Engineering Metrology

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Lecture - 4
Standards

Welcome back. We will today start lecture on Standards of Measurements.

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So, today we will be covering SI based units. We will see meter, kilogram, second, Ampere which is for current, Kelvin, mole for substance present. And then, the materials standards which were initially Yards, then modern which is made out of wavelength based measurement then length and end standards and finally, we will see hierarchical classifications of standards.

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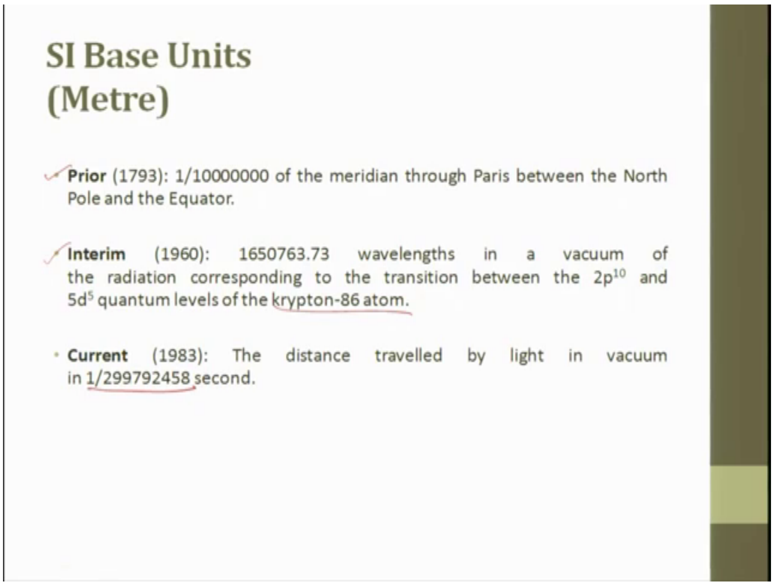

So, SI based units. So prior, it was assumed that it is in 1793, it is 1 by 10 to the power 7 of the meridian through Paris between the North Pole and the Equator. Then interim in

1960's, they say it should be 1650763.73 wavelength in a vacuum of radian corresponding to the transition between 2 p to the power 10 and 5 d 5 quantum levels of krypton 86 atoms, that was interim. Currently, in 1983 the distance travelled by light in vacuum in 1 by 299792458 of a second. So, this is the latest definition for a meter. It started in 1793 seen it is measurements significant start at very early. So, they were talking about 1 by 10 to the power 7 of the meridian through Paris between the pole North and the Equator, this is what they were.

Then, interim in 1960, it was again they started comparing it with respect to wavelength of krypton 86 atom, then now they talk about a distance travelled by light in vacuum in 1 by 299792458 of a second is the latest definition for meter.

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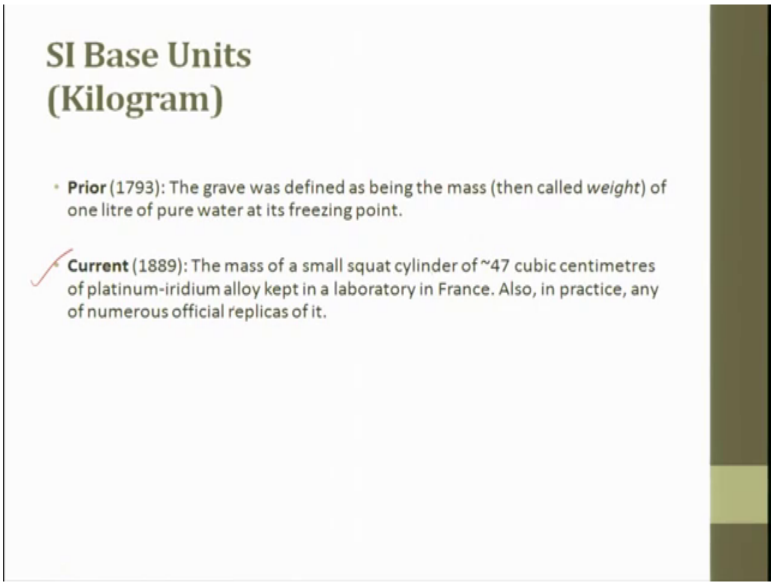

The same way for kilogram also prior that was in 1793, it was said as the grave was defined as being the mass, then called weight of 1 liter of pure water at its freezing point. That was thought about first for a kg, but currently what we do is we have accepted the mass of a small square cylinder of 47 cubic centimeter of platinum-iridium alloy kept in lab in France. Also in practice for any of the numerous officials replicate of it is accepted to be kg. So, currently this is the definition for kg, the mass of a small square cylinder of approximately 47 cubic centimeter of platinum-iridium alloy kept in the lab in France.

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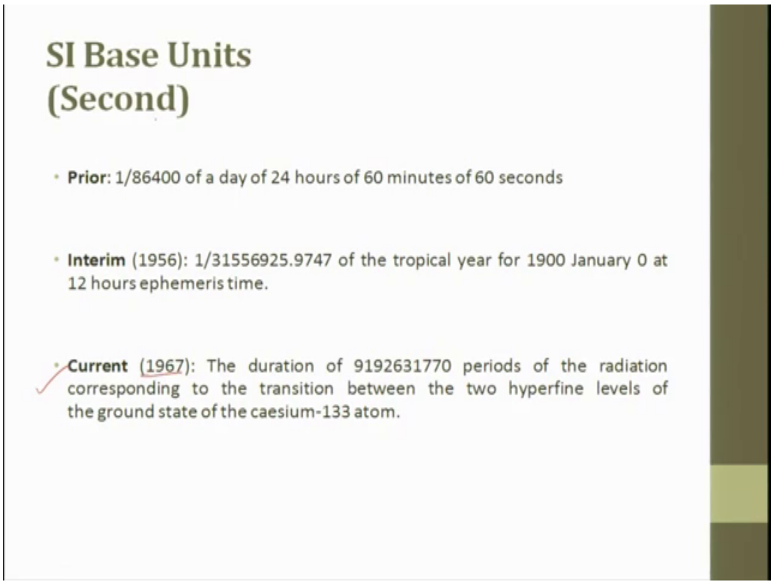

When we talk about a second prior, it was 1 by 86400 of a day of 24 hours 60 minutes of 60 seconds. So, that was the prior definition, then interim definition in 1956 came 1 by 31556925.9747 of the tropical year for 91900 January 0 at 12 hours meridian time. But currently, in 1967 this is the latest definition which is now accepted the duration of 9192631770 periods of the radiance of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom is the current definition for seconds.

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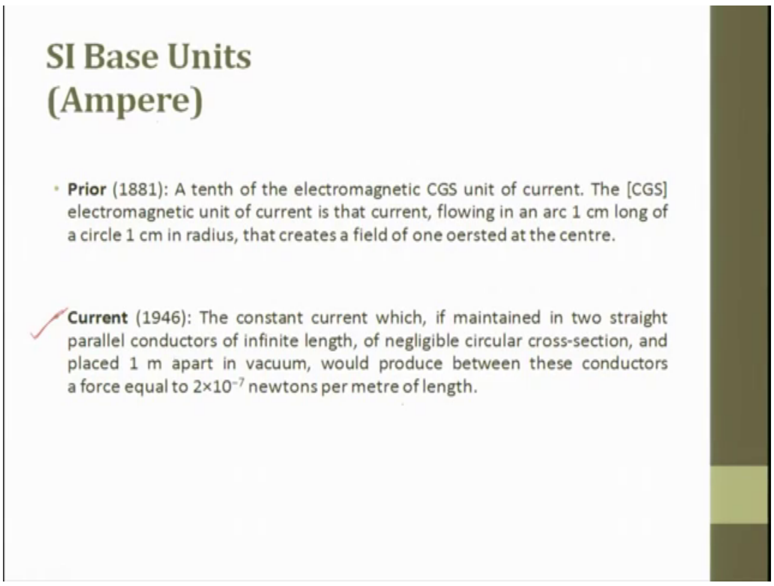

The same way for Ampere, for current, so it is prior it was defined in 1881 tenth of an electromagnet electromagnetic CSG unit of current the CSG unit of electromagnetic unit of current is that current flowing in an arc 1 centimeter long of circle 1 centimeter in radius that creates a field of one oersted at the center.

So, this was prior, but current definition for current is in 1946, it was defined as the constant current which if maintained in two straight parallel conductors of infinite length of negligible circular cross section and place 1 meter apart in vacuum, would produce between these conductors of a force equal to 2 into 10 to the power minus 7 Newton per meter of length is nothing but the definition for current. So, it is nothing but definition for Amps.

