Energy Resources and Technology

Prof. S. Banerjee
Department of Electrical Engineering
Indian Institute of Technology - Kharagpur

Lecture - 30
Tidal Energy

So, we will today start with tidal energy and mostly students have learnt about tidal energy or why tides occur in school, right? What have you learnt, let us recapitulate that. What have you learnt? Why do tides occur?

Gravitation?

Students: …

Gravitational pull of moon.

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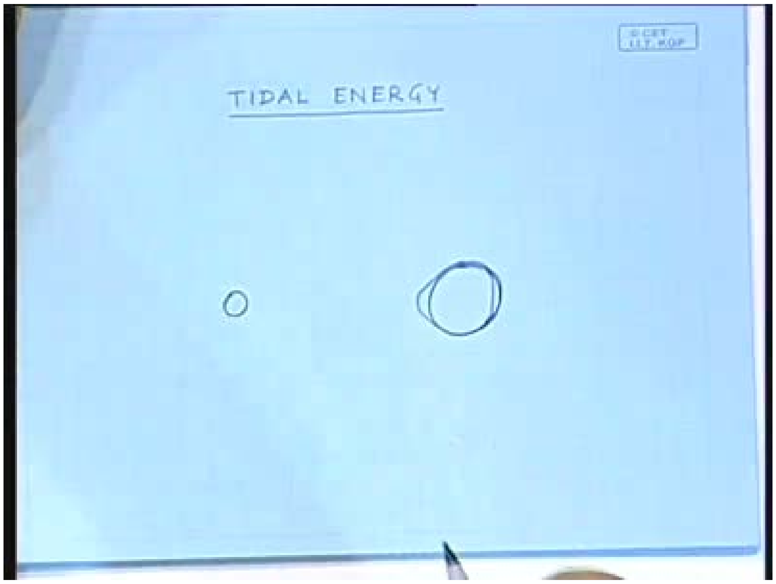

So, if that theory is correct then if this is the Earth and this is the moon, then due to the pull of the moon, the Earth's motion will experience a bulge this side and that is all, right and so, anybody at this point will experience a tide. Are you convinced? This is the theory for tides. Wrong; had it been correct, then there would be, as Earth rotates around its own axis, there would be one tide per day, but there actually is, there actually are two tides per day; two high tides and two low tides. Obviously, the theory that you learnt in school is wrong. So, something else must be responsible for it or some other kind of explanation is necessary. I was asking, today we are starting with tidal energy and I was asking what do you know about the reason for tides that you learnt in school and the answer that I got was that the gravitational pull of moon causes the tide.

The question that I am raising is if that theory is true, then obviously the structure would look something like this. Here is the Earth, here is the moon and then if you assume somewhat extended figure that the surface of the water is like this, then surface of the water will bulge in one side and as the Earth rotates around its own axis, you would experience one tide per day, but actually there are two tides per day. So, obviously the theory is wrong. Are you convinced? Are you convinced that what you learnt in school is wrong.

Students: On the other side of the Earth there will be a low tide.

Why? There will be a low tide here. Then also, as the Earth rotates around it axis there will be one high tide and one low tide per day, right. That is not there, that is not true. There are two high tides and two low tides per day. Yes, anybody residing close to the sea here? Is there anybody whose home is close to the sea? You would say there are actually two low tides and two high tides per day. So, obviously the theory that you have learnt is wrong and this is, this is pity because, this is very simple theory, but most student learn the wrong, wrong things in school.

Students: …

If Earth exerts less force than the moon, then when the moon is above your head, you will fly to the moon, right. Obviously, you do not, you do not fly, right. So, obviously that is also not correct. Yes, so that is that is what needs to be understood to begin with, the correct theory of tides. Because if the pull of the moon is greater than the pull of the Earth, then you would fly off, obviously you do not; chandralok mein paunch jaoge. So, that does not happen. So, we need to start from a point where I did not anticipate I would have to start. The fact is, in fact the explanation of the tides was correctly provided by Newton 300 years back and it is high time that that goes into the standard school text books in the correct form. The point is that when they say the Earth is moving around the sun, then actually it is falling towards the sun, it is something like this.

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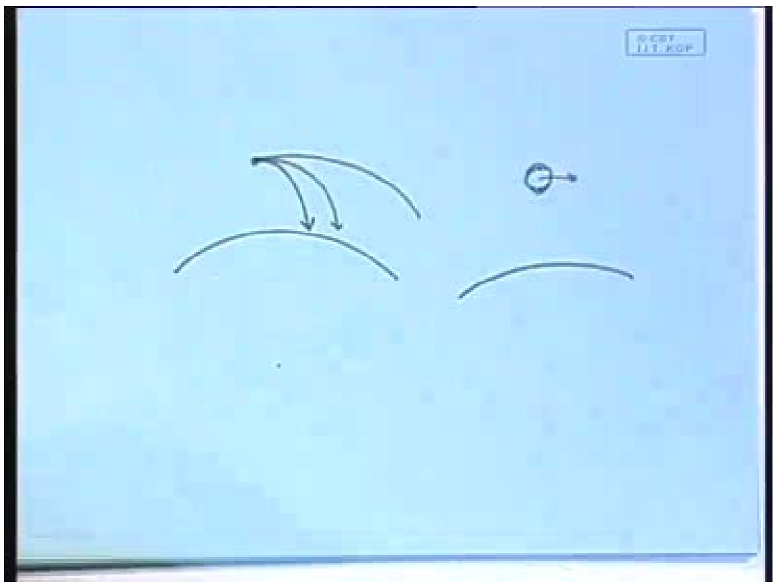

