Energy Resources and Technology
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Lecture - 34
Solar Pond & Wave Power

Today, we will cover two topics actually.

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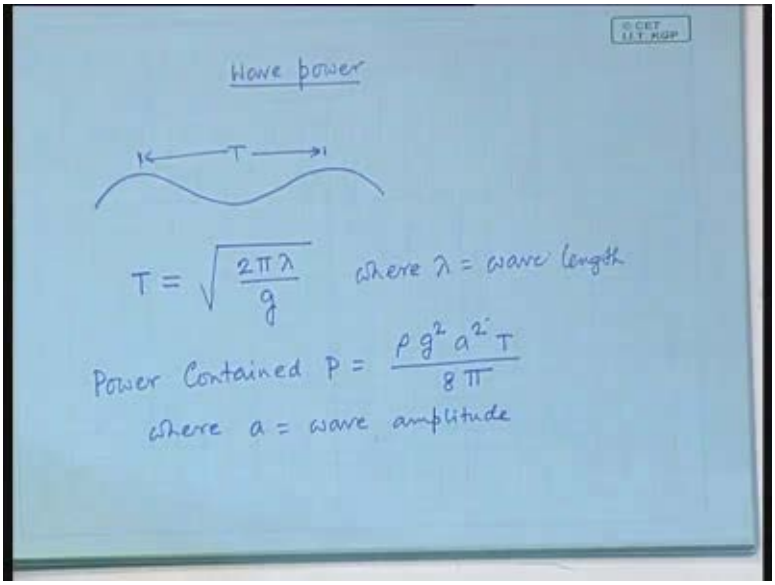

One is wave power and other is solar pond, I will come to that later. Now, as you know, there is a very large amount of energy that is available in the ocean waves and that is also solar energy in a different form, wind energy in a different form, but whatever it is, ultimately that is available in the form of the undulating motion of the ocean surface, because of the waves. You might ask how much is the energy available? It is actually very large. Often, we do not realize that when we go to say, the Puri coast, have you ever been there? Never, should go there; there is a reasonably large wave oscillation there and that you can easily feel that there is a large amount of energy available. But how large, how much is the energy available there? Well, you can do simple mathematics for that.

For example, if you have a wave going like this, then essentially the wave passes and so, if you look at a particular point, this crest will reach it at some point and the next crest will reach after some time. So, the time difference between the two may be called a T. That means T is the, assuming the wave is more or less sinusoidal in nature, T is the time period of that sinusoid. Now, the T can be expressed in this form where lambda is the wavelength. Now, T is necessary because the power contained in the wave is expressed as, where a is wave amplitude.

So, you can see that it is, rho is the density constant, g is constant, a is the wave amplitude, how big are the waves, that appears here and T is the wavelength, T is the wave, the time period between the two crests and this is constant. So, essentially the whole thing depends on the a; so, the amount of oscillation that you experience at a particular point and this allows you to calculate the power contained per unit, say if you are looking at the sea, this is the power contained kilowatt per meter of the seafront. Now, since the sea front is very large and therefore, you can easily calculate the amount of energy that is available is also very large. How large?

It has been estimated that you have, if you have wave energy converters over say, only a fraction, a small fraction of the whole coastline of India, it will still be sufficient to cater to all the energy demand. The only problem is that how to convert economically. But, the energy is there, a huge amount of energy is there in the waves. So, how to convert that? Now, in terms of conversion, various people have proposed various types of models, various types of ideas, in order to convert this available energy in the waves into electrical energy.

Now, I will slowly illustrate what they are, but essentially out of so many years of research, three ideas have been tested to be useful.

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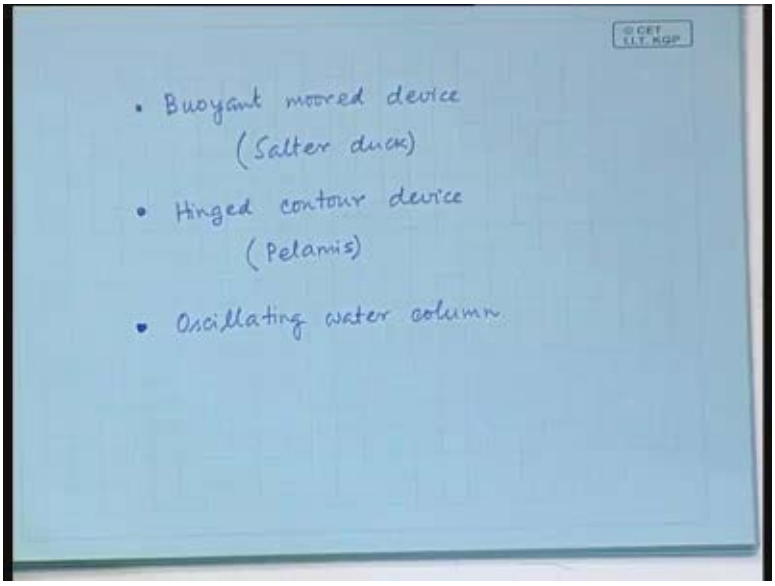

One is the buoyant moored device. It is also called the Salter duck, because it was invented by Professor Salter in the University of Edinburgh and the thing looks like a duck, as if there is a duck sitting on the surface of the sea and which is moving with the waves. That is why it is called, nicknamed Salter duck. The second idea is the hinged, it is also called the Pelamis. It is a, I do not know which language it comes from, this particular word, but probably it is from Spanish. The third idea is the oscillating water column. So, essentially these are three ideas that have been tried out in various places and found to be working reasonably well.

The first idea that came was from Professor Salter in the University of Edinburgh. He tried various designs and this device is actually very efficient, though there have been, I will come to that story later, but still all the other devices, all the other proposals, are sort of compared with the efficiency of the Salter duck, so that is a very efficient device. However, there have been misgivings about the actual installation cost of the Salter duck, as a result of which in the 70's, the wave power program in the UK was completely abandoned. Later, it was found that the estimation was about 10 times out of the actual, the actual cost. That means the estimated cost, the people estimated the cost 10 times higher than the actual cost and that is why it was considered to be, at that time,

completely unfeasible in terms of economic feasibility. However, now the whole thing has been reevaluated and again there is investment in trying out the Salter duck concept.

The hinged contour device, some companies worldwide are now developing this idea and as we will see on the computer, these have been actually installed in Portugal. Oscillating water column is where the wave pushes air column and makes a device move. I will come to all that later, but now let us look at the computer.