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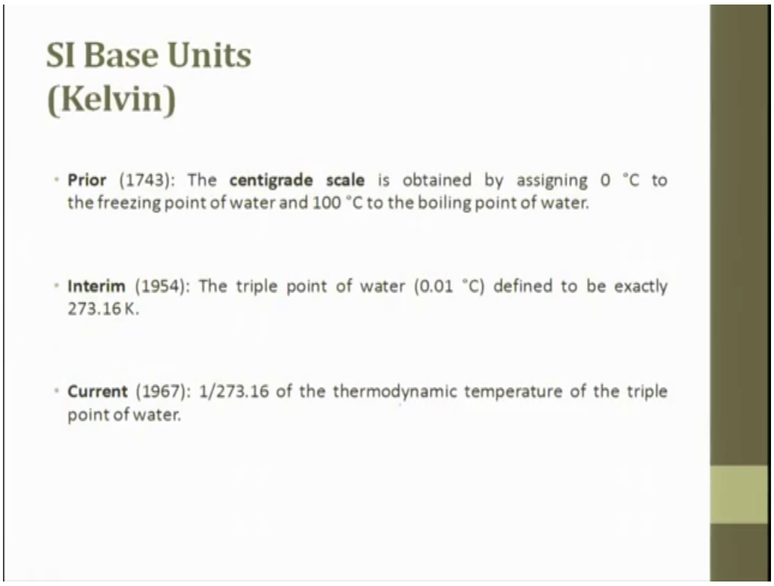

SI based unit for Kelvin, Kelvin is for temperature measurement. The centigrade scale is obtained by assigning 0 degree Celsius to the freezing point of water and 100 degree Celsius to be boiling point of water. This was prior definition in 1954 triple point of water defined to be exactly 2732.16 Kelvin, current definition is 1967. We have 1 by 273.16 of the thermodynamics temperature of the triple point of water, this defines the Kelvin.

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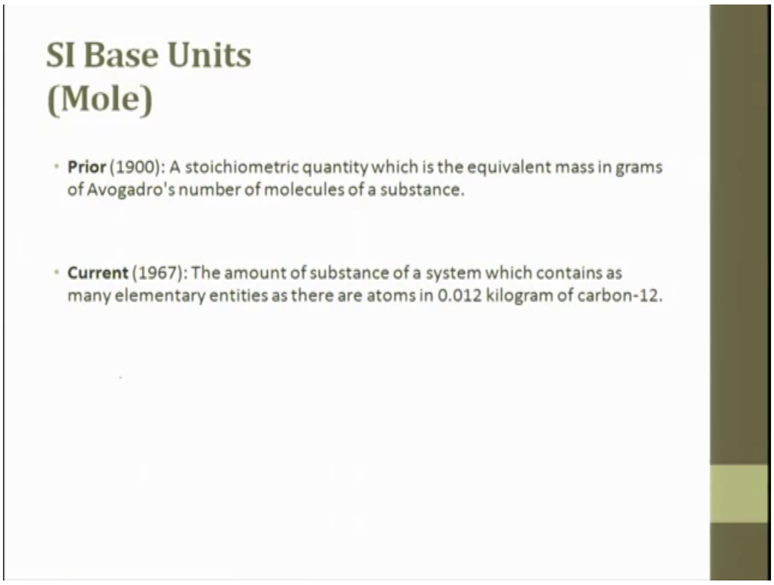

So, the mole prior the stoichiometric quantity which is equivalent mass in grams of Avogadro's number of molecules of a substance was the prior definition. And today in 1967, when it was rewritten the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kgs of carbon 12 of c 12, so, that is the current definition for mole. So, till now what we saw was; we saw various definitions for basic units. It is not definitions these are basic units.

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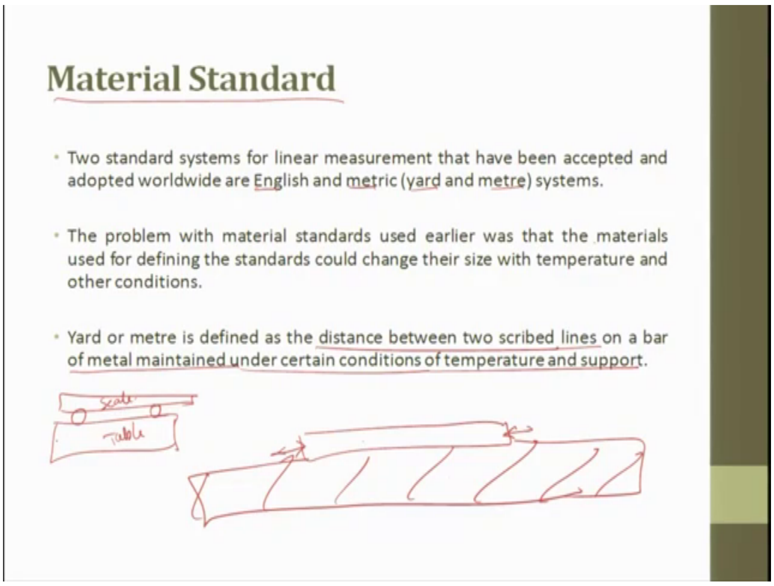

So, now let us move to the next topic where material standards. So, when we talk about material standards and when we talk about linear measurements, we try to take two standard systems for linear measurement that has being accepted and adopted worldwide are English and metric. English always talks in terms of yards. If you do look at a cricket match picture also, this is 22 yards ok.

So, English was they always use yards and metric was in meter systems. The problem with material standard used earlier with yards was that the materials used for defining the standards could change their size with temperature and other conditions. There is as a component of thermal expansion when the temperature goes very high and we are looking at very small precision measurements. So, then this carries a very important problem or this carries a very important point to be noticed.

Yard or meter is defined as a distance between two scribed lines on a bar of metal maintained under certain conditions of temperature and support, why are we talking about support? Suppose you have a bar and this bar is resting on a plate and assume that there is a temperature difference, the bar might expand or might contract expand or might contract. Same way, when this is in contact perfect contact with the table, the table can expand or contract.

When the table expands or contracts and if that scale which is touching it is having a surface, then this influences both. So, in order to avoid this, what people do is they always try to take a table, try to have pointed supporter loads and then they use to have a scale which is there and then this scale we will try to maintain the temperature and other conditions for the entire set up. So, now, there the temperature influence of the table cannot influence the scale and these rollers are kept as point contacts, so that you can maintain certain uniformity across the scale.

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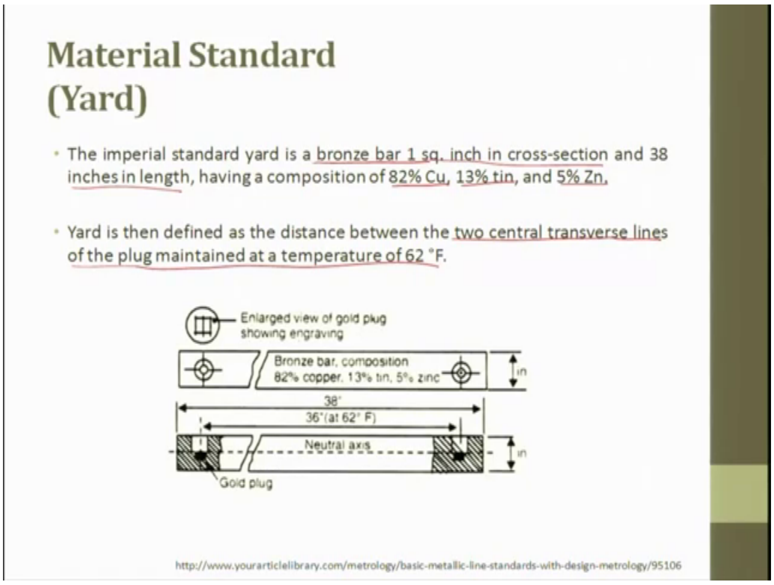

So, material standards, the imperial standard yard is a bronze bar of 1 square inch in cross section and 38 inches in length having a composition of 82 percent of copper and 13 percent of tin and 5 percent of zinc. All these things are come out because these are at this combination, they do not expand or contract and they know at certain temperature they can maintain it a constant and avoid this thermal expansion. Yard is then defined as a distance between two central transfer lines of the plug maintained at a temperature of 62 degree F.

So, this is the bronze bar which is having a cross section ok. So, here if you see this is 36 degree Celsius with a temperature is maintained and then this is 38 degree Celsius, this is a neutral axis you have a gold plug and this is a square inch. So, the bronze having all this compositions are written here. So, the enlarged view of the gold plug showing the engraving is given here ok.