Suppose, okay let us explain it the way Newton explained it. Suppose you have the surface of Earth like this and suppose at this point you have got a gun and you are shooting. So, what will happen? There will be, it will fall like this. If you shoot in this direction it will fall like this, if you shoot with a greater velocity it will fall like this and if you shoot with a even greater velocity, it will go like this. Notice that in that case it will actually not fall onto the Earth, but it will still be falling, right. It is falling, yet not falling. It will become a satellite, it will go on rotating around the Earth, though all the time it is falling; all the time it is falling.

Now, imagine that this fellow is not just a point, not just a bullet but some kind of an extended object something that is you know, soft, malleable So, in that case what will happen? If you have the surface of the Earth like this and something like this which is then falling, but not falling, like this, then the force experienced by this point and naturally the tendency of it to fall will be larger and the force experienced at this point and naturally that point's tendency to fall will be smaller. As a result, this point will fall faster with a greater acceleration and this point will fall slower with a smaller acceleration. So, what do you anticipate? What will happen? It will be elongated in that direction and this force is called the tidal force; this force is called the tidal force.

In fact, this is the force that caused the comet Schumacher Levy to break into many, 23 parts and plunge into Jupiter. So, because of the tidal force that the things break off. So, in case of the Earth and the sun system something similar would happen. Suppose this is the sun and this is the Earth, then a similar phenomenon will happen that this point will be trying to fall towards the sun with a greater acceleration and this point will try to fall towards the sun with a smaller acceleration. Therefore, there will be a pull, stress in that direction and the body of the Earth is mostly solid, the liquid part is ocean. So, the ocean water will be bulging in these two directions and therefore, you expect there will be two bulges, one here another here, right. That is exactly what happens. There are two bulges.

Now, here I explained it in context of the sun, but this bulge is because this point tries to fall faster and this bulge is because this point tries to fall slower, it falls back. The rest of the Earth, its acceleration and this point's acceleration are not the same. So, this point tries to fall slower, tries to; therefore, it bulges up in the opposite direction. Is that clear? That happens because if this, this body is soft, then that pull will be there. It is not in one direction. But, it is not because of, this is completely wrong concept, it is not because of just the attraction of the sun, it is because of the differential attraction of the sun between one point and the other. Is that clear? So, that is the concept of the tide and the tidal forces are there not only on Earth, but on anybody, any planet for that matter, of the planet on the satellites, due to the satellites on the planets, everywhere this tidal force is there.

Now, therefore we have explained it in context of the sun. There is another body close to us that is moon and in fact, when he gave the explanation he said that it is because of the attraction of the moon. So, which is stronger, attraction of the moon or the attraction of the sun?

Students: Attraction of the moon.

Attraction of the moon, why?

Students: It is nearer to Earth.

It is nearer to Earth, less mass, but nearer to Earth. Is that right? The tidal effect due to the moon is stronger than the tidal effect due to the sun. Why?

Students: …

Gravitation pull is inversely proportional and so sun is far, far off and therefore, its gravitational pull is smaller.

Students: Sir, rate of change of gravitational pull …

Rate of change of gravitational pull, no, no, no, does not change. Anyway, the theory is wrong again. Again what you say is wrong. Let us illustrate it with numbers.

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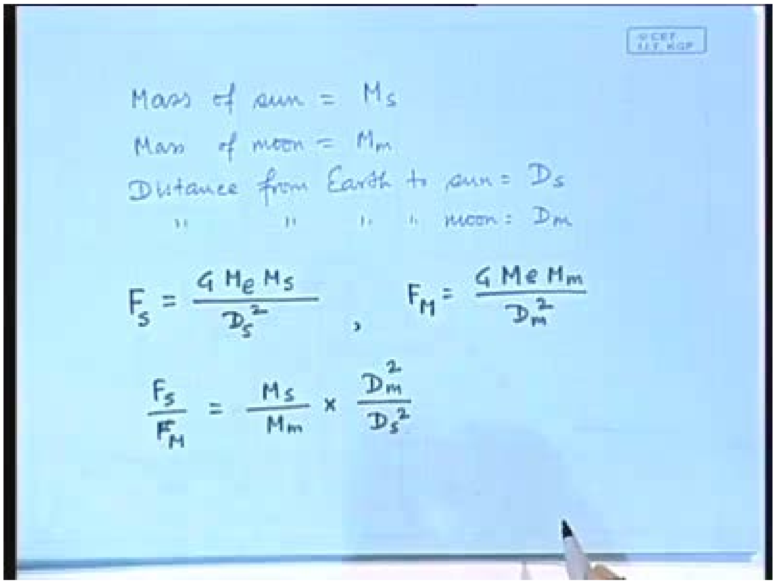

