Experimental Physics - II
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Lecture - 04
Summary of Experimental Physics - I (Contd.)

Let us continue the Summarizing of Experimental Physics I.

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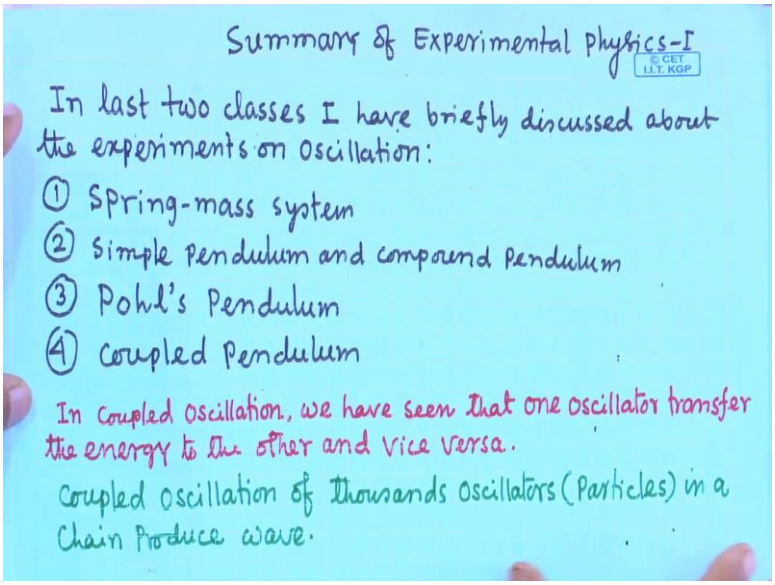

In last two classes I have briefly discussed about the experiments on oscillation. Basically spring-mass system, simple pendulum and compound pendulum, Pohl's pendulum, coupled pendulum. So, in coupled oscillation we have seen that one oscillator transferred the energy to the other one and vice versa. So, coupled oscillation of thousands oscillator together in a chain basically produce wave. So, let us see the wave experiments; on wave also we have demonstrated experiments in Experimental Physics I.

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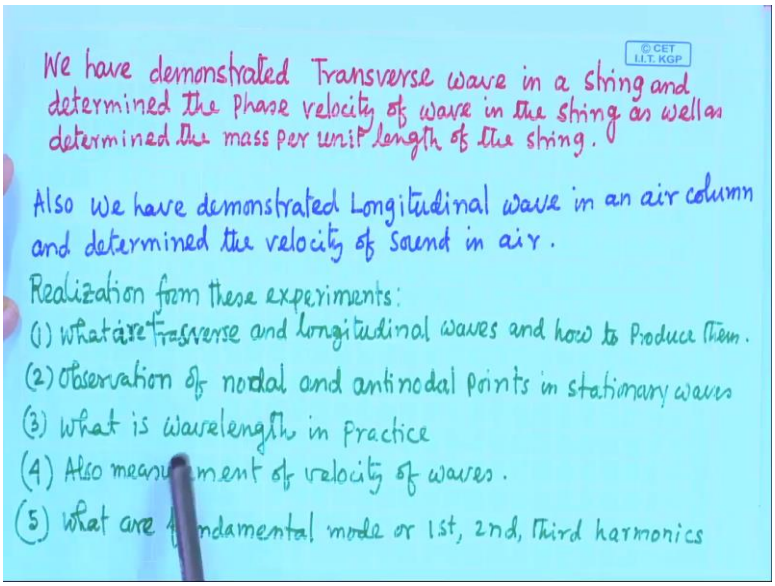

We have demonstrated transverse wave in a string and determined the phase velocity of wave in the string as well as we have determined the mass per unit length of the string. Also, we have demonstrated longitudinal wave in an air column and determined the velocity of sound in air.

From this experiment we have realized that what are the transverse and longitudinal waves and how to produce them. Observation of nodal and anti-nodal points in stationary waves; what is the wavelength in practice; in string vibration we have seen the nodal and anti-nodal points. And the wavelength they are this between two nodal points.

This wavelength is basically $\lambda/2$. So, 3 nodal points, if you take distance between 3 nodal points or 3 anti-nodal points, that is λ. That in practice we have seen, we have realized, also we have measured the velocity of waves; how to measure the velocity of waves that also, we have seen and we have realized that what are the fundamental mode or 1^{st}, 2^{nd}, third harmonics, right.

