Engineering Graphics and Design
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Lecture No. 04
Introduction to Visualization and drawing

Welcome to the course engineering graphics and design. This is the fourth lecture of the first week, and we will go into some aspects of visualization and the making of drawings.

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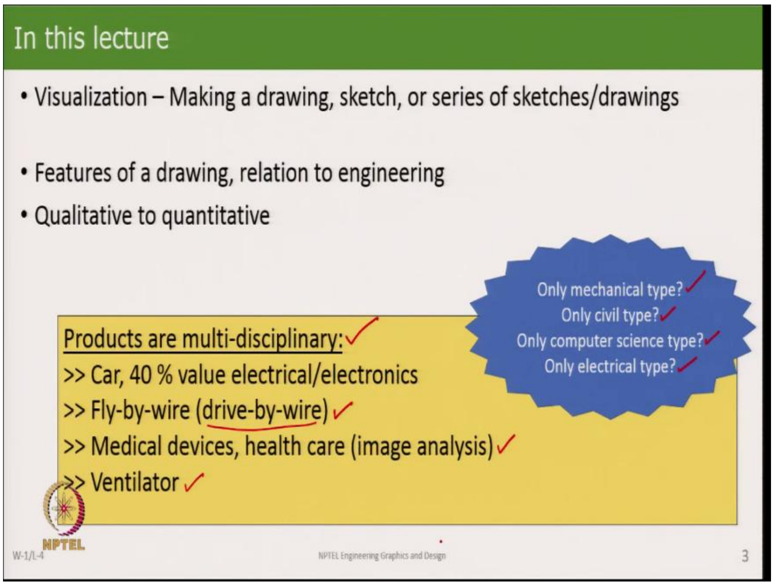

In this lecture

- Visualization – Making a drawing, sketch, or series of sketches/drawings
- Features of a drawing, relation to engineering
- Qualitative to quantitative

Only mechanical type?✓
Only civil type?✓
Only computer science type?✓
Only electrical type?✓

Products are multi-disciplinary:✓
>> Car, 40 % value electrical/electronics
>> Fly-by-wire (drive-by-wire) ✓
>> Medical devices, health care (image analysis) ✓
>> Ventilator ✓

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So, what we will learn is, how do we see things, how do we represent things, how do we make a drawing or a sketch or a series of sketches and drawings to show motion or different views of the object. We will also go into some detail into features of a drawing and see, how this is related to certain aspects of engineering.

In making drawings, we will start with the qualitative way of representing shapes, and then see, how in engineering we use a qualitative shape and we put quantitative information on it by way of dimensions, angles other features like that. We will look at objects, as a one component at a time, which may be related to any one field of engineering, but today's world of engineering products are hugely multidisciplinary.

A modern car has 40 percent of the value as electrical and electronics items, and currently, we are in a situation where the shortage of chips is hampering the manufacturing of cars. The second example of multi disciplinaries is say fly by wire, which is the technology now for almost all aeroplanes. Same thing for cars, driverless cars, buses is say drive by wire, which means that the operator gives a certain input that is converted into an electrical signal and then the electronics does everything gives an output signal which then adjusts various parts of the machine.

Same is the case with say a ventilator. The controlling is done through buttons on a screen and that triggers various actions of valves speeds flows and that adjusts the way the ventilator is used on a patient. Many medical devices, healthcare devices are like that. A good example of that, you can look up robotic surgery, eye surgery and see the complex type of machines which are there where there is a lot of engineering of all types that goes in into making of those machines.

To get there, we will learn the simplest thing, one at a time, and try to make simple things which can be put together at the end of this course. Some of the components we will look at they may be purely mechanical type. Some applications we will see civil type only. We may see certain aspects, which have related to computer science or to electrical engineering or electronics.

By idea of integrating them together we will just briefly touch in this course, but that is an advanced topic for later course. So, let us begin with some aspect of a drawing, which is what is called the scale or the scaling.

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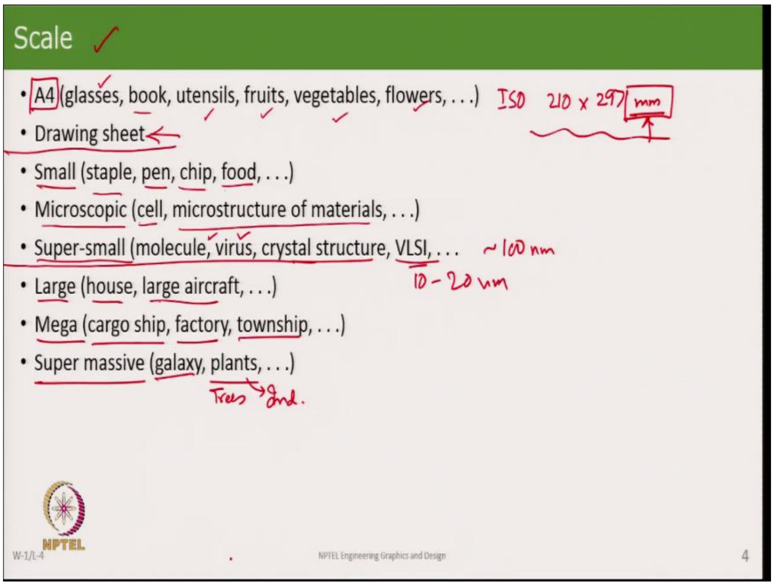

Scale ✓

- A4 (glasses, book, utensils, fruits, vegetables, flowers, . . .) ISO 210 x 297 mm
- Drawing sheet ←
- Small (staple, pen, chip, food, . . .)
- Microscopic (cell, microstructure of materials, . . .)
- Super-small (molecule, virus, crystal structure, VLSI, . . . ~100 nm
- Large (house, large aircraft, . . .) 10 - 20 nm
- Mega (cargo ship, factory, township, . . .)
- Super massive (galaxy, plants, . . .)

Trees → Ind.

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So, what do we mean by a scale that we see objects and we see in relation to somebody’s some other size. In making drawing sketches and in engineering our standard is a drawing sheet which as a standard sheet that we look at is an A4 sheet. A4 sheet is an Indian international standard, which tells you that the size of the sheet is 210 millimeters by 297 millimeters. And this is also an important thing to note that in engineering we use millimeters to denote all dimensions, and almost never used centimeters, very few times we use meters and in very large drawings we may use kilometers.

But, in this course, almost all the dimensions we will look at will be in millimeters. And then we can say no, what are the things that are there, which are about the size of an A4 sheet. And here I have listed some items, the glasses that we wear, maybe a typical book, utensils in a kitchen, fruits, vegetables, flowers, not a very big bunch of flowers, but individual flowers or small groups of flowers.

So, we can think of these as approximately beings of that size. Then, we are looking at what is drawing sheets, and we say that I can have a drawing sheet with A4 or maybe bigger drawing sheet very rarely, we will have smaller drawing sheets that is the medium on which we will finally make a drawing, and that drawing sheet could be a physical drawing sheet or everything on that could be into a computer package. So, now below this, I have listed scales of objects, which we will visualize.

We start with from A4, we go smaller size. We have small things like a staple, the nib of a pen, electronic chip, certain food items like say crushed turmeric, so these are objects which are much smaller than the size of a paper that we look at. So, making it on the same scale on a sheet, we look very small, and many of the features that are there, the small features those may not come out very well over there. And for that, we would need to look at it even more closely.

So, that takes us to things which I have listed here, as they are microscopic or you may use a magnifying lens. And now we get into things of the order of less than a millimeter or hundreds of micrometers, cell, microstructure of materials, structure of soil, things like that. And then we could look at even smaller things, I call this super small.