Suppose, the sun, the mass of the sun is say M S, the mass of moon is M m. Distance from Earth to the sun, let that be D S and distance from Earth to moon … Then, the force due to sun is G M 1 M 2 by R square. So, that would be G mass of the Earth mass of the sun divided by D S square and the force due to moon is G M e M m by D m square. So, now if we divide these two, it will be F S by F m is G cancels off, M e cancels off, so you have M S by M m times D m by D s square. Now, we need these numbers in order to estimate. Actually, the mass of the sun is far, far greater than the mass of the moon and that far, far greater than means it is more than 2 lakhs sixty thousand times.

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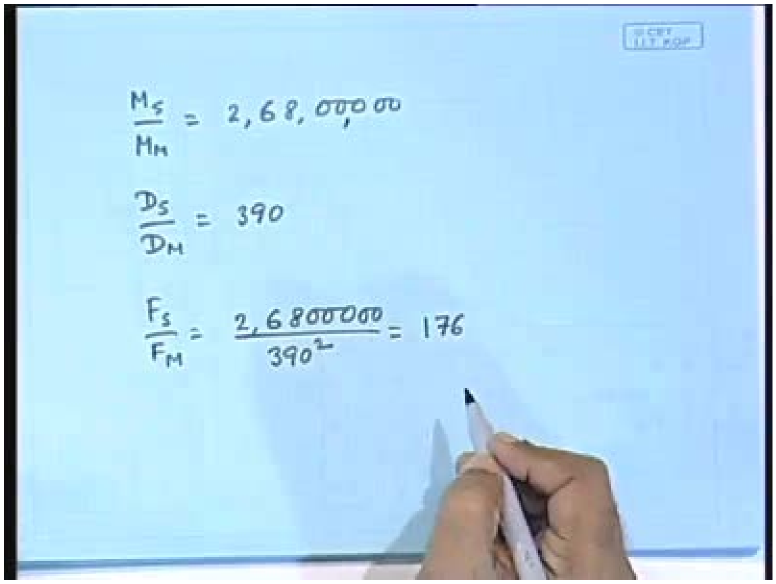

So, M S by M m would be 2,68,000; distance between the sun and the moon, distance between the sun and the Earth, this will be Earth and the moon, Earth and the sun this ratio D m D s by D m, it is approximately 390. Now, substitute it here, you get F S by F M is equal to 268000 by 390 square. Does anybody have a calculator? No, no; it is 176, the ratio, calculate.

Students: 1.76

1.76; oh, oh, oh, oh, oh, there is another, there are more zeros, sorry, 2,68,00,00; this is much further off. So, 176 is the, is the ratio which means the attraction due to the sun is 176 times the attraction due to the moon. So, your theory that the attraction due to the moon is stronger than the attraction due to the sun, because moon is nearer is definitely wrong.

Students: …

Yes, yes, so actually the force itself is not the reason. It is the differential force between the two points, two extremities along the diameter of the Earth, it is that what matters.

Now, because the Earth is further away from the sun, even though the attraction due to the sun is 176 times the attraction due to the moon, but the differential attraction is smaller, because it is far. So, because it is far, the attraction at this point and the attraction at the other point would not be much different and there on this point, the bodies that are nearer will have a greater influence.

Again in order to convince you, the engineers must be convinced in terms of numbers, so let us again work it out in terms of numbers. How strong will the attraction of the moon be in comparison to the attraction of the sun or the tidal effect due to the moon be in comparison with the tidal effect of the sun? Before that one point needs to be clarified. Many people do not understand this. The Earth moon system, when we talk about the Earth moon system, it is not correct to say that the moon rotates around the Earth. What actually happens is the Earth, the Earth moon system, as a system rotates around their common center of gravity, obviously that has to happen.

Now, that common center of gravity is within the radius of the Earth, it is not outside, because Earth is much heavier, 81 times heavier than the moon, therefore it is inside. Approximately 0.72 times the radius, at that distance the common center of gravity is.