So, changing the frequency in the string, we are able to generate/produce the waves of different harmonics. First harmonics will be $\lambda/2$ for the length of the string. This is the fundamental mode or first harmonics. Similarly, changing the frequency we are able to generate the 2nd harmonics, then third harmonics.

These are basically, whatever in theory, in books we read. These things practically we observe in our laboratory. Then, we demonstrated experiment on moment of inertia; moment of inertia of a wheel, basically flywheel.

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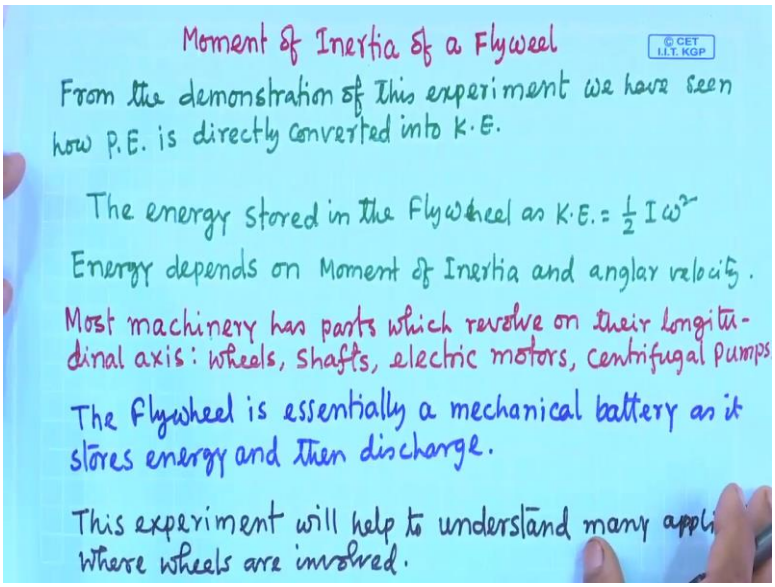

Moment of inertia of any object which rotate, which has rotational motion; you know that this moment of inertia and mass, these are basically equivalent. Whatever the function of mass in case of linear motion, the same function of moment of inertia in case of rotational motion; like in one case this force, another case is torque, right. So, moment of inertia of any object one can find out. In our laboratory we have taken flywheel.

Theoretically it is difficult to calculate these moment of inertia of flywheel, but experimentally it is not difficult to measure. From this experiment, from the demonstration of this experiment, what we learned or what we have seen, that is the basically conversion of potential energy directly into the kinetic energy, right.

We realized practically, we have seen that a small mass at a height h when it is released, that time potential energy is mgh. When height is decreasing and simultaneously the speed of the wheel is increasing, the rotational energy of the wheel is increasing, right. So, it is a direct conversion of potential energy into kinetic energy.

And they are conserved; from that conservation, basically we found the moment of inertia of the flywheel. So, the energy, actually this kinetic energy, it is due to rotating;

that means, from potential energy, potential energy is transferred to the wheel and wheel is rotating with an angular velocity omega.

As if the energy stored in the wheel that is half I omega square. This energy, from here you can see, depends on the moment of inertia and angular velocity. Most machinery has parts, which revolve on their longitudinal axis; wheels, shafts, electronic motors, centrifugal pumps, everywhere the wheels are used, right.

The flywheel is essentially a mechanical battery; it is used as a mechanical battery as it stores the energy and then discharge. There are lot of applications of this wheel, flywheel. This experiment will help us to understand many applications where wheels are involved. Next experiments we have demonstrated in experimental physics I,

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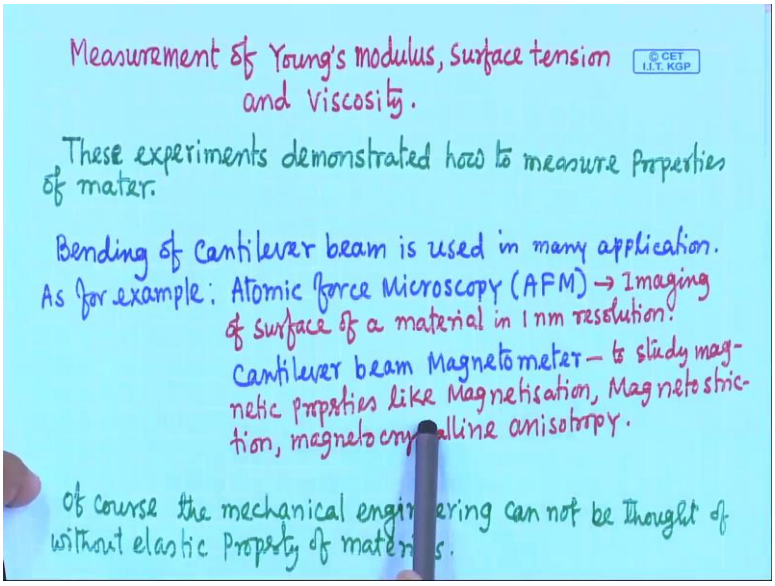