We can put some other word for it if you want, where we try to look at the picture of visualize the structure of a molecule. Such as say even a carbon nanotube or picture of a virus as we have been seeing with COVID-19, the structure of a crystal. And even visualize VLSI the way etching is done on silicon wafers to make chips. So, here we have now gone well below a micron and maybe in VLSI these days you are looking at like 10 micron, 10 to 20 nanometer type of connections that are coming up. Viruses of the order of 100 nanometers.

So, like this, we are very small things which we would like to show in a picture. Then we go to the other side, where there are bigger things that we want to show on the smaller sheet. Starting with something could be large, say a large machine, a house or an aircraft have we have seen say a late machine that could be one more thing or say a domestic refrigerator, so these are big items. We want to show them finally on a sheet, so we shrink them in size.

Then there can be even bigger things like a cargo ship, which was a ship that got stuck in the Suez Canal 400 meters long. A factory, which could be like a kilometer long, half a kilometer or townships, which are even bigger. So, what you are seeing is a lot of applications from very different fields where we are looking at very different landscapes. The townships, factories a dam, highway this was all looking at length scales of the order of not just kilometers, but maybe tens of kilometers or hundreds of kilometers. In geology, it could be even bigger than that.

And then we look at supermassive sizes. Things like the size of the solar system, galaxy, some plants, which grow very big, trees rather or plants as in industrial processing plants a refinery for instance to be much, much bigger. So, what do you want to do when we are talking about visualization or engineering graphics or drawing, if we want to express ourselves in any of these contexts, so what do we do? We start scaling, and that is an important thing.

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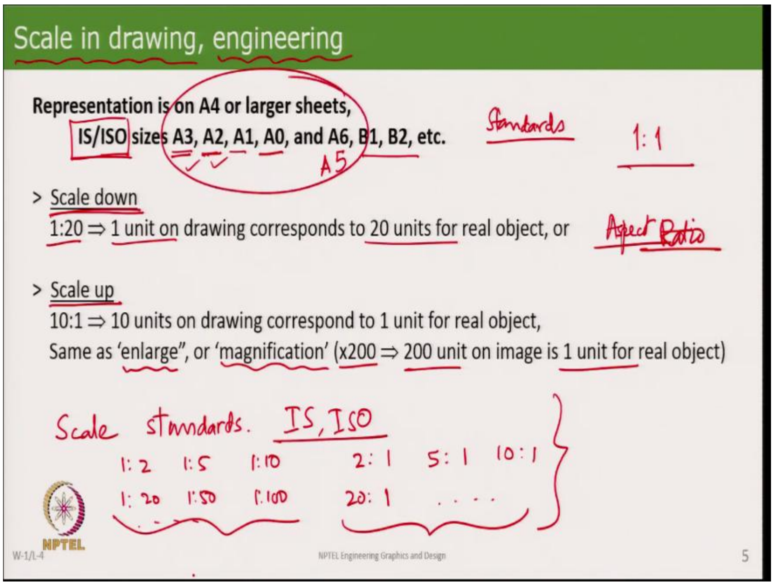

Scale in drawing, engineering

Representation is on A4 or larger sheets,
IS/ISO sizes A3, A2, A1, A0, and A6, B1, B2, etc.

> Scale down
1:20 ⇒ 1 unit on drawing corresponds to 20 units for real object, or

> Scale up
10:1 ⇒ 10 units on drawing correspond to 1 unit for real object,
Same as 'enlarge", or 'magnification' (x200 ⇒ 200 unit on image is 1 unit for real object)

And we will look at scaling in particular reference to making engineering drawings. So, we could say that, I want to show the drawing on an A4 sheet. We have already seen what the size is or we have an option. We could go for bigger sheets that are twice the size of A4 is

A3, twice of that is A2, twice of that is A1, twice of that is A0 and then we could even have bigger sheets beyond that.

So, depending on the, what you want to show, the clarity that we want it is our decision to decide what sort of drawing sheet one should take to show the features that we are looking at. And then there are smaller sheets, also. I put A6, it is actually A5, which are smaller sheets half the size of A4, and then there are other sheets like B1, B2 sizes and so on. What all these sizes come from? Where they come from, is a set of national and international standards.

And that is the importance throughout this course. We will see that while we are learning certain things, we are also learning the conventions by which engineering graphics is represented. If you want to show it on a drawing sheet, these are the only size sheets that we can work with. That is because of IS (Indian standards), ISO(the International Standards Organization). So, that is one point.

Then, one to one scale would be that we are drawing something exactly the way the object is, not the way we see the object, not the way we take a photograph of the object with the camera, but the way the object itself is. And we will see later on in this course how we actually never see the object as it is, we always see a distorted or a modified shape of that object. So, we can do two things. If the object does not fit one to one scale on any of these sheets, we could then do two things, depending on the size of the object. If it is too big, we could scale down.

For instance, we can draw in a way, so that one unit on the drawing corresponds to 20 units for the real object. That would mean a scale of 1 is to 20. So, we have made the object smaller, but not the shape. Every dimension, every aspect of the object has been proportionally scaled down. This is exactly what you would do in say a computer drawing where you make a shape. And then if you lock the aspect ratio, that is a feature that you have in all these drawing packages.

If you lock the aspect ratio, and then make the drawing big or small all the dimensions of the drawing increase and decrease in the same ratio. If the aspect ratio is not locked, some length may be get bigger, but the width may not get bigger. So, that is how many of these packages treat this. So, when the object is too big, which we cannot fit into, on a one-to-one scale, we then make different scales, scale it down and decide what sheet size is best for us. We could scale it down so much that we can put it on an A4 sheet, but then it would have become so small that you would not be able to see things in it.

So, we may have to go in for A3 or A2. And if it is okay, it looks good enough on A2, we are able to show everything very clearly than drawing it on A0 and further blowing it up and making it big, does not really make sense. So, that is a decision we have to take as a designer, so what is the best way to show the drawing, simply because ultimately, a drawing has to be always understood by somebody else, that is scaled down.

We now look at scaling up of a drawing. In common usage, this could be like enlarging the view or magnification. On most civil engineering drawings or geographical drawings or contour maps, you are always scaling down, you are always making it look small, but here, we are blowing it up. So, X200 means that 200 units on the image is one unit on the real object. So, what you have done is magnified it. The actual length maybe, say 20 micrometers, but we have drawn it as 20 millimeters that scale up.

We will come back to this a little later on, but one more thing about scaling is that scale, what scaling to use is also decided by certain standards. These are certain IS, ISO standards. And in engineering, we use only those standards, we do not use any other scaling. And typical ones, 1:2, 1:5, 1:10 and then in multiples of this 1:20, 1:50, 1:100, and similarly, going down, 2 : 1, 5 :1, 10 : 1 and then 20 :1 and then so on.

This is purely a convention of engineering, which has been formalized by these standards. And so, if you want to scale up or scale down, you would have to do two things, pick up the scale and for that you do not have an infinite option now, you have to pick up one of these. And you have to pick up one of these with the objective that I am able to show the drawing as best I can and not too much or too less. It does not look cluttered, it does not look too spread out, it is just the right size for people to appreciate. So, that is about scaling.