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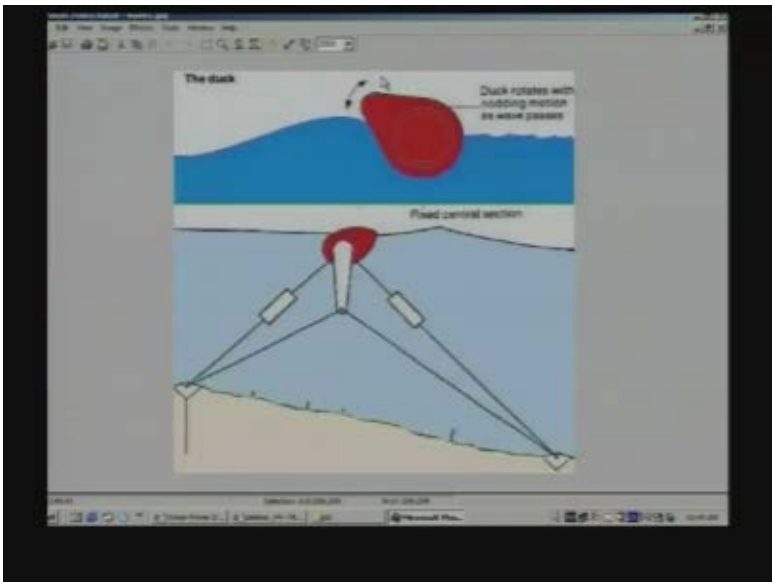

First, this is the idea of the Salter duck. Is it visible on the screen? Yes; so, here is the wave front that is coming and this device in this side it is cylindrical, but in one side it is a bit elongated, right, as a result of which when the wave comes, this side will move this way, right. Can you see the cursor? Yeah, point, the pointer ……..,yes. So, as a result of which the duck will be moving like this and these, this thing is moved to the bottom sea, sea floor like this. So, this motion it will be moving like this, because of the wave motion and the whole thing is being seen in this picture from one side. So, this whole thing is elongated and depending on the length of that, it can intercept almost all the energy, almost all the energy that is there in the wave.

Though the efficiency of the conversion depends on various other things, now this undulating motion that means it will result in an oscillatory motion, right, ultimately and that oscillatory motion is converted into a rotational motion, which in turn drives a generator. That is the basic idea which is inside this duck.

Student: Sir, can you explain the oscillatory motion?

Because of the wave, wave will push this part. As a result, it will move that way. Again, as the wave passes by, it will again come back to this position because of its own weight. There is a weight here, so it will go on oscillating like this. As it oscillates, this will cause, this oscillation, oscillatory motion is transferred inside and that is made to rotate a rotating shaft, that is all and the transformation of oscillatory motion to the rotational motion is an elementary thing that mechanical engineers have been doing since ages. So, this is not a big technical challenge.

Now, this idea, as I told you, was first invented by Professor Salter in University of Edinburgh and it was actually installed in the Edinburgh coast and that place happens to be reasonably windy and the wave height is quite large. But actually, it has been found that the wave power is more towards the West coast of Scotland and so, some of these devices have been installed in the West coast of Scotland. As I told you the history, the Salter duck was the first idea in wave power, but it was shelved for quite some time for about 20 years. Now, it is again being, people are started, people have started again experiment on the Salter duck.

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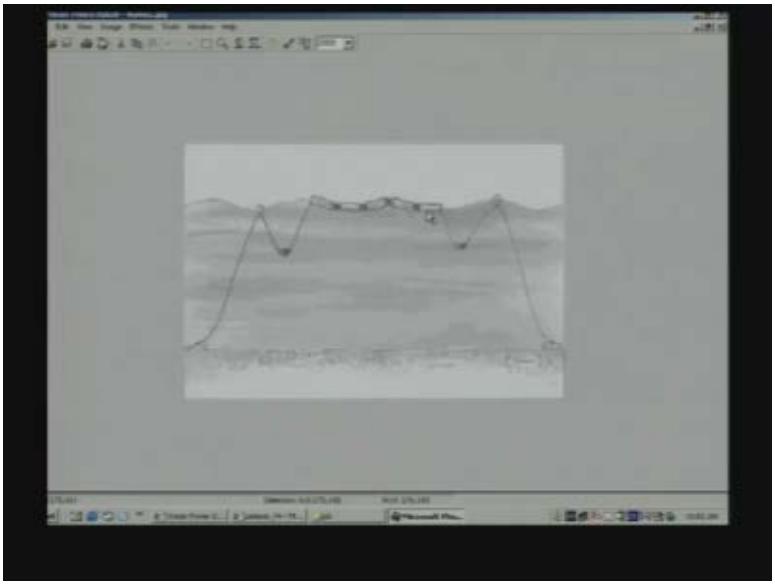

The second idea is a device something like this. Can you see? Yes; I will, I will show details of that later when I show the actual devices. Here there would be a number of such longer cylindrical floating things that are connected to each other by hinges, right and as the wave oscillates, these things will oscillate against each other as a result of which, there will be power available at the hinges. So, the hinges will move like this and this motion then is again converted into electrical energy. So, here in this case, the power is available at the hinges and a very large amount of power can be available.

Let us show some pictures of it.

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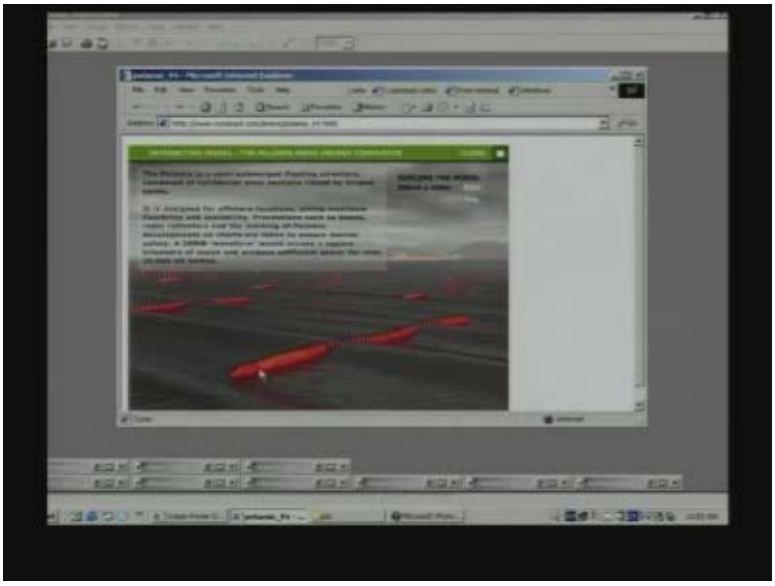

Probably it is, it is visible, right? This is the concept, where there would be this kind of cylindrical things connected by hinges like this and as the wave propagates, these individual ones will move, right and as a result of which there will be energy available at the hinges. That is the essential idea. So, a large area in the sea coast would be covered by this kind of thing. These things are also anchored to the sea floor. Let us look at the side view.