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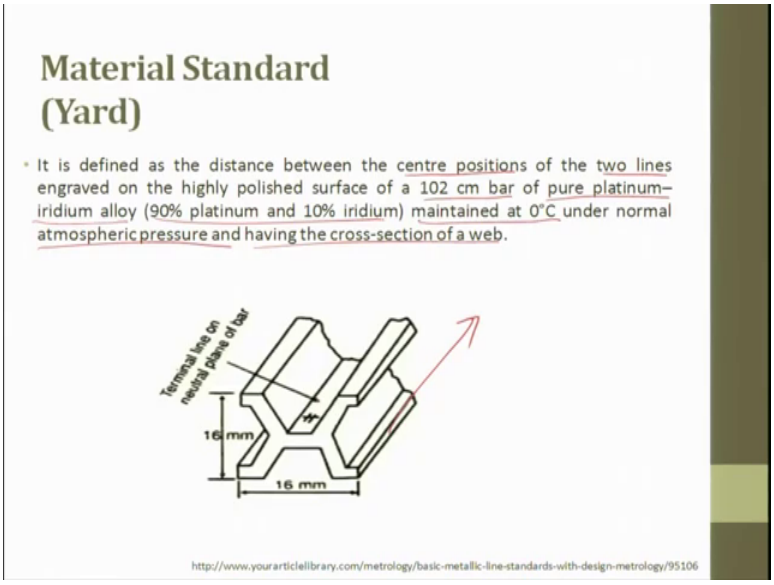

So, it is defined as the distance between the central positions of two lines engraved on the highly polished surface of your 102 centimeter bar of pure platinum and iridium alloy which has a composition of 90 percent platinum, 10 percent iridium maintained at 0 degrees under the normal atmospheric pressure and having a cross section of the web. So, this is the recent the change. So, first there are talking about copper and then this is the other definition for yard they had. So, here is it. So, they have a web which is having a cross section, length is 102 centimeter bar and this is the terminal line of the neutral axis which is maintained, so 16 inches millimeter by 16 millimeter.

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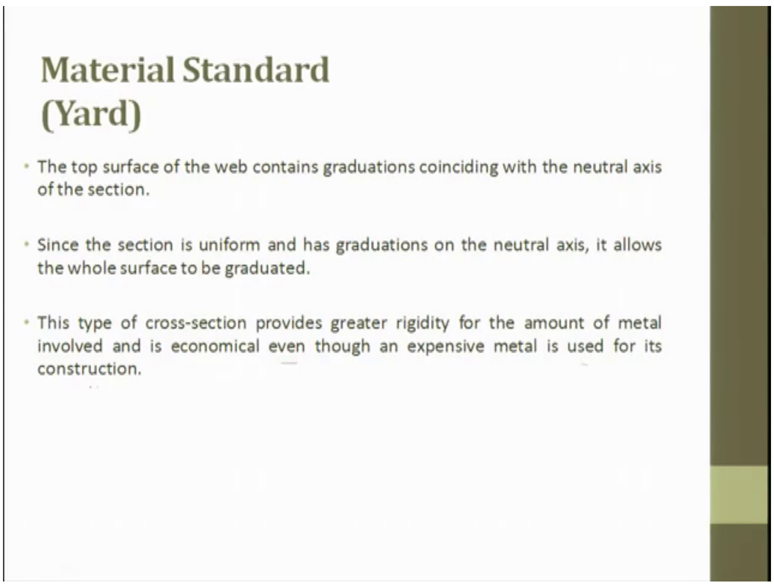

The top surface of the web contained, the top surface of the web contains the graduation coinciding with the neutral axis of the cross section. So, why the cross section is uniform is although this length. The cross section is uniform and has a graduation on the neutral axis it allows the whole surface to be graduated the type of the cross section provides greater rigidity from the amount of material involved and is economically even though expensive metal is used for this construction. So, this platinum iridium, platinum iridium is very expensive. So, this composition again is chosen such that it avoids expansion.

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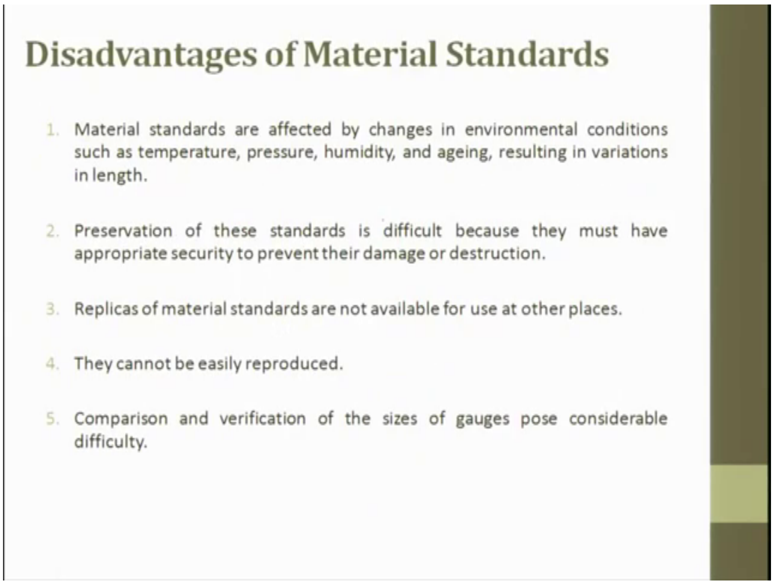

So, what is the disadvantage of this material standards? These material standards are affected by changing in the environmental conditions such as temperature, pressure, humidity, ageing and resulting in variations in length because these materials keep on because over a period of time ah, they keep expanding, they keep contracting. So, this is the major influence then of course, the humidity which is around made allow them to get corroded all those things are there. So the standards by using this platinum iridium and this copper bronze bar always is a problem because over a period of time it can change the length. The preservation of this standards is very difficult because they must have the appropriate security to prevent their damage or destruction, replicas of the material standards are not available for use at other places, they cannot be easily reproduced. It is very difficult machining exactly perfect 0, 0, it is very difficult. I will tell you a simple problem suppose let us assume you have a disk of 5 millimeter, disk of 5 millimeter, you length right and the dia is around about 20 millimeter, you want to maintain the flatness between these two. These two surfaces should be parallel to the highest accuracy of 1 micron, we cannot generate the surface. So, easily and here wherein which all throughout the length of 102 centimeters are maintaining a copper brass, this is extremely difficult for you to maintain to machine. So, under once you machine it also, it is not possible for you to replicate several times. So, this is the major problem with the material standards the comparison and verification of the size of the gauge exposed considerable difficulty.

And if it is high it is available at one place, so all this calibration has to be done as against this. So, it has to be moved and then you have to get it done calibrated and then it will be moved to the other standards.

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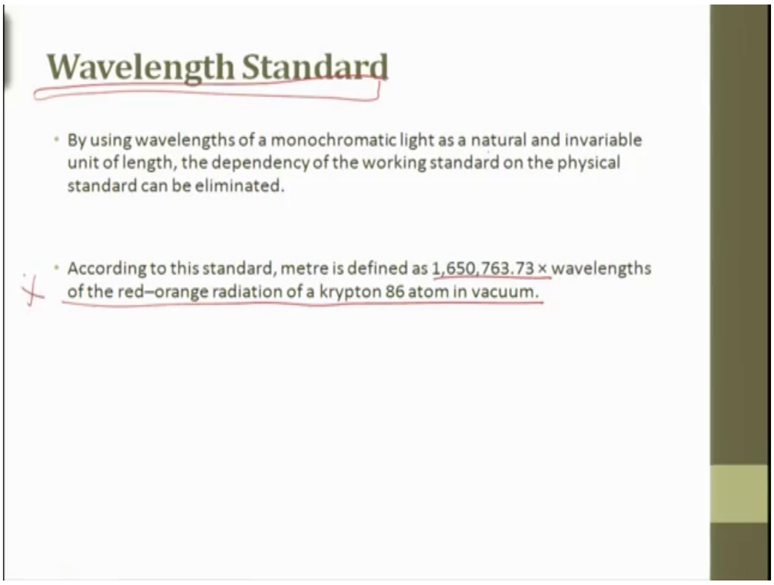

So, the easiest way of doing it is wavelength, Wavelength Standards. So, the length if I could express in terms of wavelength, so, then it is very easy and then it is economical and there is no past, there is not a material dependent parameter. By using wavelength of a monochromatic light as a natural and invariable unit of length, the dependency of the working standards on the physical standards can be eliminated. So, that is how the length standards today we always talk in terms of wavelength. According to this standard, meter is defined as 1650763.73 into wavelength of red, orange radiance of krypton 86 atom in vacuum. So, this is a very important point, we were moving out of material based standards to light base standards. Light is repeatable, light is reliable, light is economical to maintain the standards.