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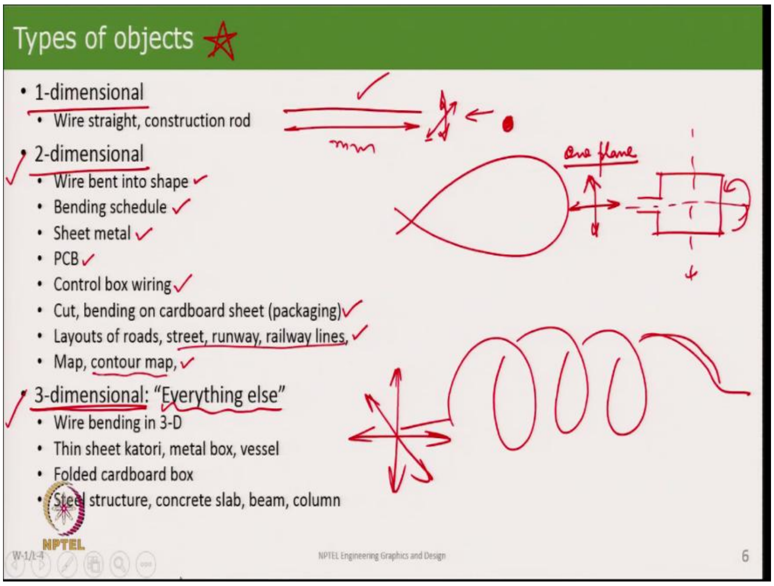

Types of objects

- 1-dimensional
  - Wire straight, construction rod
- 2-dimensional
  - Wire bent into shape ✓
  - Bending schedule ✓
  - Sheet metal ✓
  - PCB ✓
  - Control box wiring ✓
  - Cut, bending on cardboard sheet (packaging) ✓
  - Layouts of roads, street, runway, railway lines, ✓
  - Map, contour map, ✓
- 3-dimensional: "Everything else"
  - Wire bending in 3-D
  - Thin sheet katori, metal box, vessel
  - Folded cardboard box
  - Steel structure, concrete slab, beam, column

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Our next thing to look at is, what type of objects do we visualize or what type of object does an engineer draw? And I have listed them here by, as one-dimensional, two-dimensional or three-dimensional. A one-dimensional object is relatively straightforward. For instance, something which is straight like that, this could be a wire like this one. So, you can see this wire, if we look at it at the edge all we will see is a small little circle, so that is a straight piece of wire.

So, what we have here is one-dimension is much bigger than anything in the other two dimensions. And at the end, what we see, although, technically it would be say like a point, it is actually always a finite shape. The case of a wire, the cross section is typically circular.

That is a very simple set of objects one-dimensional in which case the making of the drawing is also much easier, as we shall see later on.

Then we have two-dimensional objects. For instance, the same wire we now bend it. And as you can see this have been bent in a plane. So, if you look at it, all these things is lying in one plane. So, the entire shape of this wire is in one plane. So, that is what it is, that something normal to the plane is not very consequential, but within the plane in this dimension, and this dimension this is where we have all the information that we want.

This could be any shape. This is just one shape I have shown it could even be a shape like that. A wire bent in a shape like this. And as you might have learned in school that if this was put in a magnetic field and rotated about this axis, it generates a current. So, that is one example.

A very good example is the construction of buildings, where the concrete beams and columns and walls have to be made, they bend rods, steel rods of different size to different shapes and then they are all tied up together to make the reinforcing structure and then concrete is poured over it, lots of those bars have to be cut and made into various shapes, and that is known in construction or the bending schedule.

Most sheet metal parts could be 2D, then there is the printed circuit board. If you have seen the PCB, you will see everything is in one plane, the way the board is made. Once you have put the items on it, then it becomes three-dimensional. The wiring inside a control panel, you can see all the wires go along certain walls and it makes a 2D type of an image.

These days, whatever you buy comes in some packaging. And when you open the packaging, you will find that although it was a 3D box type of structure with more features in it, by the time you open it completely, it becomes a two-dimensional shape. For example, a pizza box, when you open it up, it is actually a flat piece of cardboard which has been cut in a certain way bent at certain points and you get a box in which we transport that item.

Then layouts of roads, streets, runways, railway lines, all this happens in one plane. Even though, many of these may have elevations, but when we show in one picture, we are actually showing that it is flat and at some point we could show that it is going downhill or upslope like that. And on a very large scale in geography, you would have seen maps, you can go to Google Earth and see the maps there, what you are seeing is a flat surface of a 3D of what the earth surface looks like, but you can draw lines on that you can also make contour maps, which tells you lines of constant elevation. So, these are examples of two-dimensional objects.

Now we come to three dimensional objects, which, as I have put here, is everything else, which is a lot of things. So, there is no way one can make a full listing of this, but to continue our example of the wire, which was straight and which was then bent, we now have here a coiled wire. The straight wire had been made into a coil, and we can see this. This is a type that is used in say springs that is the easiest thing or we can there are coils made for cooling and heating purpose.

So, what it had is that we are quickly showing this as something like this where it has some features in this dimension, some in this and equally important in this. So, what we are saying is, I need to specify everything in three dimensions to fully specify the object. In this case, I need not tell what is normal to this plane. I can put a word that this is a wire of this diameter. And in this case, I do not even need to tell what are the other two cases, I said the straight length of this length, this so many millimeters of a wire whose diameter is say two millimeters that completely specifies this particular object. You need not even make a drawing, but these we have to.

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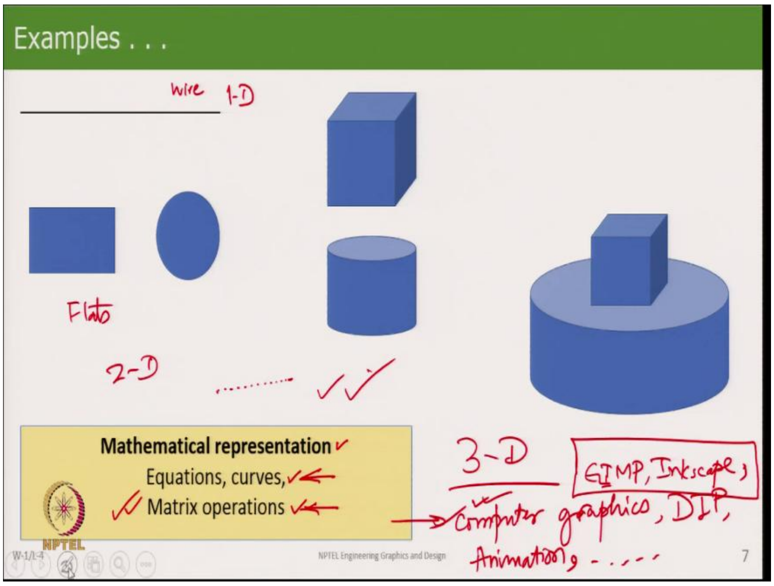
Examples . . .

wire 1-D

Flats

2-D

Mathematical representation
Equations, curves,
Matrix operations

3-D

GIMP, Inkscape,
Computer graphics, DIP,
Animation, ...

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So, pictorially here are some examples. This is the wire or a rope, then these are flats. And you can see any shape, which has anything normal to this sheet, which is not a very great significance that would qualify as a 2D shape. So, this is 2D. This was an example of 1D, and here we are seeing examples of very simple examples though, but they tell you that all three dimensions are important. And it is not necessarily that object will be so well ordered and so nice they could be combinations of shapes and that is what typically they are. And we will learn in the course, how to show them.

Typically, there are some very simple shapes, 2D and 3D using which we create a lot of complex shapes. And then, of course, there is mathematics with which we can work. A slight divergence from what we have been looking at. All these objects that we are now thinking of drawing on paper pencil, we can also draw electronically. That takes us into computer-aided design, computer-aided graphics and many of those subjects.

If you are able to visualize the object, you can use those tools much more effectively, but there is another aspect of this visualization, which goes through this field of computer graphics. And also, digital image processing, and to various things like animation, and whatnot. What a subject like this deals with is how in a computer we can show these objects? That the simplest thing is that electronically, we are storing everything as a pixel. So, if I put a lot of pixels together like that, I could show a straight line or I could write an equation and say that from here to here this is the equation, connect them.