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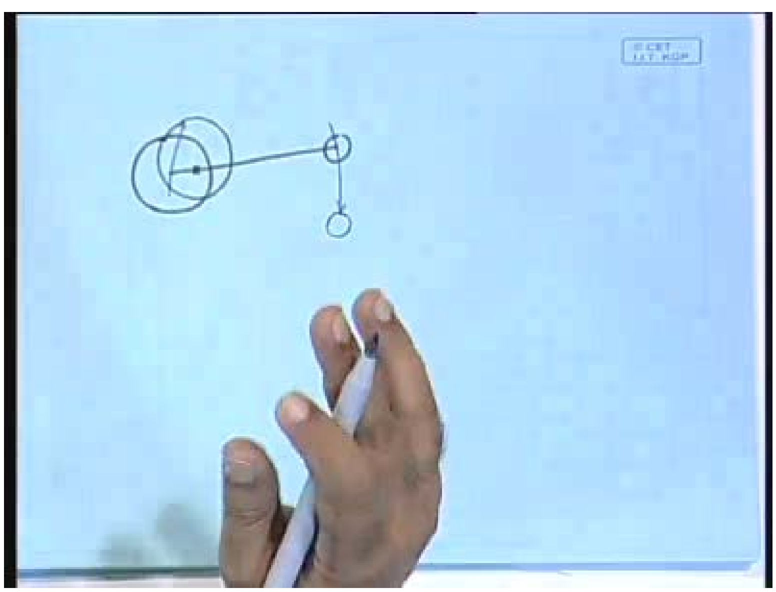

So, actually the Earth moon system rotates around a point here, which means that this fellow is rotating like this and this fellow is rotating like that around the common center of gravity. So, this fellow at one point time it is like this, another point of time it is say, around this center it is here. At that time this fellow has moved here, so this fellow has moved somewhere here. Now, in order to understand it properly, let us assume for now that the center of gravity, common center of gravity is outside the ….. path, in order to make it easier to draw it. Just to make it easier to draw, that is not true, but it will be easier to draw.

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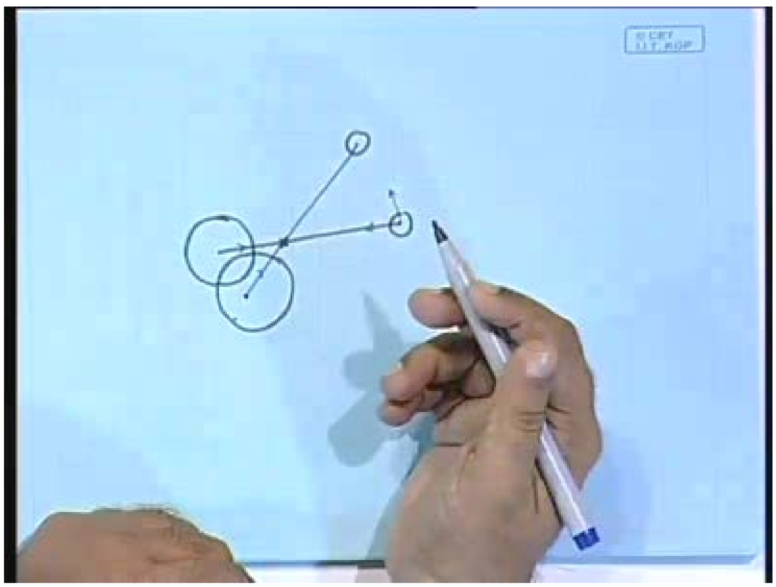

So, suppose this is the Earth and this is the moon and this is the line joining the Earth and the moon. Now, if you consider the common center of gravity somewhere here, then after sometime the moon will be say, along this line, moon will go to this point and Earth will go around this center to this position. Now, notice, when the moon is rotating from here to here, it is always having an attraction towards the center, right having acceleration towards the center and the magnitude of the acceleration is v square by r. Similarly, when the Earth is going from this point to that point moving around the center of, common center of gravity it is moving with an acceleration v square by r, its own v square, its own r. Now, what is the direction of that acceleration? Like this and for this fellow it is like that. Notice that the Earth is then moving with an acceleration towards the moon, right. Can you see that?

We normally do not see that Earth is falling towards the moon. Yes, Earth is falling towards the moon. Earth is also falling towards the moon and moon is falling towards the Earth and they are doing so, with their own v square by r acceleration and notice that all the time the v square by r acceleration that is experienced by Earth is directed towards the moon, all the time and therefore, Earth is falling towards the moon and that v square by r will obviously be different, this point and that point. The attraction will be different at this point and that point. Because of that differential attraction, you have the phenomena of tides.

Now, let us calculate the amount of the difference of attractions. How different are they? In order to do that, let us draw it like this.