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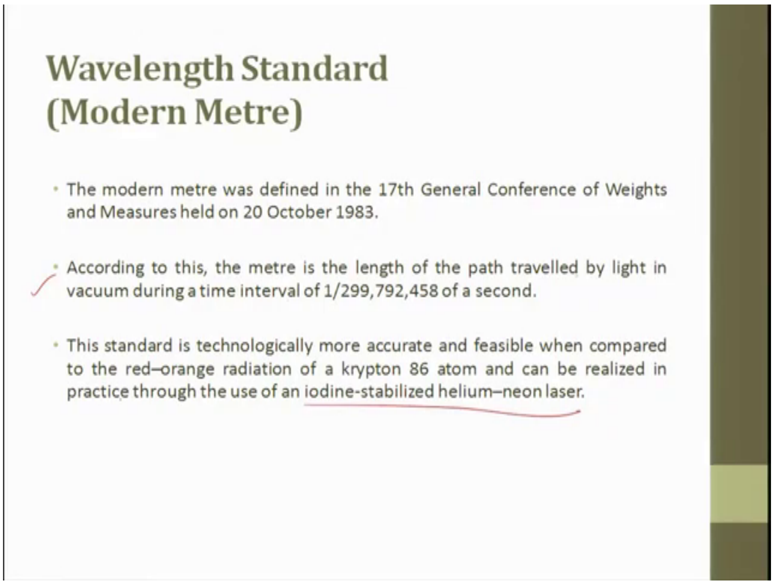

So, the modern meter was defined in the 17th general conference of weights and measurement held on 20th October 1983. According to this meter is the length of a path travelled by length in vacuum during a time interval of 1 by 299 comma 792 comma 458 of a second. So, this is the definition which is accepted for meter. This standard is technologically more accurate and feasible when compared to red orange radiation of krypton 86 atom and can be realized in practice through the use of an iodine stabilized helium-neon laser gaseous laser. So, using a gaseous laser, you can try to make a standard and we can try to measure wavelength.

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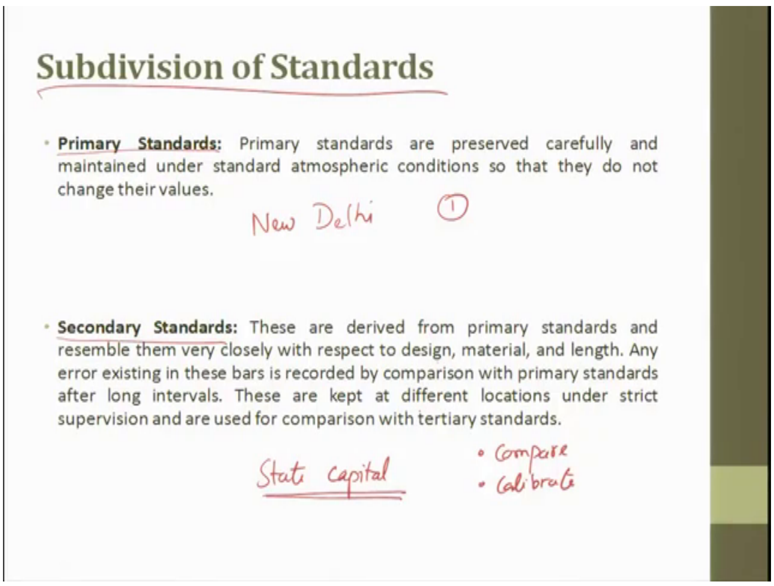

So, what are the different types of standards? There are four types of standards; one is called as primary standards, the next one is called as secondary standard, the third one is called as ternary standards and the fourth one is called as working standard.

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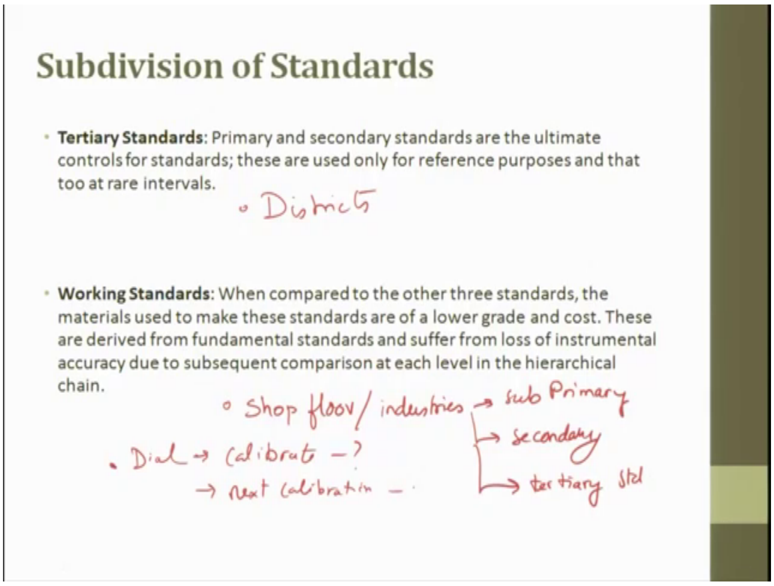

Primary standard are preserved carefully and maintained under standard atmospheric condition, so that they do not change their values. So, generally this primary standard will be kept in one in a country in one place. For example, as far as India is concerned, NPL maintains most of the standards, national physical laboratory and which is located at Delhi. So, here what they will do is, they will try to have one standard; one standard in terms of length measuring; that means, to say if they will have a device or may be a bar or a laser light whatever it is they will have one standard which is kept in a very controlled atmosphere and they all makes sure that there is no changes which is happening to it.

The next one is called as secondary standards. These are derived from primary standards and resemble them very closely with respect to design, material and length. Any error existing in these bars is recorded by comparing with a primary standard after a long intervals. They are kept at different locations under restricted supervision and are used for comparison with ternary standards. So, here for example, let us assume the standard sample in India is kept at Delhi. So, then each state will try to have state capital might have capital or any other place, might have a secondary standard. So, what they do is, once in a year these standards are calibrated. What is calibration? A process of verifying whether the my instrument and the standard instruments they are working proper. Suppose if there is error, then they quickly try to find out what is the error and correction is made.

So, this is secondary standard, secondary standard. So, you will have one, 1 standard a master piece in this discussion with respect to length. You will have a master piece at Delhi and then you will have several replicas of this master piece at several capital heads. So, this they will try to compare and then they try to calibrate. If there is any error, they make the corrections and then the standards secondary standard is corrected and sent to the capital state. Again here, it is also having a restricted en restricted access or entry, the third one is called ternary.

So, this can be in every something like every districts ok. Primary and secondary standards are the ultimate control of standards, these are used only for reference purpose and that to at rare intervals ok. Ternary is from the secondary, primary and secondary rare, they are kept at rare they are set rare intervals. This ternary is frequently checked with the secondary and it is calibrated. And the last one is the working standard which can be at every shop floor. Again every shop floor or an industry, they will have their industry something called as sub primary and then each industry might have several shop floors.

So, there they will have secondary and last, they will have at the bench where the instruments where the machining operations, it is called as ternary standards. You can have this, but every industry has to check their working output with the ternary you can have something like this. It is basically a hierarchical when comparing with the other three standards, the materials used to make these standards are of lower grade and cost, they are derived from the fundamentals standards and suffer from a loss of instrumental accuracy due to subsequent comparison at these level in the hierarchical change.

So, what we are trying to do is primary, from primary it goes to secondary; from secondary it goes to ternary from ternary it goes to working standard. So, here basically, this will be of a very high quality to be maintain at a very high quality the room or controlled atmosphere will be there; next slightly lower to that material and atmosphere.

The next one will be the common use whatever we do and the last one will be the regular use.

So, here it will be more of dial gauge if you see any dial gauge at the back side of the dial gauge, they say when was it calibrated and then they when and then they will also say next calibration. In an every dial gauge, in an every instrument, they will always have this data. So, looking at this data then immediately the dial gauge the instrument or the scale or gauge, whatever it is will be sent immediately to the to the working standards room, it gets checked and then it comes down to the table. So, these are the sub divisions of the standards.