that is, experiments of Young modulus, surface tension and viscosity. These three experiment, I mentioned here together, because they are related with the elasticity; it is related with the properties of the matter.

How one can measure the property of matter. From these experiments, like young modulus, surface tension, viscosity coefficient. These are the parameters which tell about the properties of the material, of that matter.

In case of Young modulus, we used cantilever beam method. We used cantilever beam and bending of beam is used in many applications. As for example, this instrument is

called atomic force microscopy. This is used for imaging the surface of the material; it is used to see the morphology of the material, what is the structure, atomic structure of the surface, of the material.

That imaging of surface of a material in 1 nanometer resolution; so using this atomic force microscopy we take image of the surface in 1 nanometer resolution; very very useful instrument for research in material research. In this case, this cantilever bending is used; that is the heart of this instrument. I think you will be knowing about this instrument later on.

Then this is another instrument, cantilever beam magnetometer, which I use in my laboratory, research laboratory. This magnetometer is used to study the magnetic properties like, magnetization, magnetostriction, magneto-crystalline anisotropy of magnetic material. This magnetometer uses cantilever beam principle; in this magnetometer also, the heart of this instrument is basically the bending of the cantilever. Whatever experiment we have done, this is not only that we have measured the young modulus.

But we have learnt about the bending moment theory and this bending moment theory is applied for other applications. I mentioned two of them, but there are many applications and this bending of the cantilever is very useful for application purpose. Of course, in mechanical engineering; mechanical engineering cannot be thought of without elastic property of materials.

Not only we have measured the young modulus, measuring young modulus, you can basically come to know the elastic property of materials; that is useful for mechanical engineering. This is the common use, but apart from that, also I mentioned, there are other applications of the bending of the cantilever.

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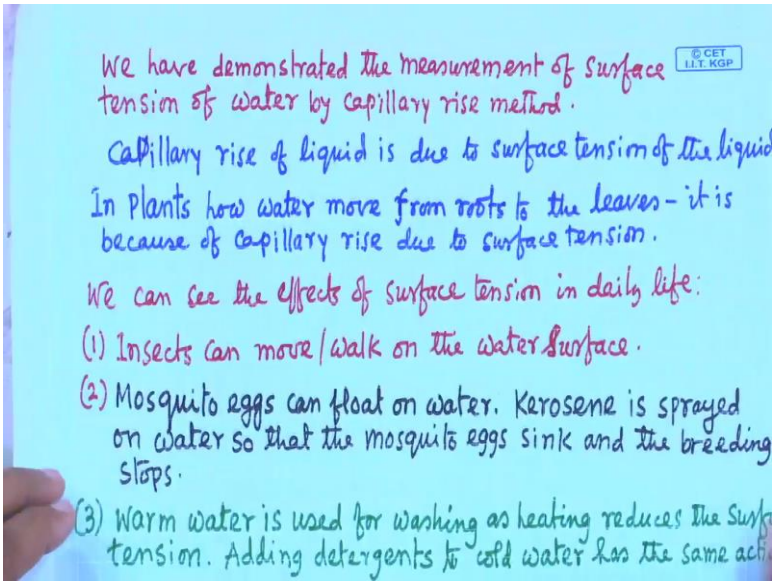

Similarly, for surface tension, we have demonstrated the measurement of surface tension of water by capillary rise method. We have seen that we have used tube with various smaller radius of hole; that is, we tell, basically a capillary tube.

We have seen that this water or liquid rise through this capillary tube, why it rises; that is because of surface tension. And it is balanced with the surface tension as well as the gravitational force downwards. That liquid column, it balanced with that gravitational weight, force which is downwards and the upward that is the surface tension.