Same thing with shapes. So, how that is done? For that you need some more detailed knowledge of data structures need a good grasp on mathematics. And for manipulating images, that once we have shown this and we want to see it by rotating it, we are actually doing a bunch of matrix operations. So, what you learned earlier in maths here and in linear algebra that all of that becomes an input there and all of this is another way of doing what we are trying to do in this course.

So, we are finally looking at the outcome and not how we actually went to doing it, but one can always go back and start looking at computer graphics to understand the nuts and bolts of it. Open-Source programs like GIMP or Inkscape. Everything is known about it. You can see the code and see how the image generation and manipulation is done. So, these are open-source programs, and you can see the entire source code.

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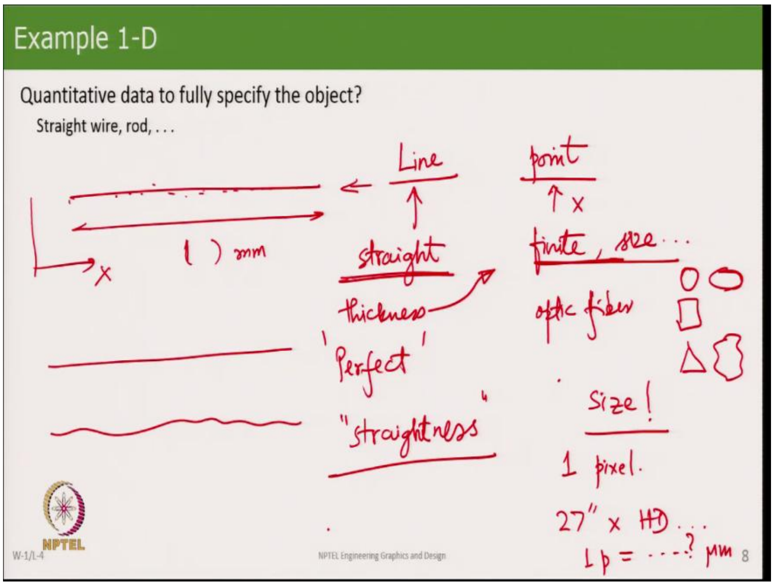

Example 1-D

Quantitative data to fully specify the object?

Straight wire, rod, . . .

So, let us go again on what, how can I put quantitative information on the objects that we just saw, beginning with the one-dimensional object? A straight object I said has got only one parameter coming in over here. It is all in one plane. And you can give this as some length parameter, and that is given in millimeters. Mathematically, this is a line whose end if you see is technically, theoretically at least is a point.

In the real world, there is no such thing as a point. Everything is finite has a size. And we have to say what is the size? You could have an optic fiber, which is say 20-microns in diameter, 10-microns in diameter. It looks like a very thin wire thinner than the human hair, but it is got finite size. That is a one example of point.

So, it has got size, it has got shape because of it, and we will always have to give some information about that. It could even be an oval shape. So, that is one idea to keep in mind. Whether we draw on paper pencil or electronically, whenever we say we have drawn a point, we theoretically think that it has got no size, practically, if you actually look at it, take it under a lens or a microscope, you can put a size on it.

Electronically, the smallest thing that you can see on any of these electronic things, whether it is a cell phone or a monitor or a laptop is 1 pixel, and the pixel has a finite size. You can do that calculation that if you have a 27-inch monitor and it has got a HD resolution of something, what is 1 pixel correspond to how many millimeters or micrometers? You can do that calculation. We cannot show anything smaller than that on a one-to-one scale.

The second thing is about the line. Line is again a good mathematical concept. When we say a line particularly in this case, we are saying that this is a straight line, there is a certain mathematical meaning to it. In that if you have a reference frame, where the X axis is aligned with this, then the Y and Z distance at any point of the line is same from the X axis or graphically, we can say that X is got certain value at any point on the line, but Y and Z are always 0.

And we did not assign, as I said in the first case, thickness that where we saw here, but now, in the real world we see one more feature, we will not learn it in this course, but good to know that it is there that when we say straight line, there is no such thing as a perfectly straight line, never. Even though, we have looked at it and say a wire or an optic fiber, if you keep blowing it measure it as accurately as you can you will see that at a certain distance, it may look like a straight line, you look at very closely and dissolve it you will find some variation in it. And that is quantified by straightness.

In this course, we will not worry about it. In this course, all the lines we draw will be perfect straight lines. We will live with it for the time being, and good enough to do the type of visualization and drawing that we are looking at. So, that is one dimensional objects.

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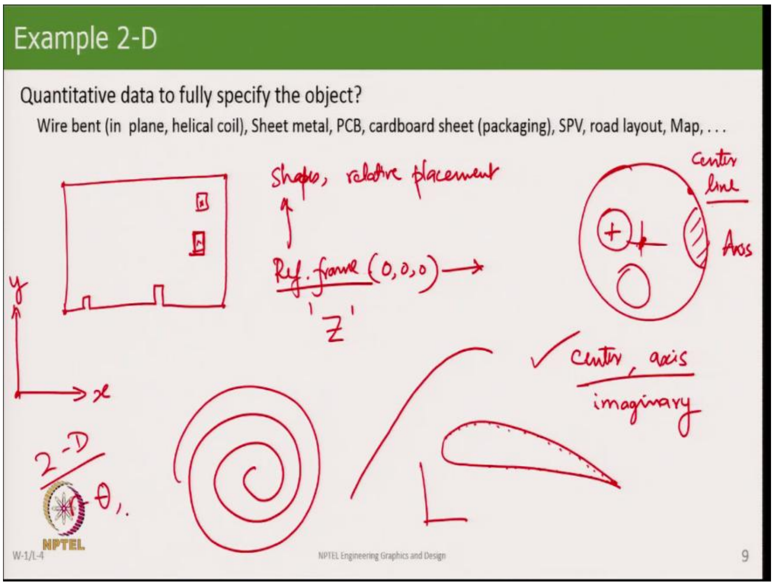

Example 2-D

Quantitative data to fully specify the object?

Wire bent (in plane, helical coil), Sheet metal, PCB, cardboard sheet (packaging), SPV, road layout, Map, . . .

Now, we look at two-dimensional objects. And I have showed the example of a coil, but we can say that I am looking at a sheet metal in which I have cut out some features. So, I can say, I have cut out these things, so these are gone. Now we say how do I give quantitative information about this drawing? And there are various shapes, their relative orientation comes in or a placement we can call it.

So, we need to completely specify each shape and completely specify their relative position for which we say that I will use some reference frame, and related to that reference frame, which has a (0,0,0) I will tell all the other information. In this case, Z say normal to this sheet has got no consequence, but X and Y if you were to define it this way, then we can say if this was my(0,0) we can say that this is a line going from here to here, another goes from there to there, like that, we can tell all these things.

And then we can see here the shape, which has got these, these, these characteristics and now, we have to tell how is the shape located relative to that shape. Another example of this could be that we have a circle in which we have cut out another circle. Now this cut circle could have been there, it could have been here also. So, how do we specify or it could even be partly cut, for example, we could say I am only cutting off this much part of this circle.

And the way to do that is that we take some point on this to define the shape and tell the location of that point relative to this axis, and then draw the shape around that. So, that is one way in which you can start implementing these things, but the point here is not how the computer does it, but how for our purpose to show the shape completely what do I need to do?

So, in this case, in all circular shapes, wherever there is an axis of symmetry, we always say where is the center. Denote the center by the center lines. Normal to the plane of paper, it is the axis. And then we say what is the shape? The trouble is, theoretically it is fine to do it, but practically the center of any of these objects or an axis these are imaginary. We cannot touch them, we cannot feel them.