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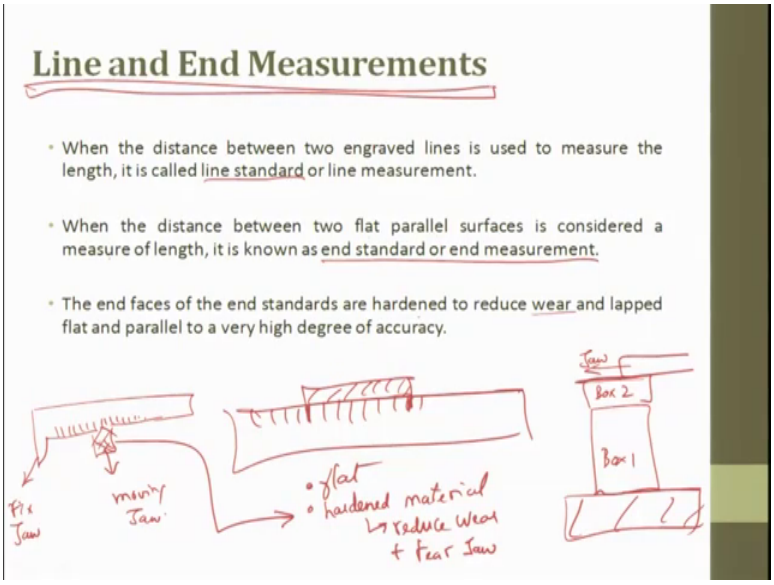

Now, let us get into line and end measurements ok. When the distance between two engraved line is used to measure the length, it is called as line standard or line measurement, you have a scale. So, here is an object ok, the distance between two engraving lines, two engraving lines is used to measure the length is called as the line standards. When the distance between the two flat surfaces is considered; for example, I have a box, I have another box, so I measure this surface. So, this is a box 1, this is box 2 and this is a jaw, main jaw or fixed jaw whatever you say. So, when the distance between the two flat parallel surface is considered, a measure of length, it is known as end standard, end measurement. So, slowly we have finished all the basics, we are getting in now linear measurement. The end phase of the end standard are hardened to reduce so;

that means, to say the end phase where there is lot of contact the end phase of the end standard are hardened to reduce the wear and lapped and parallel to very high accuracy is maintained.

So, because at if you see vernier caliper something like this, so, this is a fixed jaw. This is a moving jaw, right. So, what are we talking about is this surface. So, this surface has two points, one. It has to be as flat as possible right and then second thing it has to have a hardened material so that, whenever it is in contact with any material it does. So, it reduces wear and tear, reduces wear and tear of jaw right, because if this fellow is there is a wear and tear, no naturally it is sliding on the main scale. So, the reading whatever you get will be inaccurate. So, here we have seen two measurements; one is line measurement and end measurement. Line measurement is if you try to place an object between two lines and try to take a measurement it is called as line measurement; two ends if you take it is called as end measurement.

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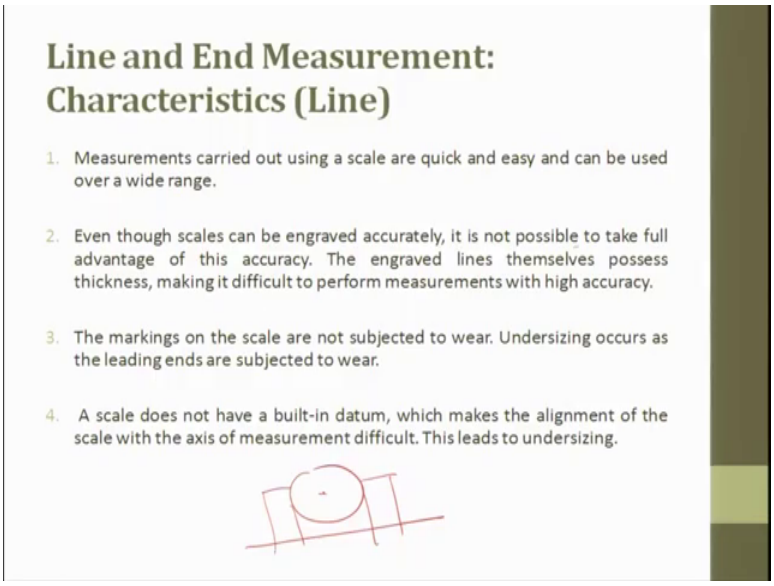

Measurements carried out using a scale are quick and easy and can be used for over a wide range. For example, you have a tape, this tape if you want to measure the height of a person or height of a table or width of a table, we use that scale quickly, grab it and then measure it and then come out of it. Even though scales are engraved accurately it is not possible to take full advantage of this accuracy. The engraved lines themselves possess thickness making it difficult to perform measurements with high accuracy. So, that is true.

Suppose, when you try to take a scale or a measuring tape this measuring tape has a zone sag or the measuring type has this small twist. So, whatever we measure, you will always say plus or minus some error will be there. So, will say it is 163 centimeter may be plus or minus centimeter. So, or we say plus or minus 2 millimeter, so, right. So, this is that is what we say in the measuring scale line, we will line measurement, we always will have is an error. The marking of the scale are not subjected to wear. Under sizing occurs as leading ends are subjected to wear, the scale does not have a built it datum which makes the alignment of the scale and the axis of measurement difficult. This leads to under sizing. So, what we are trying to say if you have an object, this when you try to measure the diameter of this object ok.

So, if it is a cylindrical one is ok, if it is a tapered one or if it is of skewed component, then we have to sure the measuring axis and the axis of the instruments should either be parallel or perpendicular to avoid error in measurement.

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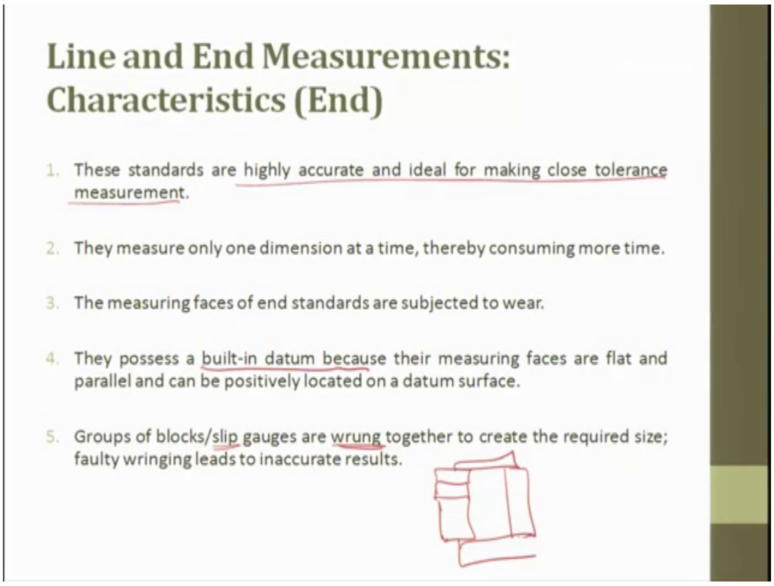

So, End measurement. So, these are lined and these are end measurement characteristics. They are highly accurate and ideal for very close tolerance because we are trying to encapsulate end to end. So, here you will make sure the alignment everything is proper. They measure only one dimension at a time. They are more time consuming ok. So, the tailor always use line table, he never use end to end measuring phase of the end surface are subjected to wear which we have already discussed.

They pose the built in datum because the measuring phase are flat and parallel and can be positively located on the datums surface, a group of blog slap slip gauges are run together to create a required size, the faulty wringing leads to inaccurate results we will see what is slip gauge in the in the due course of time. So, what is slip gauge at this point of time? Suppose let us have a block, you have a several blocks of flat plates which are attached. So, you make sure all this flat plates are attached to each error without any gap. So, how do you make sure, that is what is the run operation we do. So, they do not have a gap in between and they also do not have any inaccuracy on the flat surface. This is for end to end measurement; this is for end to end measurement.

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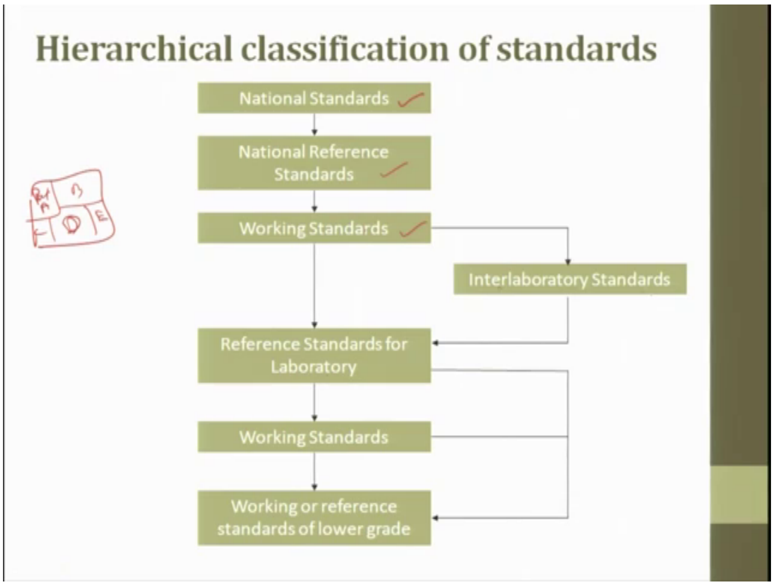

Let us now move to hierarchical classifications of standard. You will have a national standard, then you will have a national reference standard, you will have a working standard which we saw national standard. So, if you want to say primary standard, it can be in one part of the world, then you can have a secondary which is common to one continent, then the third one the ternary can be according to a nation, then fourth one can be according to your company.

