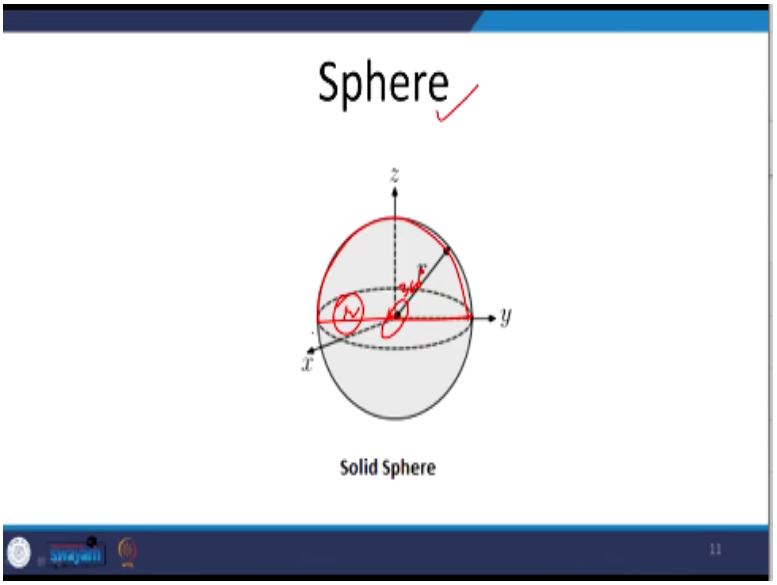

And what is a sphere? A sphere is a solid which is generated by rotating revolving a semi circle. So, if you look at this, if you rotate this semi circle by 360 degree, so, if we rotate by 360 degrees, we will get a sphere. It is as simple as that. And the only thing that we have to remember the only dimension that we have to remember is that of a radius in a sphere.

So, it is a continuous surface and it is arrived by revolving a semi circle about its diameter. **(Video Starts: 27:14)** So, you have already seen spheres. You are familiar with what spheres are. And what we have here is we are rotating this semi circle by 360 degrees solid. And then what we get as a result in solid is this sphere **(Video End: 27:33)**. So, these were the different solids of revolution, the basic solids of revolution. Now, there is another category which is derived from these basic solids, which is frustum.

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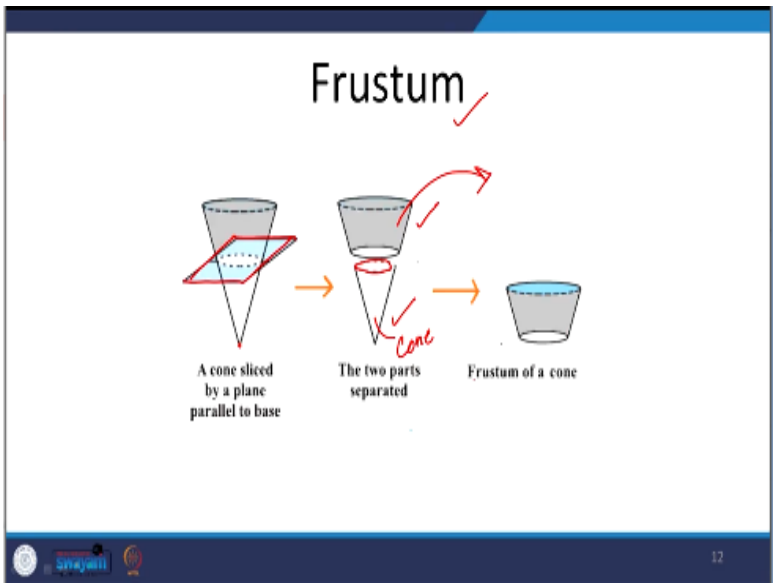

Now, the frustum could also be of the solid of revolution or of a polyhedra. But what a frustum is? When we have a cone or a pyramid, sliced by a plane, so this is the section plane. So, when it cuts, what happens? We get 2 parts of this code, the original cone, the top part still remains to be a cone, but of a different height of different dimension. The bottom part where the base originally was, which does not have an apex now is called the frustum of a cone.

So, as I said, we could be having frustum of a cone or we could also be having a frustum of a pyramid.

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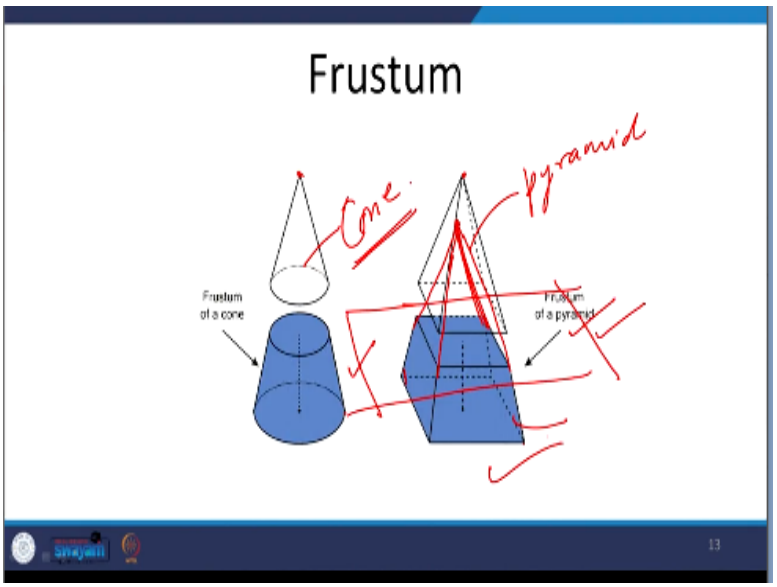

So, suppose this was a cone, then we get frustum of a cone. And in this case, this was a square pyramid. So, if the pyramid was cut through a plane or section plane here, the bottom part which is left here is the frustum of pyramid and the top part still remains to be known as the pyramid and you are in this cone in this figure, this is the cone because the original shape is intact and they still have the apex.

Here in a frustum, if we continue to produce these lines, they will still be going and meeting in an apex that is the essence of it. So, we may still have, we may still get if we continue to produce these lines upwards, they will go and meet in an apex and that is what will result in a cone or a pyramid that is what the frustum is. So, it is a regular solid, but it is just derived by cutting a regular cone or a pyramid.

So, these are the various kinds of solids that we might be needing in our engineering or architecture practice. And we have to learn to draw the projections orthographic projections of each type of solid. So, that is all in the lecture today. Thank you very much for joining me. And in the next lecture onwards of this week, we will be drawing the orthographic projections of some of these regular solids. So, thank you again. See you tomorrow. Bye, bye.