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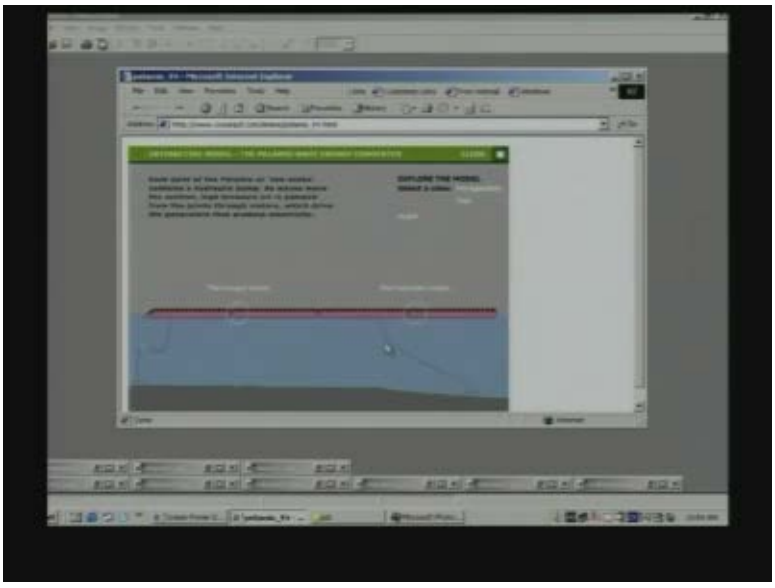

So, here is the side view and these are the places where it is anchored. Is it visible? Yeah; these are the places where it is anchored and these are the hinge, hinge points.

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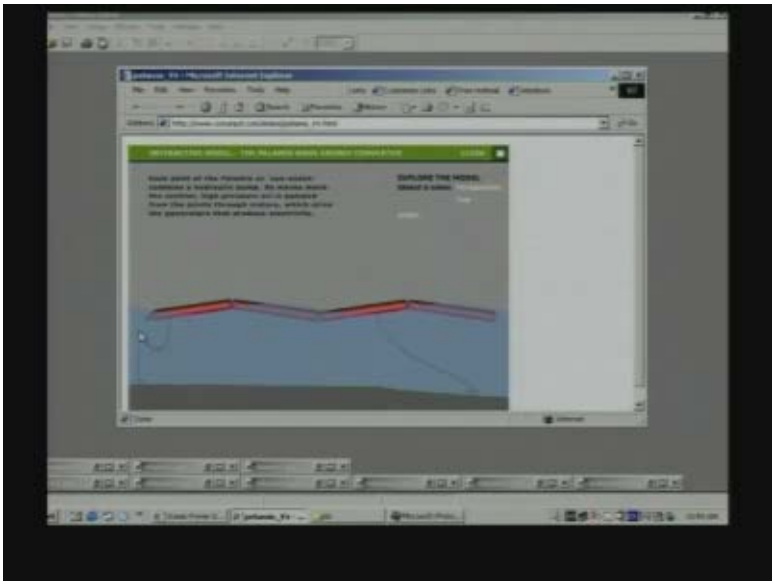

So, if I play, as the wave passes it will be moving like this, right and as a result, there will be energy available at these hinges. Can you see that? All right.

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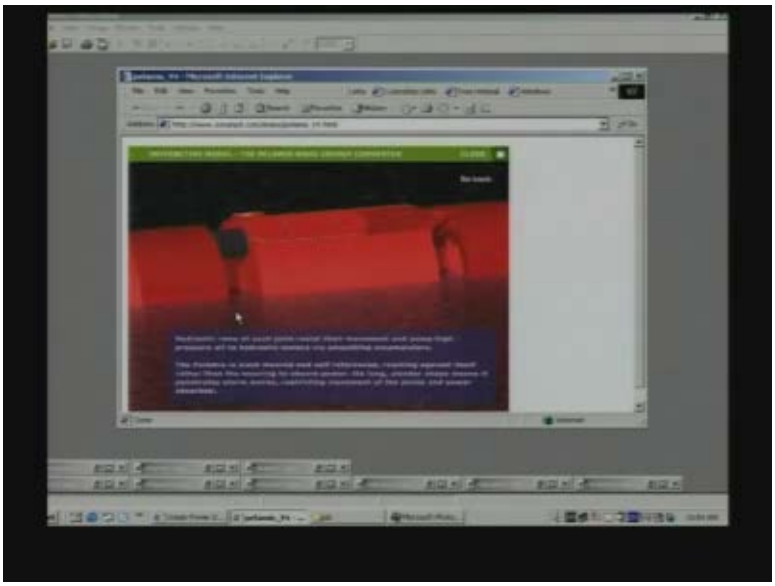

So, if you look at the hinge joint, it would be looking something like this. So, these are the joints, which actually resist the movement, which actually resist the movement and the wave will force it against that resistance, as a result of which transferring energy into that device, clear.