So, it is the hierarchy we have to see how does it go and then you have to balance it. So, it is national standard, then national reference standards you have next one and then the third one is a working standard, then you will have reference standard for working. So, national reference standards, you have reference standards for laboratory, then working standards, then working reference standards at a lower grade.

So, at every standard you have, then you will also have a reference which with respect to that nation we have that standards. So, working standard you can also have inter laboratory standard. Why is this inter laboratory standards we talk about? For example, if there is a product which is made up of 5 parts; part A, B, C, D and E and if all the companies have their own calibration and their own standards, then what will happen is then the same product is moved to the next laboratory, there will be a mismatch of or there will be an alignment problem. So, in order to avoid it what we do is, the working standard whatever you set in the nation will also be set to all the labs, inter laboratory standards you will refer it and then everybody maintains almost the same.

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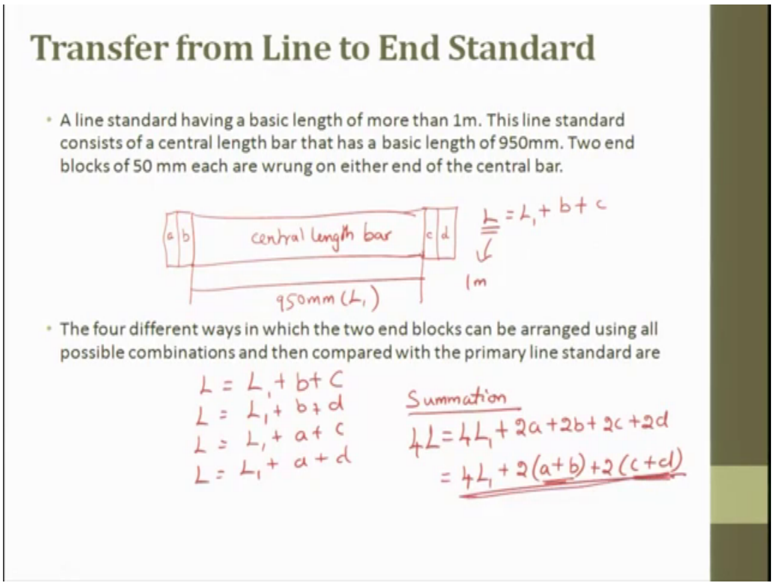

So, the next topic will discuss about transfer from line to end standards. As I told you, end standards if you have, it is here there will be not much of error. In line standards, there is a possibility of error. So, we are trying to convert as much as line standards is there to end standards. So, we can reduce the error. A line standards having a basic length of more than 1 meter, the line standard consists of a central a length bar that has a basic length of 850 millimeter. So, what we are trying to say is, we are trying to say there is a bar ok, the line standard consists of a central length bar, this is a central length bar of 950 millimeter. At both the ends, there are blocks both end blocks of 50 millimeter each are run on either sides of the center bar. So, this is a center bar on either sides what they are trying to say is, they are trying to say we are ringing with two blocks.

So, these are the two blocks. So, now, this is, so, this is 950 centimeter. So, this is a central length bar and this is 950 centimeter. So, what we do is we try to take this is block a, block b, block c and block d. So, each block put together is for 50 millimeter. So, then it sums up to ha 100 millimeter right. So, now, there are four different ways, there are four different ways in which two set of block can be used. So, let me write the equation L equal to the total length of 1 millimeter, 1 meter will be equal to L equal to this L 1, L 1 is that 950 plus b, b, c.

So, these are taken one blocks here, one block to the b and c. So, if we have two blocks for convert sides. So, we can have four different possibilities. What are the four different possibilities and this is your L 1 by the way hmm. So, here L is the total length of 1 meter right. So, what are the four different ways of combination? L can be written as L 1 plus b plus c, then L can be written as L 1 plus b plus d, L can be written as L 1 plus a plus c, L can be written as L 1 plus a plus d ok. This there are four different ways of because this, this four different ways you can do it ok.

So, here what are the four different way 2 blocks are used. So, b c, a c, a then b c b d so, there are four different place. So, when you try to sum them up, so, when you try to summation of all these things will be 4 L equal to 4 times L 1 plus 2 times a, plus 2 times b, plus 2 times c, plus 2 times d ok. This can be written as 4 times L 1 plus 2 times a plus b and it can be written as 2 times c plus d ok. Now, if you want, you can try to represent this a b, you can convert this with c d and then you can start writing it in different forms ok. So, this is what we want to convey.

So, here this is length bar and these two, we are attaching with two slip gauges, we run it basically when you try to attach to slip blocks. There can be a possibility of air or thin film or non contact. So, what we do is we make sure that these two surfaces are tightly in contact. So, tightly in contact, we try to kill off the thin film whatever is there and then we try to rung it or ring it they say ring and then these two are attached properly.

So, we make sure there is no gap to it. So, what we have done here? we have done here that this is the center bar, we are taken a block a the b or we can take c or d. So, we can join this giving various combinations and finally, we can sum it up and write it in this form.

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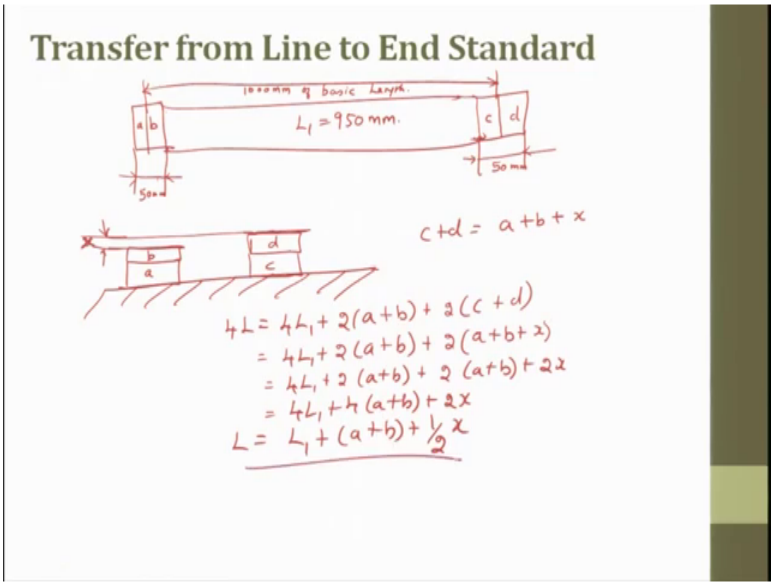

So, here what we are trying to do is, we are trying to again let us go back to the same example ok. So, this is your L 1 which is equal to 950 millimeter, this is your a, this is your b, this is your c and this is your d and this is 50 millimeter and this is also this is also your 50 millimeter and this is what is your 1 millimeter of basic length ok. Now, see if at all there is a small error, if at all there is a small error, so, how can there be an error? So, what is happening is just I magnify, I take a block, I take b block. So, this is a, b which is supposed to be 50, I take c and d, c and d. It is supposed to be 50 and this is also supposed to be 50. So, I put it on a flat plate and a surface plate I put this and then I keep this two block which is supposed to be 50, but if you try to see in a very macroscopically, I zoom the mistake and other things, I see here there is a small amount of I would say x.

So, this x there is a small amount of error, error or difference in height when I do these two blocks right. So, when I then you now look at a see suppose if I take an error and get added to it, so then it looks very difficult for you to get the basic length of 1000 millimeter, I am just taking as a example and I say there is an x component which is there. So, now, how do I write it is c plus d equal to a plus b plus that small difference of x, ok.

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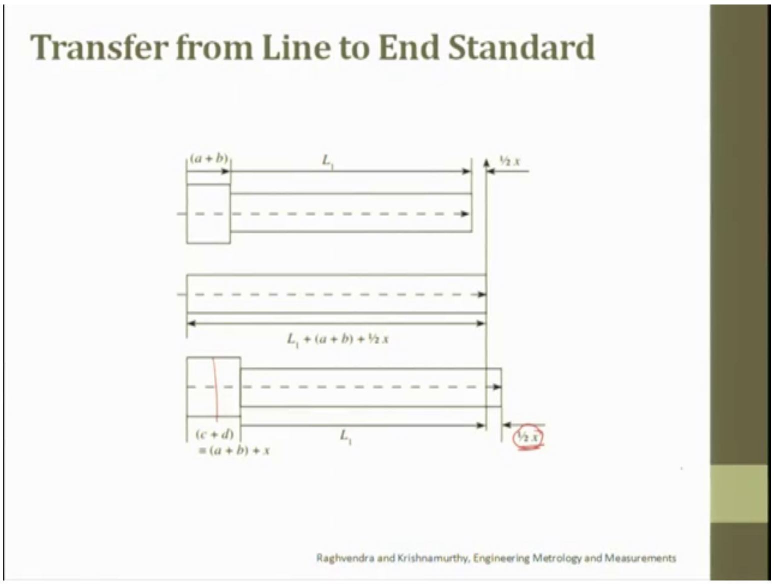

So, now if you look at it, this is what is a plus b. This is your L 1 and this is your x, this is your x before this. So, now, summation of this 2 a plus b, plus 2 is c plus d and then what we say is we are having a small.