So, these two forces, when balanced, that decides the rise of the liquid in the capillary tube. It is automatically, it just rise through the capillary tubes. That is because of the surface tension. This is because of this surface tension; we know in plants, how water move from roots in tree, how water moves from the ground to the leaf. So, that is because of this, that is basically because of the capillary rise due to the surface tension.

This is the natural phenomena, we can see in plants; also we can see the effects of surface tension in daily life; like insects can move or walk on the water surface. Small insects, they can walk on the surface of the water, on the surface of the liquid; that is because of the surface tension; also mosquito eggs can float on water, right.

That is why in rainy season time, water are in different places, they are stored and we are afraid that there will be lot of mosquito because of that stagnant water. So, we try to

avoid that stagnant water, because this mosquito, their eggs, it is provoked on the stagnant water surface. Because of surface tension and then it generates multiple number of mosquitoes.

To destroy that one, generally, I do not know whether you have noticed or not, we generally, people use kerosene oil. You know kerosene oil; kerosene oil is sprayed on water so that mosquitoes eggs sink and the breeding stops. Because, kerosene oil, it has surface tension, which is smaller than the water; when we will spread this kerosene oil then the mosquitos' eggs, no longer, it can float on the kerosene oil; because its surface tension is smaller. So, it is now underneath the kerosene oil.

Surface tension of the kerosene oil, that is used and these eggs are destroyed and so, you can stop the breeding of the mosquitoes. Another is the warm water, is used for washing. Why? Because the heating reduces the surface tension. So, when you are washing something, either cloths or the utensils; if surface tension is smaller, breeding will be better; thus this water can reach easily or liquid can reach easily into the place where you want to clean, very small pores and etcetera, right.

So, if surface tension is less, it is the better for washing. Warming water has less surface tension, because with temperature surface tension decreases of water. So, that is why, from experience, without knowing this physics, from experience people use the hot water or warm water for washing the cloths, for washing the utensils, right. So, reason is basically surface tension.

Also we add detergent. We tell that if we add detergent, cleaning will be better. Actually, addition of detergent also, it reduces the surface tension of the water, of the liquid. So, that is why adding detergent even in cold water, it has the same action. So, reducing the surface tension we can clean the things better, right. So, these are the practical applications in our daily life. Anyway, scientifically how we can measure the surface tension as well as what are the application of the importance of the surface tension in our daily life; that is what I tried to tell you.

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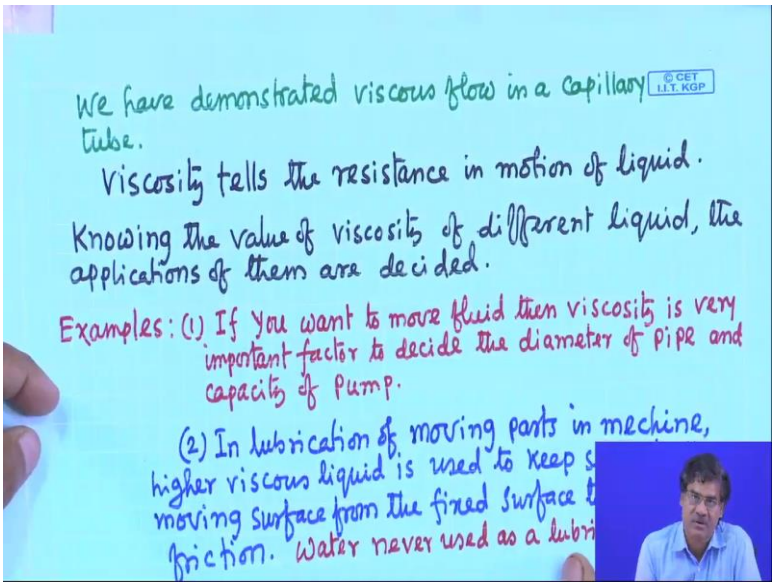

Next another experiment we have demonstrated the viscous flow in a capillary tube; we have demonstrated viscous flow of liquid in a capillary tube. Viscosity tells the resistance in motion of liquid; it is nothing, but the resistance, when liquid flows through a tube. So, when liquid have the solid liquid interface, during the motion of the liquid it feels the resistance. That we express in terms of the viscosity, coefficient of viscosity.