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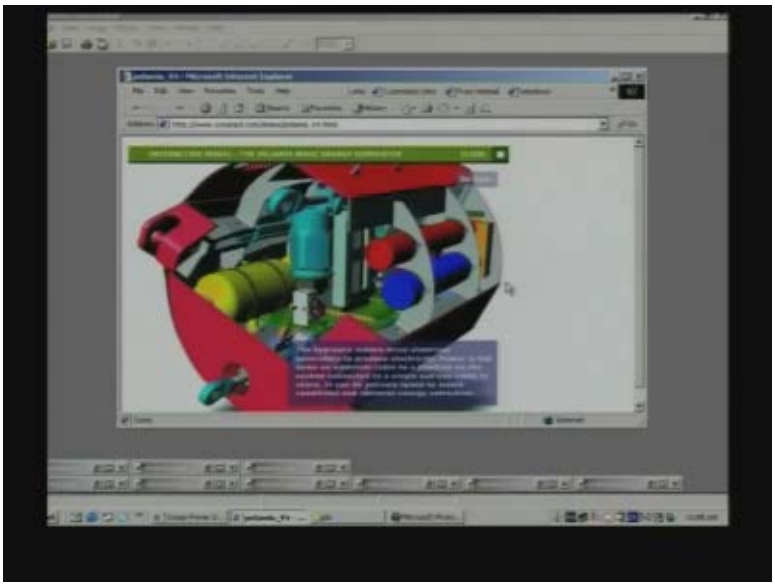

Here, you have the device at the hinge, where the hydraulic motor drive the electrical generators to produce electricity, fine. So, essential idea is that this motion will be converted into again a rotational motion to generate the electricity and the electricity is in turn transferred to the shore by means of submarine cables.

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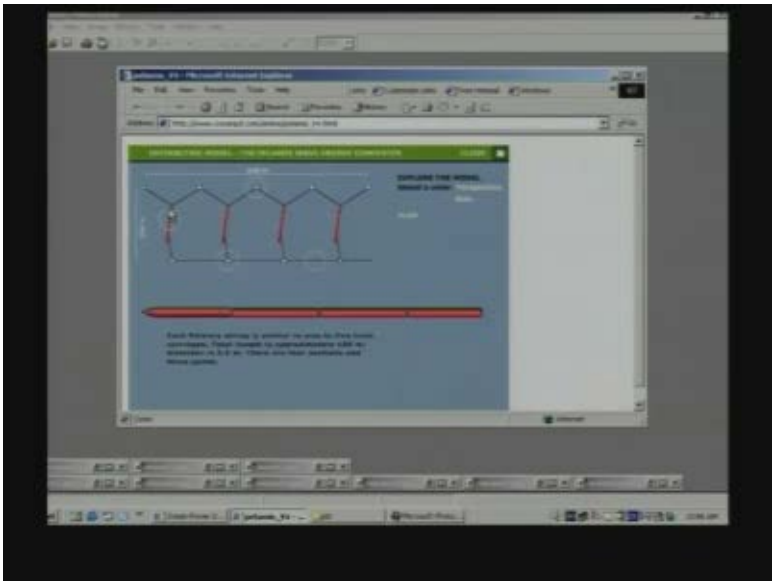

If you look at the top view, the dimensions are given. So, these are the individual ones. So, here each individual one will have four of these segments and we are considering four of these lying parallel to each other. The whole length of this installation is about 600 meters, while this length is about 200 meters, 200 meters, big thing. So, each of these segments would be of the size of a railway bogie, approximately of the size of a railway bogie and this is actually installed. It is not that it just a concept, it is actually installed in the, in the Portugal coast generating a large amount of power.

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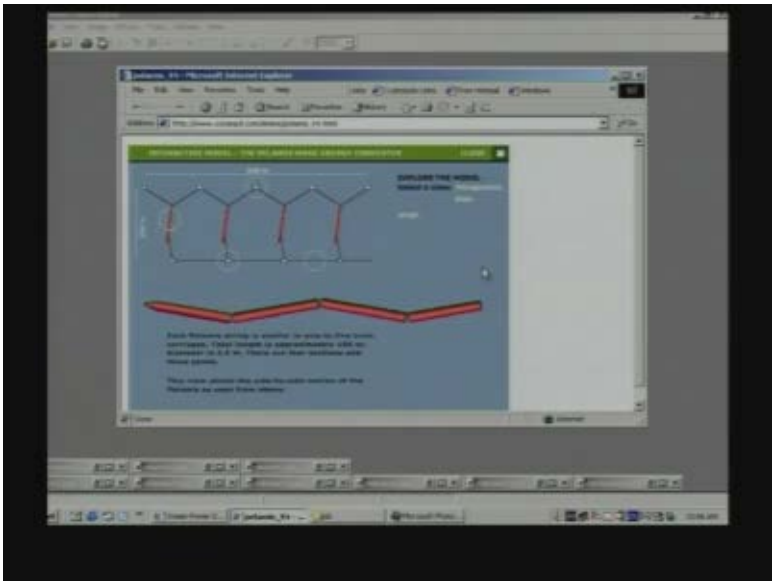

So, if I now look at the demonstration, you will have, because of the wave there will also be not only up and down motion, but also a sideways motion. There will also be a sideways motion. That means each hinge will move not only up and down, but also sideways and as a result of which there will be energy available at the hinges. Is that clear? So, at these points again, these are the places where, these points are the places where the moorings are done. That means here there would a weight down there, so that the whole thing cannot move.

Again, here there will be another box which keeps these things in place, otherwise they will move about. They cannot be allowed to move about. So, these are the places where they are moved and these are the places they also moved, so finally they keep in place. While keeping in place, they oscillate and produce energy. Is that clear, this idea? This is the hinged contour device also called the Pelamis.

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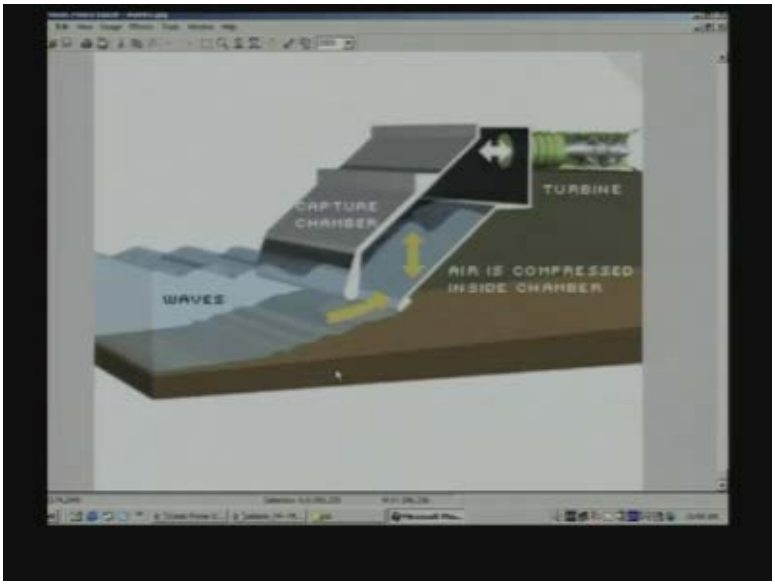

So, what I was explaining with reference to the other picture was this one.