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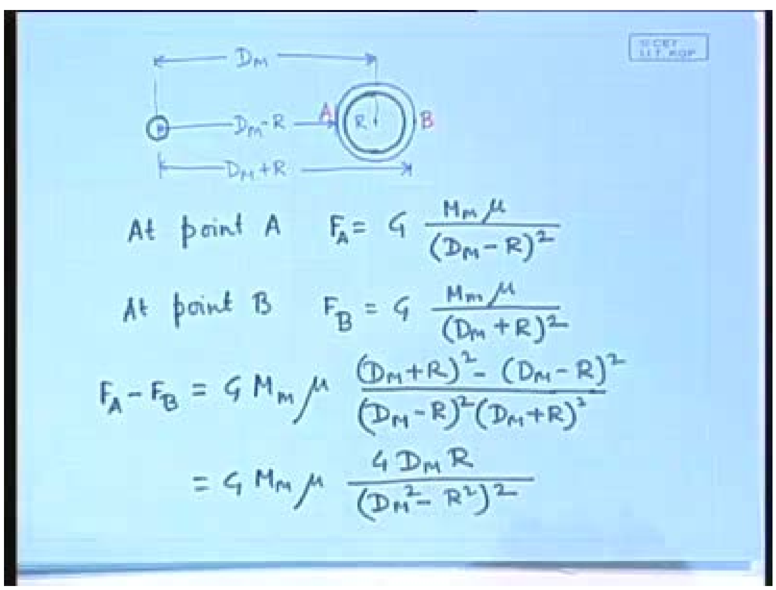

Suppose this is the Earth and you have this hydrosphere around the Earth and here is the moon. The distance between the centers is our D M, we have already used that, but the radius is R, the radius is R. So, this point to this point is R and therefore this distance is, this distance is D m minus R and this distance is…, right. The differential will be due to this differential distance. So, therefore the attraction on a unit mass, say of mass mu at this point will be, so let us call the point as A and this point as B, so at this point, the attraction at A point, the attraction due to the moon is F is G M moon times unit mass, let us call it mu divided by D M minus R square, right. At point B, this is F A, F B is equal to G same M m mu divided by D M plus R square. So, F A minus F B that is the quantity we are interested in is, this is common, so you have G M m mu comes common 1 by this square, 1 by this square.

So, you have it; you can write it as D M minus R D M plus R whole square. In the numerator you have … That is equal to G M m mu times, what remains? 4 D M R, right divided by the same quantity that is we can, we can simplify that D M minus M square minus R square, right. So, this is the quantity that we are interested in. It will be convenient to express it in terms of R by D M. So, let us just divide by D M, so that it express, it is expressed in terms of R by D M.

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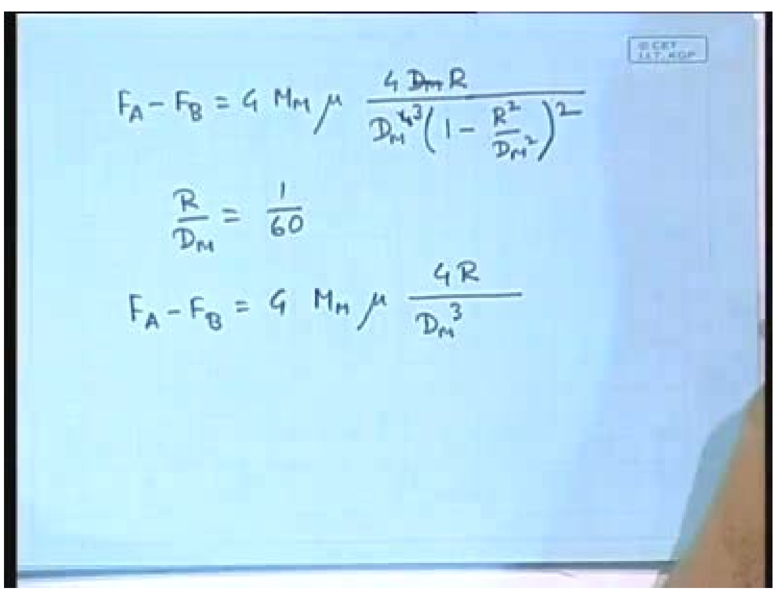

F A minus F B is equal to G M m mu, it will be 4 D M R divided by D M to the power 4 into 1 minus R square by …, right. D M cancels off, you get, get 3 here, good. Now, the distances are such that R by D M, the radius of the Earth divided by the distance between the Earth and the moon is around 1 by 60; 1 by 60 square here, which is much less compared to 1 and therefore, this term we can ignore, safely ignore. That simplifies it; F A minus F B is equal to G M m mu times 4 R by D M; fine, good. So, we have got this expression for any object, any body that exerts differential pull on the surface of the Earth.

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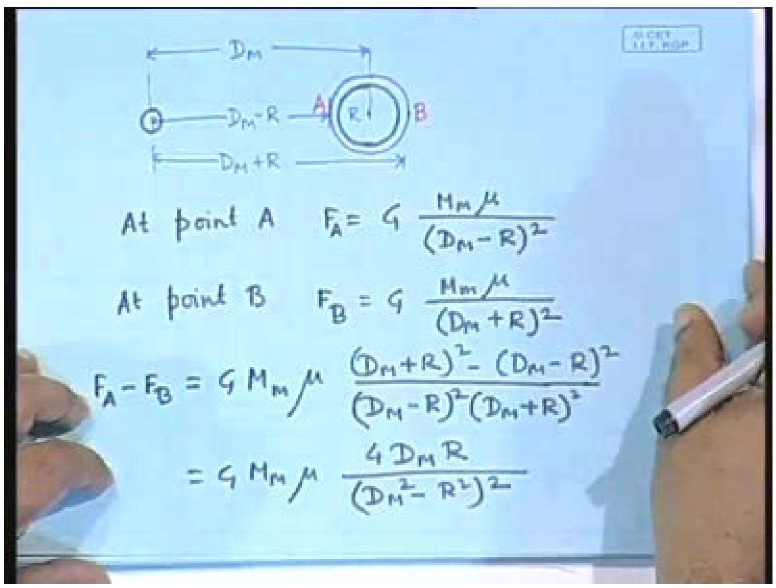