Knowing the value of viscosity of different liquid, the applications of them are decided. Where you want to apply, what is the coefficient of viscosity of the liquid, it is necessary, it is required to know. As for example, if you want to move fluid, then viscosity is very important factor to decide the diameter of pipe and the capacity of pump.

Which liquid you want to flow through a pipe and what is the viscosity of this liquid, depending on that one has to choose the diameter of the pipe as well as pump capacity of the pump. You want to pump the liquid through the pipe, you want to move liquid from one place to another place through a pipe. Which liquid you want to, whether water or whether some other liquids, the design of the pump and pipe size, its length, its diameter will depend on the viscosity of the liquid which you want to flow.

Another application of viscosity you are quite familiar that, for lubrication purpose we use the liquid. In our vehicles where something is rotating, there we use lubricant for

lubrication of moving parts in machine. Higher viscous liquid is used to keep separate the moving surface from the fixed surface to reduce the friction, right.

Say something is moving about an axle, about an axis. When it is moving, there will be friction between the rotating wheel as well as the axle. Wherever there will be friction, it will generate heat etcetera. We want to reduce this friction; for that what we have to do, what we need to do; we have to keep the contact surface of this wheel and the axle, we have to keep them separate.

To keep them separate we use liquid. If I use water, cannot keep them separate; because its viscosity is lower. So, we have to use a liquid which has higher viscosity ok. Then that will be able to keep separate the contact surface of wheel and the axel, ok. That is why we use mobil kind of things or some lubricant, its viscosity is very high compared to the water.

These are the practical application of viscosity and the measurement of coefficient of viscosity is also very important. One has to know the viscosity coefficient of liquids, which you want to use for applications. Next we have demonstrated few experiments.

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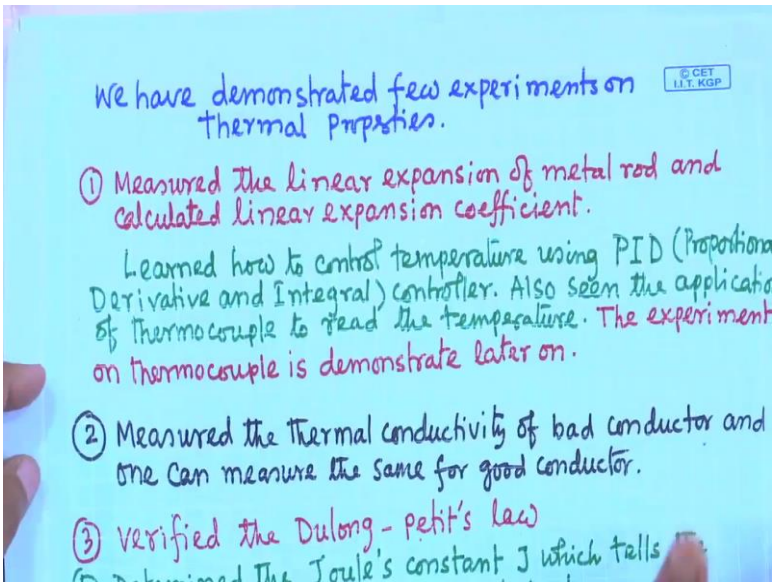

We have demonstrated few experiments on thermal properties. What are the experiments we have demonstrated? We have basically measured the linear expansion of metal rod and calculated linear expansion coefficient. From that experiments specially, we have

learned how to control temperature using PID controller; PID that is proportional derivative and integral controller. I explained during the experiment. I explained, how it controls the temperature; how it is very useful for precise control of temperature.

Also we have seen the application of thermocouple to read the temperature in this experiment. Of course, the experiment on thermocouple we have demonstrated separately of in our laboratory. Then another experiment: how to measure the conductivity of bad conductor and one can measure the same also for good conductor; methods are different, but we have demonstrate only how to measure the conductivity for bad conductor.

These are the parameters, you know the property of the material, thermal property of the material. For application it is very important to know the conductivity of different materials. We took probably glass when we were measuring. One can find out the same for other bad conductors: the conductivity, thermal conductivity.