The third concept in wave power is a concept where, here I am showing the sectional view of the concept. Here is the ocean, here is the ocean floor and as the waves come, there is a chamber and there is an opening. As the waves come, the waves push it through and water goes in. There is an opening here. Because of this opening, the waves push its way in and as a result, there is an enclosed air column inside. The water itself acts as a piston and pushes the air in. Is that clear? The water that goes in, acts as a piston and pushes the air, which in turn runs a turbine like thing.

There are turbines available, because when the water again recedes it will pull the air column back. So, the air column will move to and fro, air column will move to and fro. While it does so, it will generate power at the turbine and there are turbines available which work, which move the same direction irrespective of the direction of the flow of the air. There are such turbines available. So, this is another concept by which we generate wave power. It is, this is the oscillating water column concept.

So, there are essentially three concepts of wave power generation. One is a Salter duck, which is cylindrical device, eccentric cylindrical device. Because of the water, because of the wave, the whole thing moves like this. We showed here the sectional view from the side and as a result of this, this wave motion, the whole thing moves and this motion without an hinge door, a single cylindrical, eccentric cylindrical thing, that oscillatory motion is converted into the rotational motion and that is what is used for producing electricity.

In the second concept, we have four generally such individual sections connected by hinges and because of the wave, there would be this kind of motion and this motion is, this motion that is available at the hinge, if you have a device to convert this motion into rotational motion, again go into electrical power generation, then what happens? It is connected to electrical generator, which is connected to the seashore by means of some kind of a cable. If you load it, what will happen? If you load it, there will be a back torque available at the generator, which will be applied to the hinges, which would be essentially reflected as some kind of friction in the hinges, some kind of resistance to any, any motion like this. So, the wave in contrast to that opposition, it forces it to move and as a result of which it forces the generator to rotate.

That was the second concept, the hinged contour device and the third concept is where the wave, this is generally not offshore, this is onshore at the junction between the shore and the sea. That is where you put this kind of a device, where the waves come, pushes the air column and naturally the air column moves to and fro, which drives in turn a turbine, air turbine. So, these are the three concepts. As yet in India, we do not have any large scale demonstration plant for wave power. These has in the main been developing in the Europe, not even in US, mainly in Europe. But, you can see that, since India has a large coastline, if India goes into production of these devices it can generate a large amount of power.

Now, let us come to another concept. Is there any question about this wave power? Is there any question about this wave power generator? If not, then we can, we can go into

another topic. These things we are covering a little faster than we did for say, solar energy and solar photovoltaic, the wind, because wind, photovoltaic, these are already in use in India, while these are concepts and I hope during your lifetime, you will see them coming to fruition.

Now, we will come to a concept that is actually being tried out in India. You see, when we talked about solar energy, solar thermal energy, we said that it can be trapped. It can be used by means of having some kind of a greenhouse effect. That means in the solar flat plate collectors, you had the solar energy coming in heating the plate and we had arrested that heat by not allowing it to go away. How? By means of a glass plate; glass plate allows you the heat to go in, the light to go in, but heat cannot come out. That is the character of glass. It does not allow the infrared radiation to come out.

Now in, but nevertheless, you have to make those things and you have to cover some area and the actual amount of energy that you can use depends on the above amount of area covered and firstly, you have to make those things, you have to put them in place and you have to walk around. So, you cannot really pack them very closely. You cannot really pack them very closely, you have to have sufficient space to walk around them, clean them and stuff like that. So, out of a whole area, only a fraction of the area is really covered by these devices. If you imagine that you would be generating power, then also only a fraction of the area is really covered by these devices and often the solar thermal energy is used for thermal purpose only, because it is relatively low grade heat and there are large number of industries that require that low grade heat, so you need.

Now, there is a concept by which the packing density becomes very large. Why? Because, okay, I will, I will explain that concept, but normally have you ever taken bath in a pond? He has, he has taken bath, so what have you noticed? As you go down, you feel that there is a temperature difference and normally you find that the upper, absolutely upper level is not very cold, but not very hot also. Why? Because, it is in contact with the air, so whatever heat it has, it dissipates in the air. Slightly below that is the, is the area, where you find it relatively more hotter and below that you find it relatively colder, right.

Why is the area below colder? After all, if the water is more or less transparent, then it does not absorb the air, absorb the heat or light or energy, whatever it is, right on the surface.

The light actually goes into the bottom and then it is absorbed. So, why is the top layer relatively more heated? Because of convection; so, where it is actually absorbed, there the water is heated up and the heated water has larger buoyancy, so that it rises to the top and that is how it dissipates the air, dissipates the energy into the air. So, you do not really have the ponds heating up to very high, to high temperatures, right. That is what happens really. Now, imagine if you can somehow stop the convection to happen. Then what will happen?

If you can stop the convection, then the energy will come in it, will be absorbed and it cannot dissipate, because above that is the water layer and water layer is not moving. If there is no convection, water layer is not moving and therefore, the heat will be trapped. Do you see and as a result of which, the whole area covered by the pond will become the absorber area. You do not really have to clean anything, you do not have to really walk around the collectors, just there. That is the concept of the solar pond. That means there will be ponds which will absorb the energy and which will also act as storage of energy, so that the energy will also be available at night. So, this is not only an absorber, not only a solar energy converter, but also a solar energy storage device. But the question is how can you stop the circulation, the convection current from being setup?

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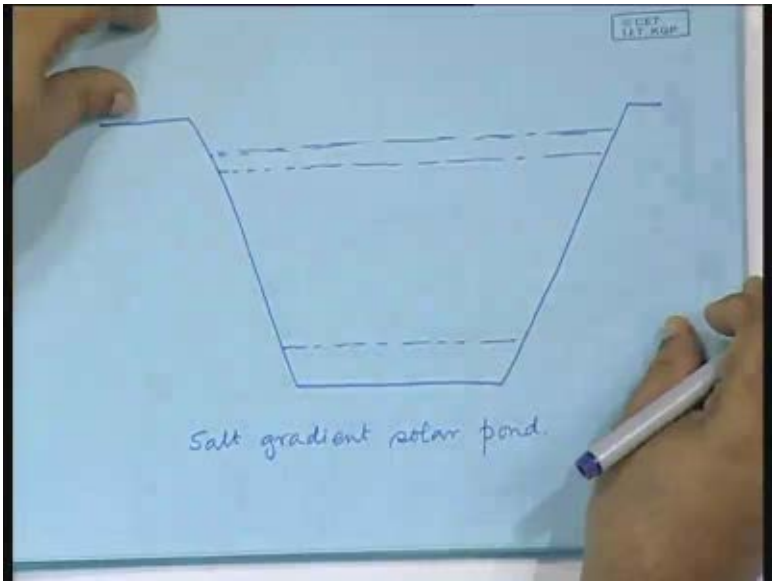

The idea is something like this that if you have a pond something like this and here is the water, then why does the convection current setup? Because, here if the water is heated up, its density relatively at least becomes lower than the density here. So, it rises. So, if somehow you can increase the density here by some other means, so that that density does not rise, does not go down, cannot go down, go below the density at the relatively upper level, then obviously it gets trapped. How can you do that?