It could be moon, it could be sun, so in case of the sun, we will only need to replace the M subscript by the S subscript; that is all nothing more. Now, we are interested in the force that is responsible for production of the tides.

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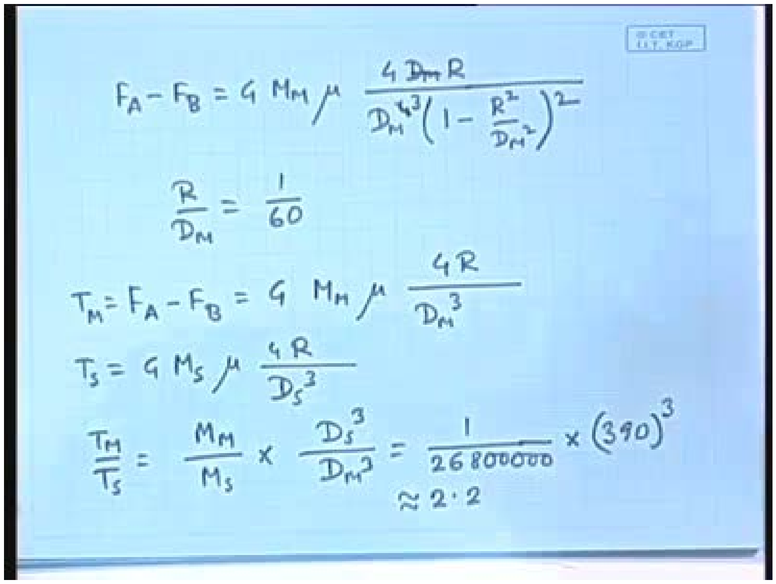

Let us call it, if this is for the moon let us call it T M, in case of the sun T S equal to G M S mu 4 this R is, remains the same. This is, so now we can write it as T M by T S, the ratio of the tidal force produced by the moon and the tidal force produced by the sun. Now we can divide and many things cancel off. What? This cancels off, this cancels off, this cancels off, so what you finally have remaining is, no, M M by M S into D s cube by … Now, you substitute the numbers. You already know the numbers. So, if you substitute D M m by M S is 1 by 26800000 times D s cube by D m cube, this is the distance between the Earth and the sun, this will be the Earth and the moon, that ratio is approximately 390. How much does it come to be? 2.2 times, so approximately.

So, the tidal force due to the moon is 2.2 times the tidal force due to the sun. Do you understand now, why this happened? Because the moon was nearer, because of that even though the actual attraction due to moon is far smaller than the attraction due to the sun, but the differential attraction was 2.2 times. That is the thing responsible for the tides. So, we may visualize that there would be tides, two tidal bulges at the two sides of the Earth due to the moon and there would be two similar type tidal bulges at the two sides of the Earth due to the sun.

Now, they are not in the same direction or same position or same angle. So, normally imagine that the Earth is here, the moon is here and you have the tidal bulge in these two positions. Now, the sun is there, the tidal bulge is in these two positions.

Students: …

Yes, tidal bulge means two high tides. So, imagine there is no sun, only the moon. Then there will be two tidal bulges. Bulges means high tides, the two tidal bulges in the two sides, one towards the moon another opposite direction to the moon and in between there would be the low tide regions.

Student: Sir, has the center of mass of the two systems ….

No, no, no, no, no, no, no, no; bulge is always towards the moon. Notice, notice that here or you want it to be placed inside the, let let me draw again.

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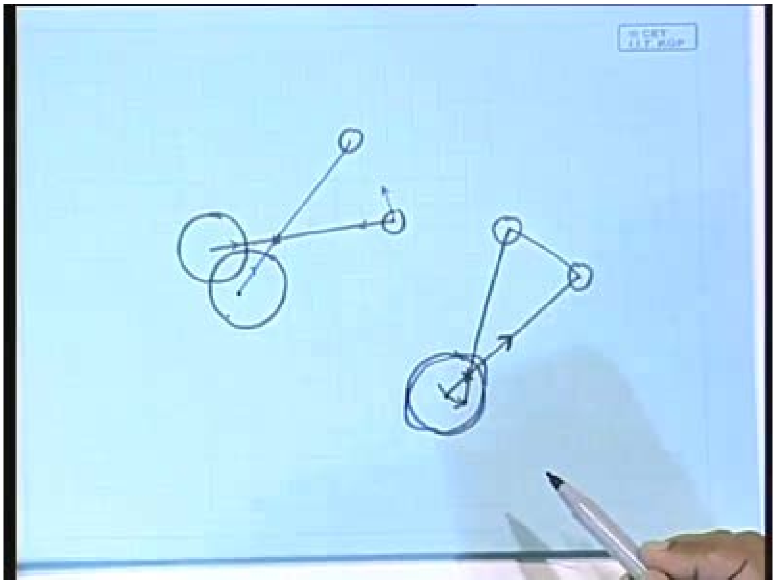