So, now this difference ok, so now, if I go back and try to take the same equation of here I rewrite this equation here. So, when I rewrite this equation, we write it as 4 L equal to 4 L 1 plus 2 times a plus b plus 2 times c plus d right. So, now, I replace this c plus d by this a plus b. So, now, it is 4 times L 1, 2 times a plus b plus 2 times, I write it as a plus b plus x and then I finish it. So, now, this if you try to do it, it will be 4 times L 1 plus 2 a plus b plus 2 a plus b plus 2 x. What is this x; x is the small error whatever we had. So now, we if we try to rearrange, it will be 4 times L 1 plus 4 times a plus b plus 2 x. So, this is 4 L. Now when you try to divide both side by L and other things what you get, L equal to L 1 plus a plus b plus half of x.

Now, if I want it to represent this in a figure, so you can go and look into it here. So, you can say a plus b I have taken, L 1 I have taken and there is a half x which is the error or which is some small missing data which has to be there. If everything is perfect, then it is going to be here L 1 a plus b plus half x will give you 1 meter. Then I put c plus d, this half will be extra. So, what will happen is you will see that the end to end gauge when I put the blocks c plus d, so it is nothing but a plus b plus x. So, it will be a projecting outside. So, what is getting to be to projecting outside is nothing but half x ok. So, now, you are able to understand. So, what we did in this two exercises was, we were trying to take a center line and then we were trying to take two blocks of 25, 25 added on both sides, so that we made it a an end standard. We converted the line into an end standard and then from here what we did was we did calculations and we tried to the represent get to know the error also ok. This is what it is a plus b half x is less, c plus d half x is more ok.

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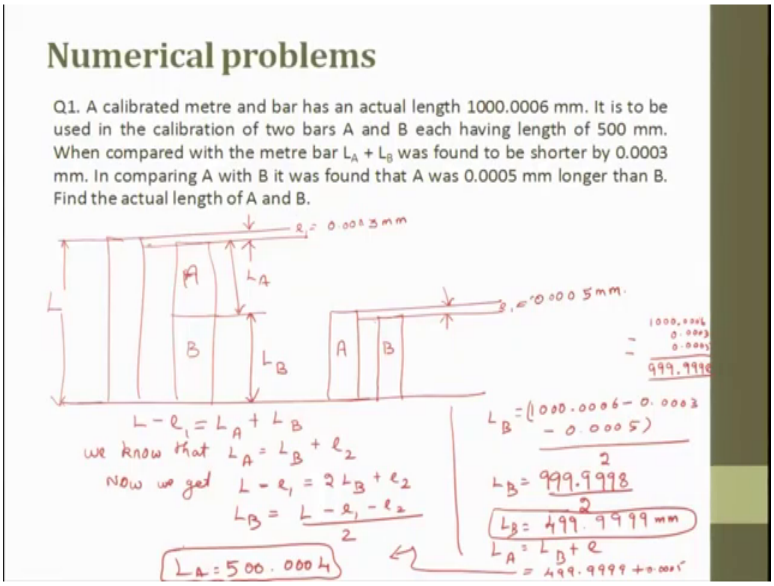

Now, let us look at problem statement and we will work with two problems. So, the first problem is a calibrated meter and a bar has an actual length of 1000.0006 millimeter. It is to be used in the calibration of two bars a and b each having a length of 500 millimeters. When compared with the meter bar L a plus L b, we found out to be the shorter by 0.0003. In compare a with b, it was found that a was 0.0005 millimeter longer than b. Find the actual length of a and b. So, what we are trying to say, we are trying to say here is it.

So, this is now split into two blocks ok. This is going to be your L ok, this is going to be your A and B, this is your a this is your B and then what do you say is we say between these two guys, there is a there is a there is an error of e 1 which is nothing but 0.0003 ok. So, this is this is L A and this is L B ok, then we also give you one more data what we say is we say A and B, A and B, they also have an error or this error is nothing but difference in height e 1 of 0.0005 millimeter. These are in millimeter ok.

So, now, what we have to do, we have to from all these figures what we have we know that L minus e 1 minus e 1 equal to L of A plus L of B, right. We know that L of A equal to L of B plus e 2. So, now, we get L minus e 1 equal to 2 times L B plus 2 times L B plus e 2. If you want to write it on your other way round, we can write it as L B equal to L B 2 times. So, L B equal to L e 1 minus e 2 whole divided by 2 is equal to L B ok. Now, substituting the value of everything, so now, substituting the value of L B, L B is we can take it as L B. So, L b equal to 1000.0006 minus error of 0.0003 minus 0.0005, right. So, the whole whatever it is that divided by 2.

So, what we get L B equal to L B equal to, so now this becomes 1000.0006 minus 0.0003 and minus 0.0005. So, it is approximately 8, you have to minus. So, when I subtract 8 from here, it becomes 999 point it got it is 9, it is 999 and this is 3 and 4, 3 and 4 one more, one more here so, it is 9998 may be. So, it is 8, 16. So, 16 is 8, so it can be 999.999 and I just have to check, so if this is one more and this is also one more. So, it is 9998 correct 9998 divided by 2. So, this L b will be equal to 499.9999 millimeter.

Now, if I know this, so now, I know why so, now, I have to calculate A. So, calculation of a will be L A equal to L B plus e ok. So, this is going to be 499.9999 plus e, e is 0.005, 0.0005 which is I will try to write the answer here, try to write answer here. So, which is nothing, but 500.000 it is 4 ok. So, this will be your L, this will be your L A. So, this will be your L B, this will be your L B and this will be your L A. So, now, are you able to find out if there is a small error, how do we calculate.

So, we first step is we should understand this is the length I want, I have two round, I have two slip gauges or two blocks which is expected to be 500, 500. When I put it on top and find out there is an error, then these two blocks also there is an error. So, now, we are trying to find out how to sort out this thing. So, what we have done is we have converted an a line scale a line measurement in to an end measurement.

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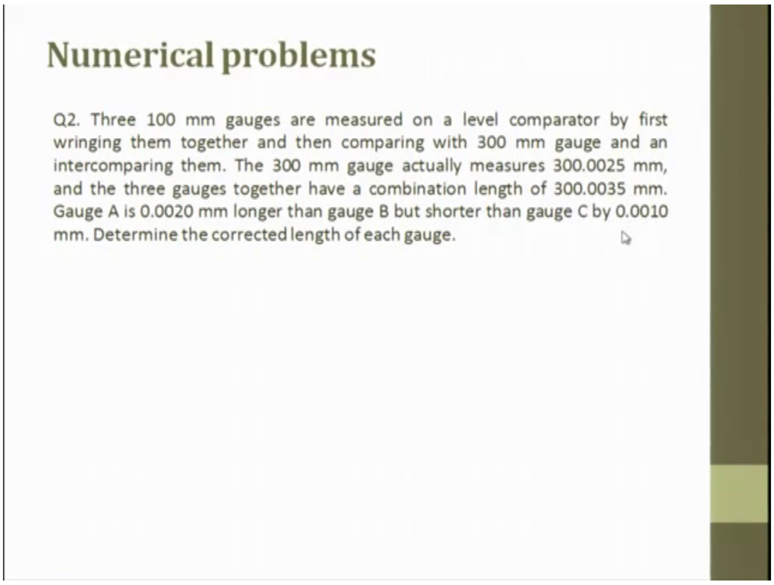

So, let us try one more problem. So, this problem is also very easy. So, let us look at it. So, there are three 100 millimeter gauges are measured on a level comparator by first ringing them together and then comparing them with 300 millimeter gauge and inter comparing them. So, 300 millimeter gauge actually measures 300.0025 millimeter and the three gauges together have a combination of 300.0035. So, the gauge A is so much longer than B, but B is shorter than C by this much. So, determine the correct length.