Simply by mixing with salt, simply by mixing with salt, so the concept is essentially called the salt gradient solar pond. So, at the top there will be a layer, blackish water, but transparent water, then at the bottom there would be a layer which will have very high density and which actually will be absorbing the incident solar radiation. But in between, there would be a water layer, a definite depth of water, where the density of salt actually goes higher and higher as you go deeper and deeper. Without that you will not be able to do that, there has to be a gradient. It is not just that you mix salt and that is it. You have to keep the gradient in such a way that the density is high at the bottom and density is low at the top, so much so that even due to the heating, the density at the bottom cannot be higher than the or cannot become lower than the density at the immediate upper level.

So, there is a, there has to be a gradient and the gradient has to be such that, because of the heat, the density gradient cannot be reversed. That is the point. So, the density gradient should be something like this.

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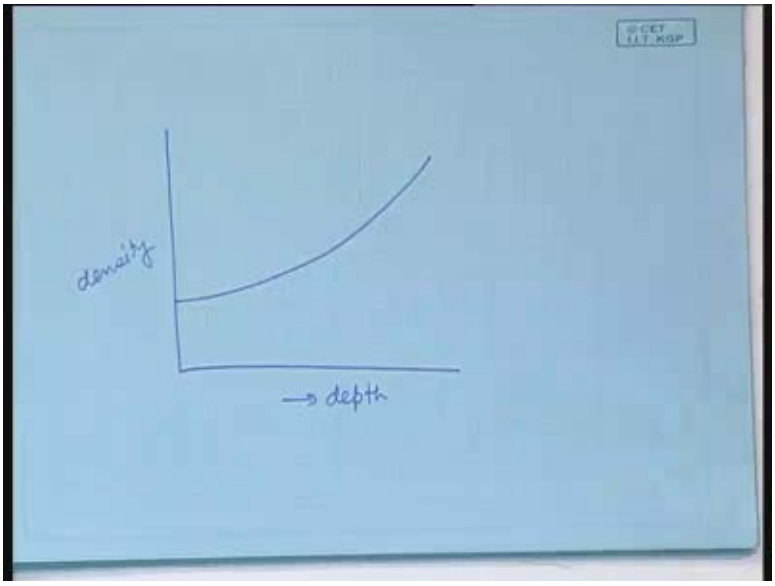

If you have, in this part I am talking about this from here to here, the intermediate level which acts as the trap, the intermediate level which acts as the trap, in that range it has to have a character something like this. So, this is the depth and this is the density. So, it has to, the density has to go up, as you …

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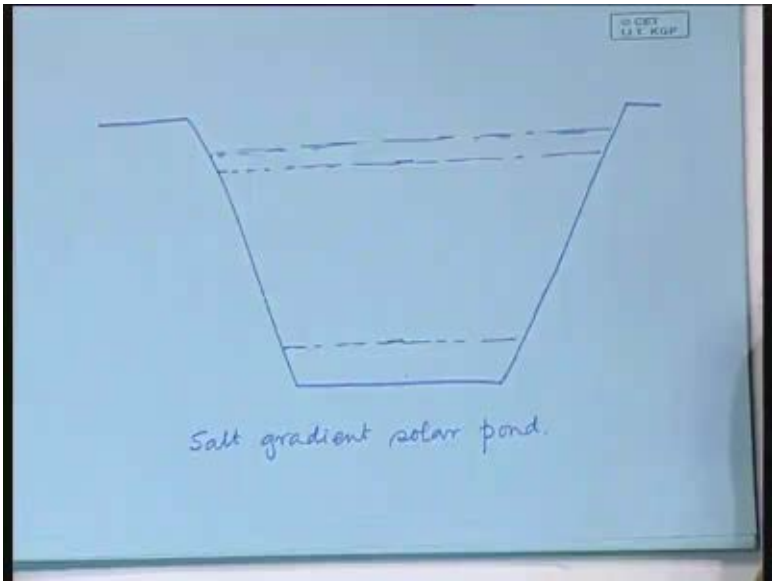

Now, you might ask how to do that? Now, doing that is not really big difficult thing, because all you need to do is to have a lot of salt here, so that by normal diffusion process it diffuses to the upper levels and naturally, it will normally have a temperature, a density gradient. But, this is often reinforced, because after all, you will have to use this water. How do you use this water? After all, the energy is there; so, in order to use this energy, you have to either pump up that water from the below, from the bottom or you have to have some kind of a heat transfer pipes in this part, which takes the heat away; either of the two and normally in many of the installations that are there, this water is pumped up and as a result, there will be, it will tend to mix and so, as it is pumped up, you will have to again reinject very high density water in this part. That is all.

Now, let us look at some of the installations. One important installation is in US that is in El Paso in Texas. I will come to that; this can be now deleted.

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Here is the picture of the El Paso facility. Can you see? Is it visible now clearly? Yes; so, you see this is the pond and here they have, there is a lining. It is not just normal pond, it has to be brick lining, so that the pond water cannot really diffuse or from this side ground water cannot come in and you have the facility of reinjecting the salt water at the bottom.