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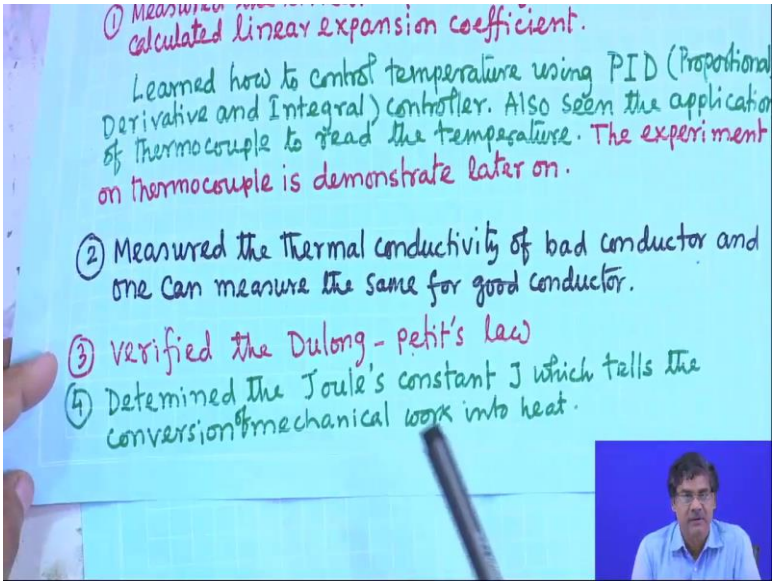

Also, we have verified the Dulong Petit's Law; this experiment we have demonstrated. Also, we have determined the Joule's constant J, which tells us, Joule's constant J tells us the conversion of mechanical work into heat; what is the ratio between the mechanical work and heat when they convert to each other, right. This is the fundamental constant, you know, J Joule's constant; that also we have measured in our laboratory. I mentioned already that the thermocouple was used for the measurement of temperature.

In most of the cases, this thermocouple is very useful for measuring the temperature, especially higher temperature in industry, in our laboratory, research laboratory for different instruments, most of the instruments where we measure the property as a function of temperature. We have to use the thermometers. So, basically these thermocouple is a very useful thermometer for measuring higher temperature. So, different kinds of thermocouples are there that I have described.

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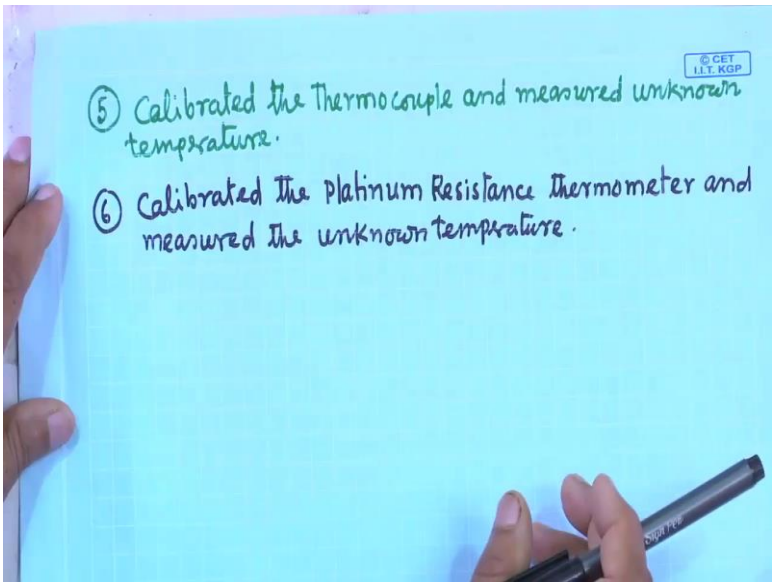

How to measure the temperature. How thermocouple is used for measuring the temperature. We have shown the calibration of the thermocouple in the laboratory; calibration curve for knowing the temperature; what is the EMF generated; what is the voltage generated; that first one has to calibrate the thermocouple. And then we can use that thermocouple for measurement of the unknown temperature. Also, we have discussed, we have demonstrated the platinum resistance thermometer and also we have measured the unknown temperature.

These are the experiments related to the temperature, related to the heat, related to the thermos-properties of the matter. We have demonstrated in the laboratory. These are the experiments, we have demonstrated, are non-electrical experiments; basically most of them. And now in thermal properties they are the junction between the non-electric and electrical where heat is converted into the voltage.

This is the junction between the electrical and non-electrical experiments. In next class, I will discuss about the experiments on electricity and magnetism, whatever we have demonstrated in experiments physics-I. Let me stop here.

Thank you for your attention.