If you want to say I will measure the radius, well, you can put the instrument at one end over here, but there is no such, no place to put this instrument. Whatever we create is random. It is arbitrary, it is not exact. But it is a good idea to have this, and we will show it. So, relative to that we can say what is the axis of this, and give the (X, Y) relative to the center. Similar thing we can do here with some of these shapes.

Then there could be shapes which do not have very specific things, they could be more complex shapes. For example, a shape like this. It may look complex, but actually mathematically you can put a simple equation to it, but there could be some other shapes which could be like this. If you look at the aircraft wing and take a cross section of that, the aircraft wing would look something like that.

We need to give the shape. It may not have an equation everywhere, but then the easiest thing to do is say set up an X,Y axis somewhere maybe relative to the shape itself and say that what are the X and Y coordinates of so many points along this. So, when you join it, you can in between points, you can join it by a continuous straight line or some other curve fitting technique can be used and regenerate this shape. So, those are the ways by which we give quantitative information. And that is what we will use extensively in this course.

The point here was that we have to specify information only in two-dimensions. It could be (X, Y), as I have used down here or it could be R theta in cylindrical coordinates or theta phi in spherical coordinates.

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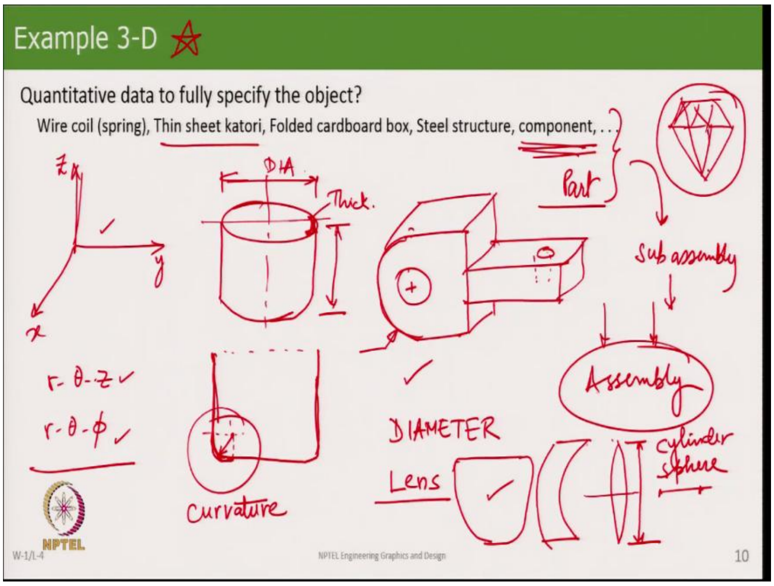

Example 3-D

Quantitative data to fully specify the object?

Wire coil (spring), Thin sheet katori, Folded cardboard box, Steel structure, component, . . .

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In three-dimensional objects, we need all three axis or r -theta-z, if there is axis of symmetry or r-theta- phi if there is spherical symmetry. And it could be such that part of the object has got this, part of the object is this, part of the object is this, entirely possible. Here we have some examples coil spring I had given. Let us take the example of a khatori that is there at house.

It is an object let us something like this. The thickness is small, but the shape is three-dimensional. And if I were to cut this thing like that, the khatori may look like that. I will also see the edge at the back. So, what you are seeing in this case is, a three-dimensional shape with an axis of symmetry. And we will show axis symmetry line by this notation, we will look at it later on again.

But one shape can show it. And in computer, if I make the shape and rotate it around the axis, I generate the shape that I want. And then there could be many more components. There is too many of them, we can just take one example, say, a thing like this. Maybe there is a hole through this, that could be a component or it could have maybe a hole which goes only some depth in it. So, they are looking at each one of these individuals things and we call these as a component or a part.

Lot of components and parts put together would make a sub assembly, and sub assembly plus parts together will make an assembly. The final product you see is always an assembly. The LPG stove or a mixer grinder, they are all assemblies of a lot of parts. So, in this case, we have to give enough information and say that I am fully specifying what this part is. And we give an example here, we can say well, I must tell you what is the depth of the khatori?

What is the diameter of this? What is the thickness of this? And diameter, we have to say, whether it is the outside diameter or the inside diameter. And all of them have such a rounded edge, we have to say well, how do I specify a rounded edge. And the way we will do it, you will say that this thing the way I make it is a quadrant of a circle.

So, what we will do is, we will show two lines. This becomes the center from which I have drawn an arc, which is 90 degrees. This is called curvature. And for the reasons I had just mentioned before that access and central lines of symmetric shapes can never be measured. So, unless there is no other way of telling it like in this case, we will always mention the diameter.

Diameter can be measured. Radius cannot be measured. But if it is some object which is like this, this we can say that this has a certain radius of curvature, and this becomes important in say, when you are looking at an application like a lens. This could be the lens in the eye glasses or spectacles that we wear or it could be the lens of, say, the Hubble Space Telescope or one of the big telescopes that astronomers use on earth a 10-meters diameter, 16 meters diameter made of glass.

So, in all these cases, what you learned in school. Say if this was a concave lens like that or a convex lens like this, in school we were taught about the focal length and the center of curvature, but now we have to say something more. And which if you get your glasses made, the ophthalmologist will give this prescription, that merely showing this length like this or showing the lens like that and telling what are the curvatures of these two surfaces needs to be further qualified by saying are these cylinders or spheres.

So, that is one information that comes out. And then we also need to specify what is this size of the lens, which as you have seen, in the third case, when you are looking the lens of the glasses that we wear there could be so many shapes and this shape has to be generated. And we need to geometrically completely specify this shape before we can cut a lens, and it has to match the frame into which the lens has to fit.

So, we are specifying. And in this case, what will happen is since this is a lens, it is not in one plane, but some part of it is coming out of the plane, some of it is going into the plane, but this shape which has been cut, even this need not be in one plane. So, we have to specify a lot more information than what we have over here. And the last example would be that of a diamond where India produces most of the world's diamonds.

How do we specify the shape of a diamond? How do we design it? How do we cut a raw diamond into a finished shape, all of that goes through a lot of very sophisticated visualization, and, of course, then implementation in computers, but our ability to represent a three-dimensional shape that is very important.

So, we will do more of these exercises as we go along in this course, that in all these dimensioning we have to make sure that we are given adequate information, appropriate information, and there should be no contradiction in the information. That is what one needs to do when checking a drawing. That if the drying falls short on any of those, we should not proceed with the drawing. Go back, correct it, complete it, and then only we work with it.

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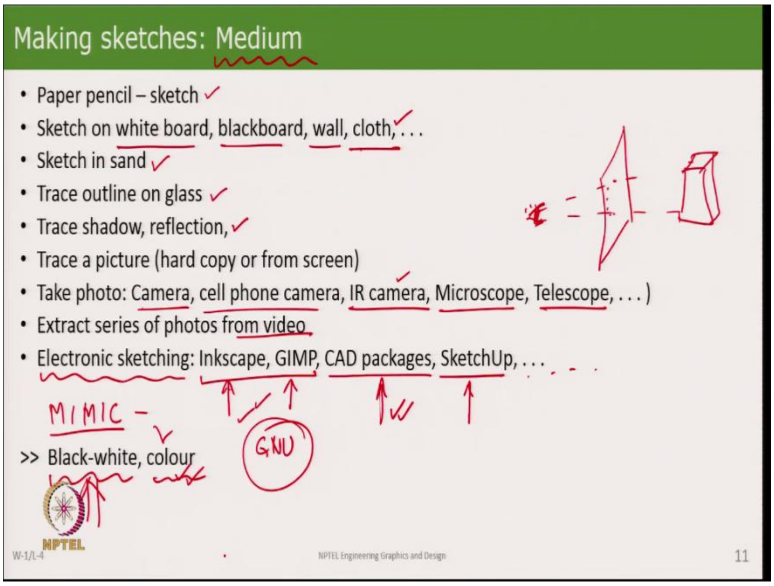

Making sketches: Medium

- Paper pencil – sketch ✓
- Sketch on white board, blackboard, wall, cloth, ✓ . . .
- Sketch in sand ✓
- Trace outline on glass ✓
- Trace shadow, reflection, ✓
- Trace a picture (hard copy or from screen)
- Take photo: Camera, cell phone camera, IR camera, Microscope, Telescope, . . .)
- Extract series of photos from video
- Electronic sketching: Inkscape, GIMP, CAD packages, SketchUp, . . .