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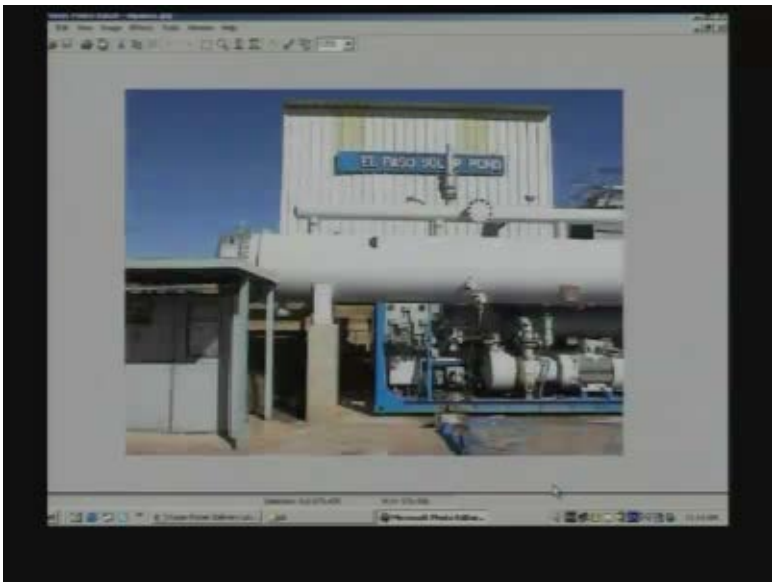

Now, in this case, this particular facility had, yes, it has electrical power generation facility that means with this electrical power is generated, about 100 kilowatts. So, from a pond of that size about 100 kilowatt power is generated and here is the power generation facility, where I will show you that there is a place where the water from the, hot water from the bottom is pumped up and this is where you have the generator and the turbine and other facilities. Obviously in this case, the water would be something like 100 degrees or 120 degrees, about 100 degrees. So, at that temperature, there are two things possible. Either you can flush, produce steam and in the same way as we have illustrated in the case of the OTEC, you generate electricity or you can have a secondary fluid.

In this particular case they used Freon, Freon 112 as the secondary fluid. That means with the help of the hot water from the bottom of the solar pond, they produce high pressure vapour of the Freon and that is what runs the turbine. The turbine is somewhere here.

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Next picture, here is the facility to pump the hot brine from the bottom of the pond and these are the channels by which they go. So, this facility is right there at the, at the side of the pond and that goes sidewise to the bottom and from where it is pumped up.

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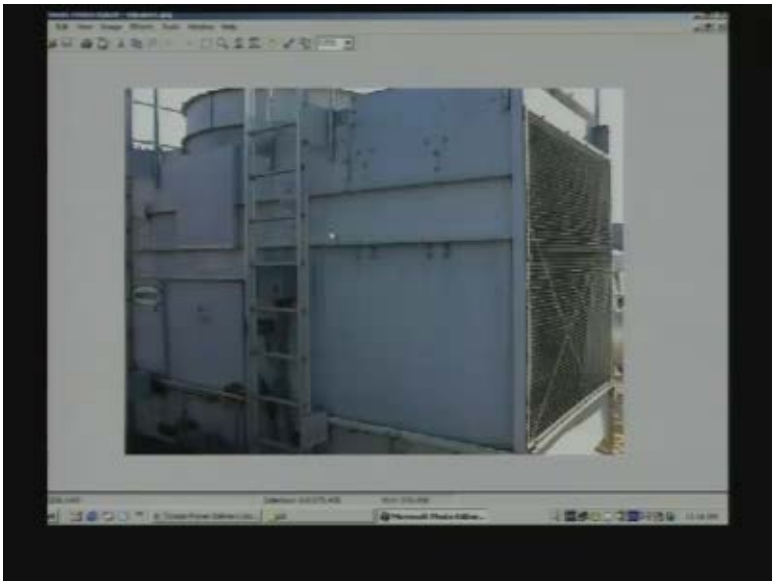

Here, so this is the, then you need a condenser, so naturally in this case you would need two temperatures. One temperature is at the bottom of the pond, the other temperature is normal water. So, here you have the condenser.

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Here is another view of that facility, where this is the surface of the pond and it is actually divided into segments to make it easier to control and here you can see the pipings. This

is a facility established in El Paso. By the way, India also has a solar pond. The Department of Science and Technology has established a solar pond in Bhuj. Unfortunately, the photographs that are available on the net are too small to be visible on a full screen. That is why I could not show them, but it is in Gujarat in Bhuj, in the run of Kutch and it is not used for electrical power generation. It is actually used for producing low grade heat, but it is there; it is working. It is there, working and that low grade heat is actually needed for dairy farms. So, that heat is actually supplied to the dairy farms, dairy farms need the heat in order to run their facilities.

So, the essential concept is where you will have a pond; the more the area the better. You do not really need to have a large depth. It is only necessary to have the salt gradient in that depth, so normally the depth would be not more than the depth of a swimming pool, may be. But, at the bottom you will have the darkened surface and that water is what really captures the energy. There will be a depth for which the concentration is constant and then above that the concentration slowly reduces to the top, where again there will be a small depth without the, without any concentration gradient. So, concentration will be the same at some depth, then will slowly increase and at some depth again it will become more or less the same. So, it results in clear separation of the layers. Do you see that? That separation of the layers again requires a lot of theory.

Where will the separation be created? Depending on the amount of salt that you pump in, so there is one layer and there is a very clearly defined boundary of the three layers. So, at the bottom there is a layer, then there is a boundary. You do not really create the boundary. You do not really put any artificial membrane or something to create the boundary. Because of the salt gradient, automatically there will be a boundary created. So, as a result of which if you dip thermometers at various levels you will find that for some level for some distance the temperature more or less there is constant and then after that it decreases very fast to the level at the top, where the temperature is the air temperature. So, the energy is really trapped and the energy can be used continuously over the whole day irrespective of whether there is sun or not. At night also it produces the same amount. Why?

Because the energy is trapped, it cannot really go away and people have experimented that in this case you can have brine heated at 100 degrees and you can just leave it like that and the heat is, heat will remain trapped there. In case of the India's facility, there have been some problems with that because India experimented with various types of linings. Linings means how do you make the pond? Obviously you cannot simply dig it and fill it up with brine water, because in that case the water will seep through. You have to have some kind of a lining.

In India, the main attempt was how to make the lining with locally available materials, so that the whole cost becomes very low. You can of course make things with concrete or everything, but that becomes expensive. How can you make it with locally available material? What was observed was after a few months of operation, the brine was leaking out. As a result, the temperature was not stabilized, temperature was going down. So, finally that problem has been overcome and now we have a reasonably working unit that is supplying the dairy farms in that locality. So, this is the, these are the two concepts of wave power and the solar pond.