So, you have the Earth like this and here you have the moon and the actual center of gravity is here. But, what is the direction of the acceleration of the Earth? Is it towards the center of gravity? No, it is towards the moon, it is towards the moon. The Earth is actually falling towards the moon.

Student:

No, no, because, you see again, notice carefully the logic. The Earth is having, is moving in this direction around this. As a result, it has a, it has a, as a result it has an acceleration that is directed towards that.

Student: …

Now, yes, you can always say that, but it is also directed towards the moon. Now, the moon goes there. Now, you have the Earth situated here. Now, it is still directed towards the center, all right, but it is also directed towards the moon. So, all the time the Earth's acceleration is directed towards the moon, all the time the Earth's acceleration is directed towards the moon. It is created because of the attraction of the moon and that attraction because of the differential force in the two sides is stronger here than here. That is why this point will try to move with the larger acceleration, this point will try to move with a smaller acceleration. That is the point. Even though the center is inside, it is not that, it is not that it is attracted towards that.

Student: …

Fine, but it is not attracted towards that. It is not attracted towards that, the attraction is towards the moon. The center of gravity is not the gravitating point. It is just the center of gravity, center of, center of mass you can say. The gravitating point, the point that actually pulls it is the moon, right. So, all the time Earth is accelerating towards the moon and since Earth is much heavier than the moon, it so happens, it just only so happens, that it is inside. Really, there is no distinction between it being inside and the outside. There is no distinction. The tidal forces would not be different if the Earth were smaller, more denser, so that the Earth's, Earth moon systems center of mass would be outside the

Earth. There will be no difference, same tides will be created. So, all the time the Earth is attracted towards the moon and the direction in the moon you can see that this point is nearer to the moon and therefore, it will have a larger acceleration towards the moon and this point is farther from the moon, therefore it will have a smaller acceleration towards the moon. That is why it will tend to bulge.

So, the bulge will be one here, another here, as the Earth rotates around its axis. Therefore, it will see two high tides and two low tides. Low tides means when this point comes above you, right. So, this is the high tide and this is the low tide part. This is how it will bulge. I have exaggerated the dimensions. Actually in the open sea the amount of bulge is not more than 2 feet, very small. But nevertheless, that is there are two of these bulges in these two directions and there is a sort of less bulge in this direction. That is why as the Earth rotates, when you come on the bulging point you see high tide. Again after sometime Earth rotates and this point comes above you and then you see a low tide. Again after sometime this point comes, again you see a high tide and all that happens within 4 high, two high tides and two low tides come within one lunar day, clear. So, there would be two high tides and two low tides. That is most important. Is that point clear or you still have difficulty?

So, when you have a new moon phase, a new moon phase means when the sun and the moon are in the same direction. When they are in opposite direction you have the full moon. So, in the new moon phase, then the sun and the moon are in the same direction and therefore you have, not exactly in the same direction, exactly in the same direction happens in the time of eclipses, slightly off, but nevertheless more or less, so in that case, the two bulges will coincide. The bulge due to the Earth and the bulge due to the sun, bulge due to the moon and the bulge due to the sun will coincide and therefore you will see a larger bulge. These are the very strong tides that come sometimes. Calcutta is inundated some days. So, that happens when on those specific days, when the Earth, sun and the moon come in the same direction.

Similar thing happens, in the new moon time, full moon time, when the Earth, when the sun and the moon are in the opposite direction. Then, the opposite bulge due to the moon coincides with the forward bulge due to the sun and therefore, you again have large tides. On the other hand, if moon is in this direction and the sun is in that direction, then when for a particular point when moon says you should bulge, sun says you should go down and therefore, they actually are out of phase with each other; two sinusoids out of phase with each other, so they will more or less cancel each other, you have very small tides.

So, the tidal head is also not fixed, that varies, that varies with the phases of the moon, clear and that is exactly why you sometimes have very high tides that is sometimes you know, flooding situation in many places. Even the low lying regions of west Bengal have floods every year on those days. Have you seen, the Calcutta streets flooding, because of that particular, on that particular day? Only few days back that happened. No rain or anything, suddenly you find the Calcutta streets flooded, because of the very strong tide, spring tide.