MIMIC –

>> Black-white, colour

GNU

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Now let us look at the medium that we have for making sketches. The simplest one, paper and pencil, paper pen, paper crayons, cardboard and crayons all of that we have. Lot of it is fun, lot of it is good. It is also important not just for making drawing, it helps you concentrate. It helps you do something better.

If you want to improve your concentration for studying physics, maybe making drawings will improve your concentration, and then your physics will improve. We could sketch on a whiteboard, blackboard, and invariably you would have seen small children they just loved to draw on the wall a whole house becomes so called ugly, but that is the child's way of making a picture. That is important, very important. We could draw on a cloth.

So many of these things, we see in various types of traditional ways of making various fabrics it could be a bedsheet, it could be a saree it is done by taking a cloth and making pictures on it by various techniques. Then there could be sketching in sand. You can just make a picture right then and there, sand is there everywhere, you can quickly express your idea. We could trace the outline on a sheet of glass.

And in this week, you will do some exercises on that, that you have an object kept somewhere, whatever it may be and we have a sheet of glass in between, and here you are looking at it. And as you see this, we figure out the points on the glass where this thing overlaps in the object. We could do that tracing. We could look at shadow or a reflection. We could take a picture. And these days, it is so easy to take a picture with a cell phone, and then use that picture to convert it into a drawing, and there are software that do it or we can look at the picture and reduce any of the earlier techniques to make the drawing.

So, that is what we took a camera or a cell phone camera that use your visual drawing. Much more exciting things happen when you look at an infrared camera. It gives you a pictorial representation of the temperatures on a surface, microscopes and telescopes, they show you a world which is not visible to the eye at all. So, you get lots of exciting ways of making a picture.

We could also make a video and then extract frames from the video and make the picture that we want. And finally, the medium for making a sketch electronic medium, very common these days, sooner or later everybody has to learn it. There are open-source packages,Inkscape and GIMP. GIMP is GNU Image Manipulation Program. Both are open-source, free, you can download it, play with it, learn, and these are very good powerful softwares. GIMP in a way is an open-source version of Photoshop.

Then there are various CAD packages. Some are open-source, many of them are priced, but for students they are available for free, we will be using those in this course. We could use these anytime in our lives. Then there are other packages like Google SketchUp and many more. They are good for making certain things. These are good for engineering, these are good for making drawings of various types. And taking a photo and in manipulating it, it can be done with either of these packages.

So, we have a lot of medium here. And in this course, we will do various exercises with various forms of these things. Each one of them has their own strengths and shortcomings, but that is where we learn to do something what is the best way of doing it. We could do it either in black and white or in color, that is our option. But in engineering drawings, we invariably just stick with black and white.

Electronically or when we show it on a screen, which is like a MIMIC this could be color. And many other drawings for example, the IR camera picture different colors will denote different temperatures. So, you can do a lot more with color and you can even add artificial color to it. For example, if the pictures are being sent from the surface of Mars, we enhance that picture using our own coloring scheme and make the image look more vibrant.

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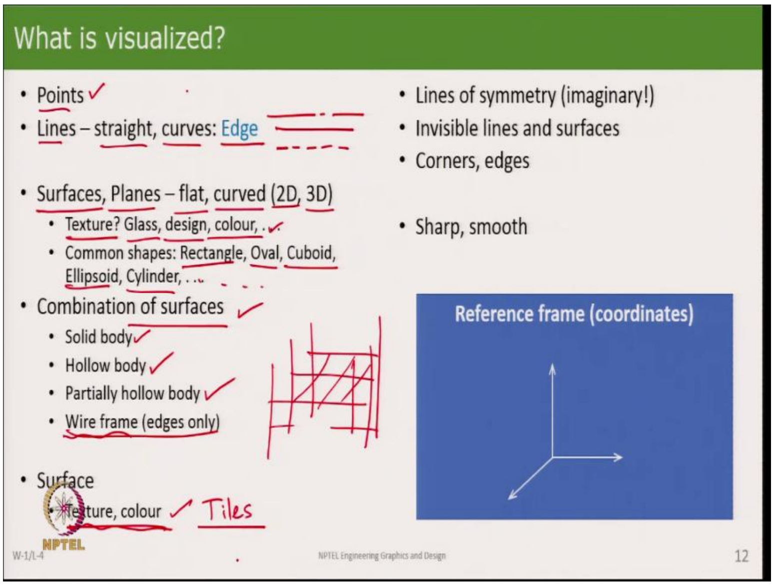

What is visualized?

- Points ✓
- Lines – straight, curves: Edge
- Surfaces, Planes – flat, curved (2D, 3D)
  - Texture? Glass, design, colour, . . ✓
  - Common shapes: Rectangle, Oval, Cuboid, Ellipsoid, Cylinder, . . .
- Combination of surfaces ✓
  - Solid body ✓
  - Hollow body ✓
  - Partially hollow body ✓
  - Wire frame (edges only)
- Surface
  - Texture, colour ✓ Tiles

- Lines of symmetry (imaginary!)
- Invisible lines and surfaces
- Corners, edges
- Sharp, smooth

Reference frame (coordinates)

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Now, what do we visualize? We have already looked at this in the earlier slide, so we quickly go over this. First, there is a point then we said there are lines, which are straight and curves or also line is an edge formed by the intersection of two surfaces. Mathematicians would talk a lot about that. We use those concepts of mathematics in computer graphics. Then we like to visualize surfaces and planes, which could be flat or curved in two-dimensions or three-dimensions.

So, for points and lines there is nothing much to think about. Point is just that, line is just that. The thickness is their color we can decide what we want. What type of line we want to make that is also our freedom. We could have made a line like this, we could have made a line like that, we could have made a line like this, fine. They all mean different things to engineers. But when it comes to surfaces and planes, we have more things which we could show in the end in an object, it will come this texture.

For example, it would be a glass reflective surface or we could have designed it or it could have a certain color, it could have a certain pattern, there is so many features that you can give to a surface. The common shapes that we use the rectangle from that also includes a square, oval, and circle, cuboid, these are three-dimensional things, ellipsoids, cylinders and many more things, which are the standard features that we can use. Many more are there in many of these packages, the way they implemented.

What we also visualize is that objects or combinations of surfaces, could be a solid body, could be a hollow body. What we are saying is that, we have cut out a certain portion of that object it is hollow, it could be a partially hollow body or we could say we are only looking at the edges of that as a wireframe. For example, if you go to the market, you will find a stand, which is made entirely of wires.

So, you have a bunch of wires over there, these are joined at different places and then there is more wires over there, and we get a stand on which you can keep things. So, this is an example of what we may call a wireframe, but we will denote wireframe as something where we take an object and all the edges are shown as wires. So, only thick lines come there, nothing else that shows them. So, these are different ways by which we will show surfaces and that is how we will look at them.