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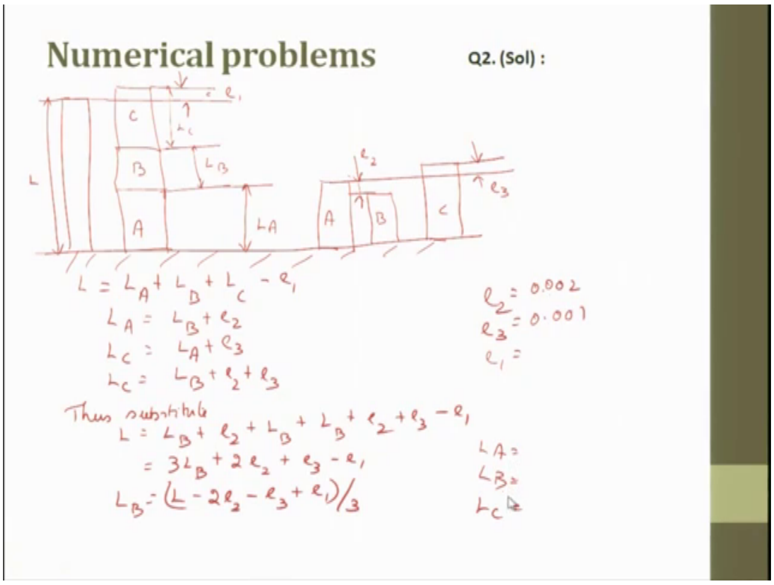

So, you will try to solve this problem. So, first what we do is we try to take L which is length scale. So, this is L and then next to it we have three gauges attached. So, now, I have also set this is slightly larger. So, I will try to take, I will try to take here. So, I will do one block, two block and three blocks right. So, I have said that C, B and A. So, you can see here, this is the error which is nothing but e 1 and in turn this is my L C, this is my L B, this is my L B and this is my L A ok. Now the next thing in this is your base next thing that we have said we have said that, you have L A, then you we have L B, then we have L C right.

So, what we said was, we said A, B and C. So, between A and B, you will have an error of e 2 and between A and error C, we have an error of e 3 equal e 3 right. So, we have e 1, we have e 2, we have e 3 fine. So, now, let us solve the problem. So, first what we do is, so we take the lengths L A, L B, L C is given for A, B, C block when I when the lengths is given and it is said as L A, L equal to L A plus L B plus L C minus e 1 will be your L and, then what I said is I said L A equal to L B plus e 2 then I said L C equal to L A plus e 3 and then L C equal to L B plus e 2 plus e 3 ok. Now, what we do is thus when you try to substitute all, thus when you substitute each and then do all those things, so what we get is we get L equal to L b plus e 2 plus L b plus L b plus e 2 plus e 3 minus e 1.

So, this can be further simplified as 3 L B plus 2 e 2 plus e 3 minus e 1 or it can be L B equal to L minus 2 e 2 minus e 3 plus e 1 whole divided by 3 ok. So, now, what you have to do is, you have to start substituting all the values of e 2, e 3 in this things. So, what is your e 2, e 2 is nothing but a is 0.002 longer than b. So, this is your e 2. So, your e 2 is 0.002. What is your e 3, e 3 is something taller than e 1 right. So, how much was it taller? It was 0.001, it is 0.001 and what is your e 1, e 1 in the problem is the 300 gauge actually measures 0.00325. So, this is going to be e 1.

So, now, if you substitute all the values, you will get your end answer. So, your e 1 is going to be e 1 is going to be e 3 is given e 2 is given and e 1 is also given from the sum you can try to get this and then finally, you can try to find out what is your L A, what is your L B and what is your L C, which is just by substituting you can start finding it out and then you try to get the answer. You try to solve this, you will post this answers in the solution manual or in the discussion forum we will try to put this ok. So, from the question, you can try to get the value for e 1 and then you can substitute it here, then what you get end answer will be L A, L B, L C ok. Please try to solve this and we will post the answers of L A, L B, L C in the solutions.

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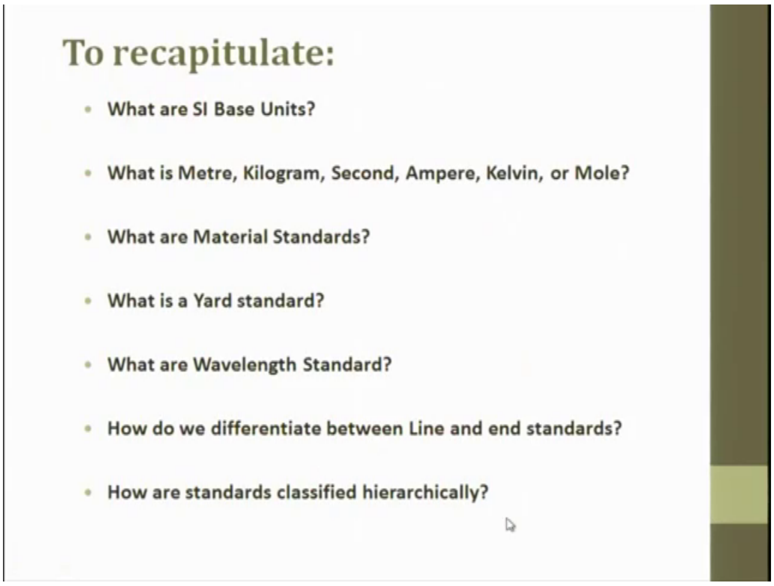

So, to recap whatever we have seen in this particular lecture is we have seen first what is what are the SI based units, then what is meter, definition for meter, kilogram, second, Ampere, Kelvin or mole. Then we saw material standard two different material standards, then we saw yard standards, then we saw wavelength which is more common and then we saw how do we do differentiate line and end standards.

And then, we also saw the hierarchical classification of standards. Now, I have a question. So, take home there will be a question for the students ok.

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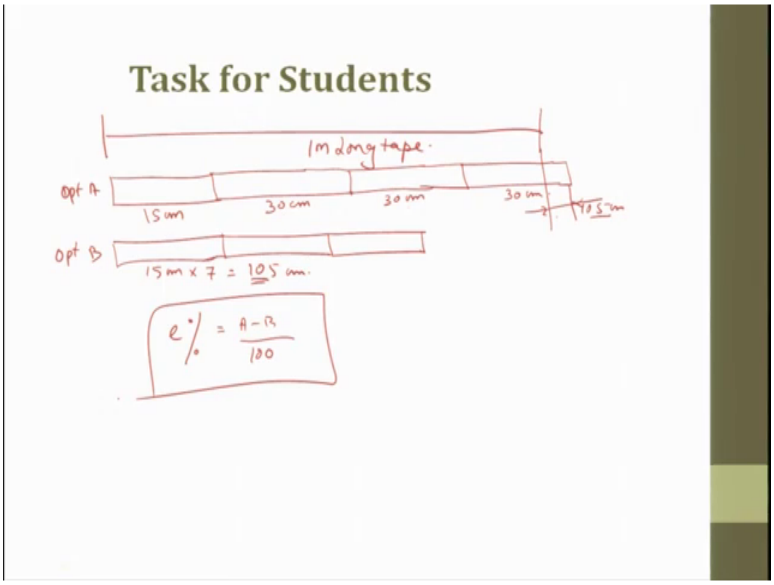

So, now let us try to take 1 meter long, this is 1 meter long tape ok, 1 meter long tape then, let us try to take 115 centimeter scale and then we will try to have one more, one more scale which is 30 centimeter, one foot, half foot 2 scales right. And then, we would also try to have one more 30 centimeter. So, it is 60, 75 and then we will have one more scale of 30 centimeter right, so, this 30 plus 30 plus 30, 90, 105. So, we have 15 centimeter scale and we have 30, 30, 30 scale. These are scales which are blocks right.

So, now, I sum it up and then I try to measure this 1 meter. Of course, there will be a 5 centimeter error. There will be a 5 centimeter error, try to understand. So, now, with this scale you try to add up the scale and try to measure this one meter long tape and now what I would request you is I want you to take another set of scales and then try to have all with only 15, so many 15s. So, it will be 6 time 90 and then it will have 7 time 105. So, it will be 15 centimeter scale, 7 times which is equal to 105 centimeter. This was 30 plus 30 plus 30 plus 15, it was 105 right.

So, now, you have 1 meter long tape or scale or whatever it is you have one. And now, what you have is you have pieces of small scales, you sum it up it came to 105 you had another variable you did not have 30, but you have so many 15 and also the sum was 105. Now what I want you to do is try to measure this 1 meter by using this combinations and try to figure out is there any error has happened between this 105 and this 105. If at all there is a error, try to find out the error percentage between option A and option B, option A and option B. Suppose if there error, find out the error percentage has to be 100 percent.

So, you have to do, if A minus B and B minus A, I do not know that. So, that a assuming that A minus B, find out what is the total sum coming, what is the total sum coming and then try to figure out this. So, what we are trying to say is though we know there is a 1 meter long scale and if I take a small pieces of small scale if I sum it up, do I get to do it a same value or between these two options, is there any error? Both are going to be a combination of different scales. Please try to do this experiment for yourself, then you will start appreciating whatever we have learnt and the chapter whatever we have learnt, we are talking on micron accuracy. Here we are talking on centimeter accuracy ok. So, thank you very much and let us discuss in the next lecture will be limits, fits and tolerance.

Thank you.