Yesterday when I was talking about the ocean thermal energy conversion, there is one aspect that I forgot to mention, one additional advantage of ocean thermal energy conversion. That is what is actually happening? You were pumping in water from the ocean bottom, using it for the, for the condensation part, condenser and then releasing into the sea. Now, the water that you are bringing in there is very nutrient rich. Why? Because, all the nutrients settle down there, so that is nutrient rich. It is cold and because it is, because it is at that kind of a depth, it does not have much organisms, as a result of which there is a lot of nutrient, but nothing to eat it. So, the nutrient is there. If you pump it up and mix with the surface water, then the organisms that are there in the surface, they get that nutrient. So, this has the additional advantage of supplying food to fish planktons and what not, whatever there is in the surface. So, the advantage of the OTEC is seen from many angles.

One angle is that you can have desalination. Second angle is that you can have power generation. Third angle is that if you do not want to transmit the power to the shore, then you can have industry on site and the forth advantage is that yes, somebody mentioned fishing, yes in those places there will be a proliferation of fish, because of the sudden availability of nutrient rich water and that can, yes, that can be used for increasing the amount of fish yield in that locality. That is another aspect in which people have studied, found and now it is being seen from that angle, the advantage of pumping in water from the lower level. Even there are places where people are thinking of pumping in water just to increase the fish yield, but now if you have an OTEC plant, then the water has another use. That is pumping from the, from the bottom, so that is the, that has further advantages.

So, you see in the last few classes after we covered the wind energy and solar thermal, solar photovoltaic, these three can be said to be economically competitive with the main stream power generations. Then, we covered a few things that are sort of more advanced concepts like the wave power, like the solar pond, like the ocean thermal energy conversion and the reason that I covered it in the necessary details, not very great details, for example, I did not solve the equation that will talk about the creation of the boundary layers; if you read about solar ponds in normal text books, you will find a lot of equations have to be solved in order to find where the boundary layers will be created and the amount of brine mixing will have to depend on that, because that produces the boundary layers, so that knowledge is necessary. I did not go into that kind of detail. But, the reason I covered it was that in all probability in your lifetime we will see these coming into fruition and I would like you to take part in bringing them to fruition. That is why you need to know in greater details.

But, you also need to know that the amount of details that I covered in it that is sufficient for second year level, all right. That is sufficient for introductory course on energy engineering, but you need to have more detailed exposure in order to understand a few things. Let us stop it today. The remaining classes we will talk about the other non-conventional sources like the geothermal energy. Is there anything that I missed? What

are the other energy sources? Earlier in this course we had listed that these are the energy sources that we to have to cover.

Obviously, we are not talking about sound energy or something. Some of guys shout too much, but that does not mean that that energy can be converted feasibly into usable form. But, what other energy sources that you can think of that we need to cover? Geothermal is definitely one, geothermal is definitely one. Do you have any idea of what geothermal energy is? The energy that is available inside the Earth.

Students: Volcanoes.

Volcanoes, yes; that is a surface manifestation of the energy that is available. So, volcanoes are surface manifestations of the energy that is available below the surface of the Earth. But in India, we do not have volcanoes. So, obviously we cannot really go to Honolulu to trap the geothermal energy. We have to do something here. So, what are the other manifestations of the heat that is trapped?

Student: Geysers.

Geysers, yes, but we do not have geysers here. Geysers means places where there is natural upwelling of steam which happens in a few places in the whole world. One is in the geysers area in United States. There is a, there is a place called Geysers, because of this reason that normally steam comes out. There is another place in Newzealand, there is a third place in Italy. So, these are the places where you normally have steam coming out of the surface. We do not have, right. So, what do we have? Hot springs, right. We have only hot springs and do you know any places nearby where you have hot springs?

Student: Rajgir.

Rajgir, yes, Rajgir has; any other place? There are many, there are many in India. There are many and you should actually be on a look out for these places, because these are the

places where you know that there is a lot of energy somewhere down there. But what is the, what is the source of that energy, any idea?

Student: Sun's heat.

Sun's heat, how do you get stored there?

Student: ….

No, wrong; sun's heat is not responsible for the geothermal energy.

Student: Internal energy

Internal energy, where did it come from?

Student: …

Core, mantel, crust, these are the three layers, all right. How were they created? How were they created? Well, you might say that it has been there all the time. Obviously, that will not be taken by me as a, as a feasible answer. Why, because it must have been related to the process of the creation of this planet. Do you know how this planet was created? Hi, you never asked that question to your teachers.

Students: Out of question.

Out of question? No, of course this is a very valid question. How was the Earth created and I think you have read that in geographic books in school, right. No, it was not there in geographic book, how the Earth was created. How?

Students: By the condensation of gases.

By the condensation of gases; that is what you have read.

Students: …

No, no. Is that what you have read about the creation of the Earth? Earth was not created as a big bang; come on, do not say that. So, it is definitely created in a different process. So, what is the process? Is he right? Is that what you read in school that it was created in the production of, in the condensation of gases? What kind of gases, from where?

Students: We do not know, Sir.

Do not know.

Students: It was already existing.

It was already existing? Since when? 1936; no, no, wrong, wrong. Earlier it was believed, in fact when the Earth is there, the question is a valid question. How was it created? There were some people that believed that it is there, has been there. But, there are also some people who believe that there have must have been a process of creation, must have been a process by which it was created, a physical process, not the creation in the spiritual sense, a physical process must be responsible for that.

Now, initially there were two kinds of ideas. One said that it is created by means of, earlier the sun was there and either there was some kind of a disturbance, either initially the idea was that there was a comet that collided with the sun, as a result which some part got ripped off which went on rotating around the sun and that is what ultimately condensed into the planet. That is what you read. Later it was found that comets are so tiny; even though they look big, they are actually so tiny that they can have no impact if they fall on the surface of the sun. Do you remember sometime back a comet fell on the surface of Jupiter? Only, the scar remained only for a few days and after that everything vanished. No, no, I mean no visible change. So, the comets are really tiny.

Then, the idea was changed into, that it may have so happened that the sun was there and another star passed by. As a result of that, when it passes by, because of its attraction a part of the sun got ripped off again and that went on spinning around the sun, that condensed. Probably you have read something like that in school, right, from the part of the sun that condensed, you finally have the Earth created. Is that right? Today there is no time; we have got another class, so we will continue with that. First we will need to understand the process of creation of the Earth and then from there we need to understand where now the energy can be trapped, energy can be available. Everything is related. We will come to that in the next class.