Finally, texture and color. Although, in engineering, we do not go into details of this, we may just write on the sheet what the color image is. In all our pictures, we do not show details of these aspects. Practical designer, say a product designer, a fashion designer an architect in those drawings, we will show the texture and color. For example, if you are putting tiles on the floor or outside the building, we will, there is an infinite amount of colors and pictures that are available, we will have to specify that. And these days they get printed using a computer, so you can really create even a building of whatever color you want and the picture you want.

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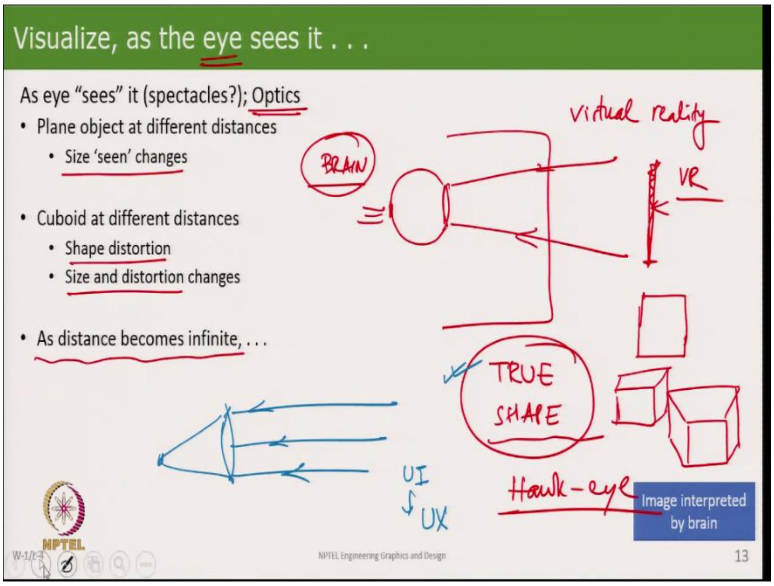

Visualize, as the eye sees it . . .

As eye "sees" it (spectacles?); Optics

- Plane object at different distances
  - Size 'seen' changes
- Cuboid at different distances
  - Shape distortion
  - Size and distortion changes
- As distance becomes infinite, . . .

Image interpreted by brain

I will spend a few minutes on now talking something, which will practice also, which is what is the what do the eye see. When we see something, what is it that we are seeing? The thing is that as you have learned in school, the eye has a lens, there is an object somewhere there, and rays from the object come and form an image on the retina. And that is all what you learned in school, physics as optics.

This image is then goes through the nerves and it is interpreted by the brain as a certain image. There is a lot of research going on how we interpret and see images. It is also the starting point of how you can now go the backward thing that to create that sort of a feeling in the brain, what should I see here. And if it is not at such a distance, can I wear a special type of glasses and I see a different world that is now become virtual reality. VR becomes a very common thing these days.

It involves cognition, it involves understanding, how the brain works it requires understanding of optics and also discourse visualization. And so, what we see is not exactly the way the object is. An object maybe a complete box, but when we see it from a distance, it may look something else. For instance, it may look like this or it may look like that.

The point is, are we able to interpret the true shape from what we see. And that is a field of tremendous amount of research. We have 2 eyes so we have stereoscopic vision, but the depth is not captured. For that you need a third viewing angle. And an example of that is, what you see in goal line technology in football or Hawk eye in cricket that is what they do there, they have three cameras at least, which are calibrated to that pitch, and then using software you create the trajectory of the ball or the bat or whatever you want to look at.

So, depending on the size from which we are, look, the distance from which we look at an object its size changes. There is shaped distortion, as I just showed you size and distortion also changes, and we cannot interpret the depth with a great degree of accuracy. An important thing happens when the distance becomes infinite. Because in the close object the rays are coming like this, but when the object is far away the eye sees the rays essentially coming parallel.

Sunlight is a good example. The sun is so far away that the rays coming on earth have very little distortion, and we are looking at straight lines coming there, and then we get some image over there. In that case, if the rays are coming straight we end up seeing the true shape. So, that is what we see. And what various possibilities which are there in future for doing things that is this one. One, would also do all of this in designing your screen designs and user interfaces, and this is of course, these days the UX for design of websites, web pages, your screens on cell phones all of that.

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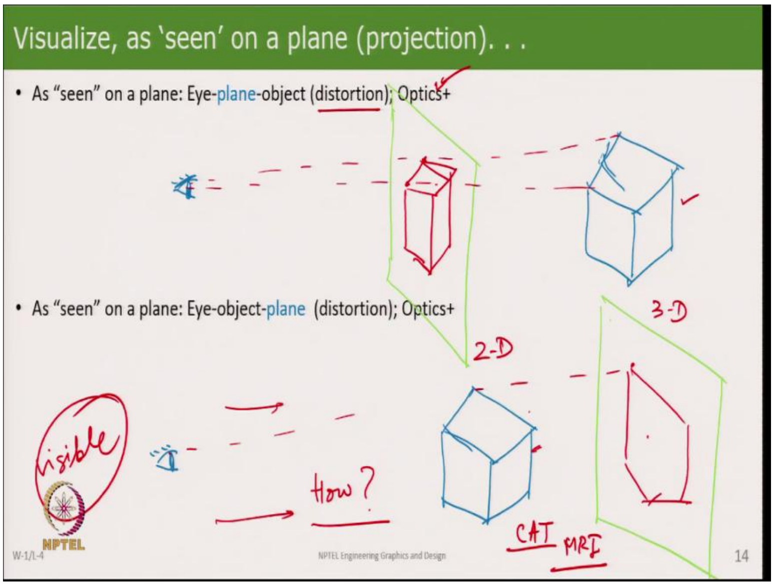

Visualize, as 'seen' on a plane (projection). . .

- As "seen" on a plane: Eye-plane-object (distortion); Optics+
- As "seen" on a plane: Eye-object-plane (distortion); Optics+

We now look at two other techniques by which we can visualize. One is that, we have an object there, and we are looking at it over here, but what we do now is something slightly different. We place an object an imaginary or a real sheet, transparent sheet between the eye and the object, and then, we say well, as we see it this line intercepts this plane at a certain point.

Similarly, this line. And by seeing it what we end up doing is that we make an image of this object, which was three-dimensional on the screen, which is two-dimensional. We are projecting that on a screen. This is a physical way of doing it. And in this week, you will do some exercises like that. The same thing can be done in software by doing a bunch of mathematical operations. So, there when you look at with the eye, yes, there is distortion, but basically what it is doing is very basic optics that we have learned in school.

The second technique that is listed here is that the plane is somewhere else. So, we have the object the eye is here, but now the screen is placed behind the object. And we say, well, whatever I see, can I project it on this and get a picture, make a picture on this? That is one thing. The other is, you could even say, well, this is being illuminated this way. Can I at least draw the outline of the shadow of this object over here.

So, that is a different way of looking at this object. The point in both cases is that whatever we have drawn here or drawn here, we are only drawing those surfaces and edges, which are visible. The object is three-dimensional. What is behind the object is not visible. So, we probably do not have enough information by looking at one projection, as to what the full complete shape of the object is, and that gives rise to the idea that is it possible for me to view the object from different directions, and create the complete 3D picture? And the answer is, yes. The question is, how many such pictures do I need to take to fully interpret an object?

A slightly different thing is done in something like a CAT scan or an MRI scan. They take pictures of a certain three-dimensional object, they could be the lung, could be the brain, the slice, they take slices on which the image is taken, then using the picture that came out and each one of those slices over 360 degrees they create a three-dimensional picture, which is then used to interpret various aspects of health and disease. Similar mathematics objective is visualization. We now look at the idea of why are drawings important?

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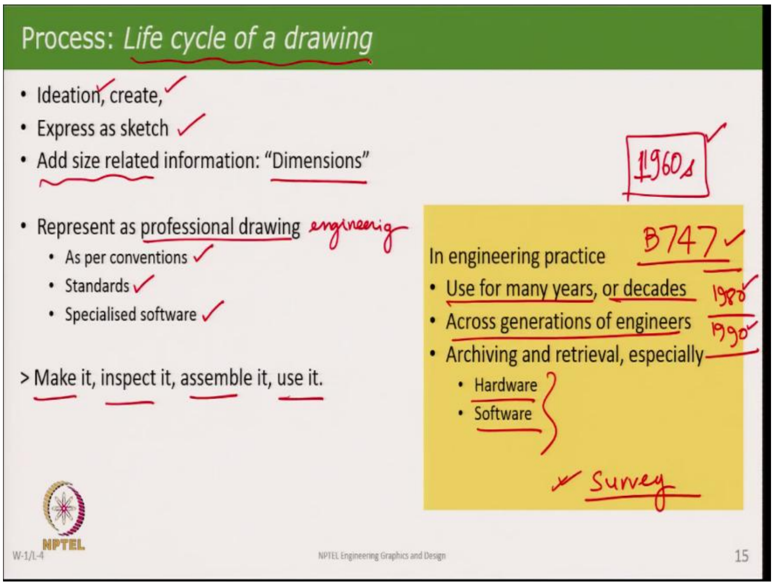

Process: *Life cycle of a drawing*

- Ideation, create,
- Express as sketch
- Add size related information: "Dimensions"

- Represent as professional drawing engineering
  - As per conventions
  - Standards
  - Specialised software

> Make it, inspect it, assemble it, use it.

1960s

In engineering practice B747

- Use for many years, or decades 1980
- Across generations of engineers 1990
- Archiving and retrieval, especially
  - Hardware
  - Software

Survey

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And we have already mentioned that ideation, creation, innovation. The idea starts with a sketch. When you express it, we can convey that meaning to somebody else. And when you put dimensions on it, we get size-related information. So, we make up a drawing.

A professional drawing in engineering has certain restrictions. It is not an artists like an art drawing, but it is made according to conventions, standards at least two standards came in this lecture, one on sheet size and scaling and then there are specialized software for engineering. A general-purpose sketching software is decent for certain types of engineering drawing, but not very good.

You can even use a package like world to make simple drawings, but that is not a professional way of making drawings. After we make a drawing, we make the product, inspect it, assemble it, use it, and like that it goes on, but in engineering, a product that is made is used for many years, maybe even many decades. An excellent example is the first jumbo jet which stopped manufacturing last year.

The first plane was designed in the early 1960s. There were no computers, calculators were very rudimentary all drawings were made on a tracing paper by hand. The engineers who made the drawing maybe they are no more. Planes are still flying, customers who fly airplanes may still need spare parts. So, a new generation of people who are working in the factory need to read and understand those drawings make exactly what both engineers that thought about and supply to that client.

A 747 made in say 1980 or 1990 could have different components, they may look same, but there could be a difference of a fraction of a millimeter and that is not acceptable. So, the correct part has to be made for the correct aeroplane. Think of the future. Now that we are in the world of software, how do we communicate that over generations of engineers because hardware keeps changing, software keeps changing, file formats may keep changing, how do we make sure that what we draw today and what we invent today is available to somebody whom we do not know even today or maybe 10, 20, 30, 40 years down the line.

Some drawings are even older. This is an example of drawing that last 60 years. Survey drawings go on for hundreds of years, civil engineering drawings where you survey a road or valley a mountain, those drawings are there still going on. So, the lifecycle of a drawing goes on from many years, and we have to make it enough, well enough and clear that people who maybe not even born today maybe to understand that drawing.

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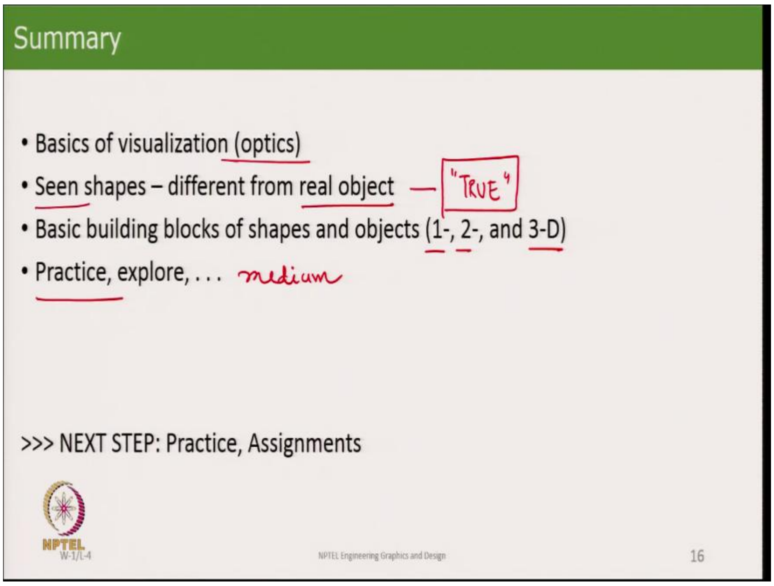

Summary

- Basics of visualization (optics)
- Seen shapes – different from real object — "TRUE"
- Basic building blocks of shapes and objects (1-, 2-, and 3-D)
- Practice, explore, . . . medium

>>> NEXT STEP: Practice, Assignments

So, in concluding this lecture, I have presented some basics of visualization, and seen how optics computer graphics gets connected. We have seen that when we look at an object what we see as a shape is likely to be different from an object. But to represent the object in engineering we will see, how this issue of a true shape comes up that is interpreted unambiguously.

And we saw that there are basic building blocks by which we can make one-dimensional, two-dimensional and three-dimensional objects. We saw a lot of media or the medium by which we can make drawings, and in the assignment and the practice things we require you to go ahead and make certain drawings and develop that ability to visualize and make a sketch. That ability will come only with practice.

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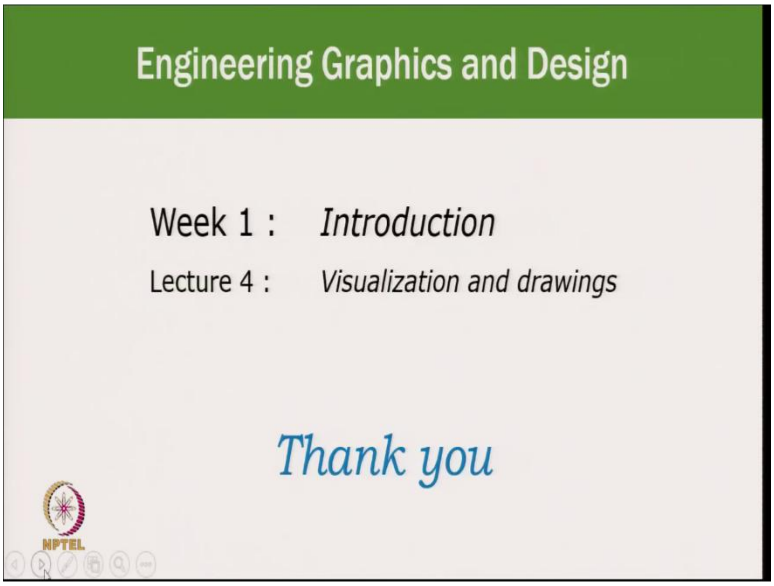

Engineering Graphics and Design

Week 1 : Introduction

Lecture 4 : Visualization and drawings

Thank you

With that, we will end this lecture. Thank you.