I mentioned that the open sea has a tidal bulge of an extent of not more than 2 feet, but obviously 2 feet is no way sufficient to produce energy. So, also you should notice that the places near the coastal region experience tide that is far larger than 2 feet. So, something else happens, something more happens. That something more is that, even though the tidal variation is only of the order of 2 feet, as it comes close to the shore line more things happen. For example, a few years back there was the Tsunami, you remember. That very day there was a ship coming from the Andaman's to Calcutta and everybody was very worried what happened to the ship because everything in the coast line was devastated, right. When the ship arrived in Calcutta, to everybody's surprise they found that the ship people did not know that there was a tsunami. They did not experience, they did not even notice that such thing happened, the tsunami wave went. Why? Because, in the open sea that is very small, open sea it is not large.

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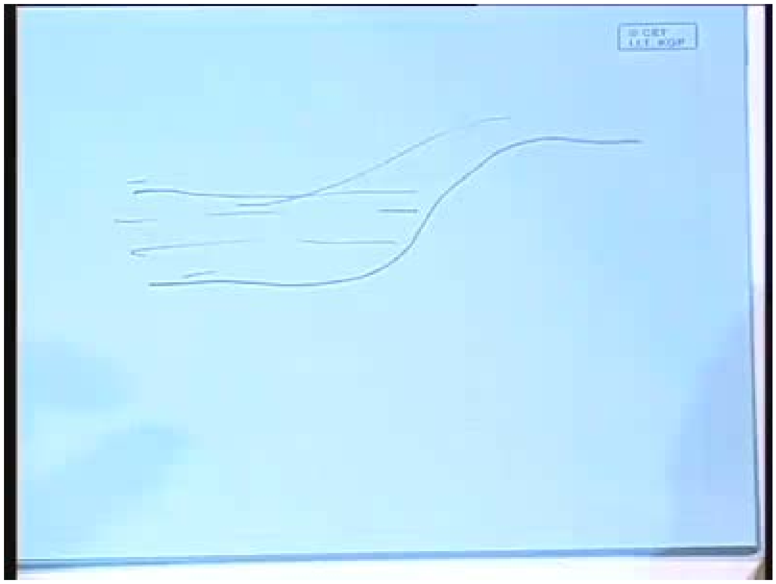

Only when that comes close to the shore line, for example if the shore line is something like this and you have the sea water like this, as the small bulge approaches the shore line, because of this specific topography that pushes the water up. So, as it pushes the water up, water goes into the estuaries and again the low tide comes, the water goes down. So, you see, there is one oscillation in the open sea and there is one oscillation in the estuaries. Estuaries means where the rivers come and meet the ground or when there are some, you know, creeks and something like that, the place that hold water, water going in and water coming out, so that has its own natural frequency of oscillation and the tidal variation has its own frequency of oscillation.

When these two frequencies match there is a resonance and it is because of that resonance you have in some places very high tide of the order of even 30 feet. For example, the Bay of Fundy in Canada, East coast of Canada, has a tidal variation of the order of 30 feet, very large. That is because of this particular fact that the specific topography of that Bay, its natural frequency of oscillation that matches with the frequency of oscillation of the tide and therefore, you have very high variation. It is actually a phenomenon of resonance.

It is also fact that not all the seas experience tides. For example, do you know that the Mediterranean Sea does not experience any tide? Why? Because, the Earth as it rotates, the tidal bulge moves from the East to the West, right. East to the West tidal bulge is there. Earth is rotating and therefore, tidal bulge is moving from the East to the West. East to the West means, imagine you are standing here and sun is rising or moon is rising say, because the effect due to the moon is stronger, moon is rising over Japan, so at that point of time with some bit of phase lag, there would be the tidal bulge on Japan. As moon moves towards the Malaysia, the tidal bulge also moves towards the Indian Ocean. So, it is moving from the East to the West. After sometime, over the Indian Ocean you have the tidal bulge. So, in the Bay of Bengal you see the tide, go to Sunderbans, you have the high tide, all the smaller islands are inundated and stuff like that.

As time progresses, it goes to the Arabian Sea. When the tidal bulge is there in the Arabian Sea, you have the ebb tide here, the water is emptied. So, the tidal bulge goes from the East to the West. Now, it so happens that the Mediterranean Sea is open only to the West. There is no opening to the East and therefore, the tidal bulge cannot enter the Mediterranean Sea. That is why the people who were close to the Mediterranean Sea, in the initial part of the civilization, they had to, they had to cross a whole ocean, no, they had to cross a whole landmass in order to see the tide. In fact, there were scientists at that time who had to go to great distances, in order to see the phenomenon of tides.

So, the tide then is a phenomenon that is very local, even though it is global. But, the fact that it bulges only at certain points, only resonates at certain points means that only certain specific geographic locations will be suitable for tidal power generation. You might enquire what are these? For example, worldwide what are the very good tidal locations? One, as I mentioned, the Bay of Fundy in Canada, they have tidal power generators, very large ones. One is in France, it is a place called Rance, Rance. There is another very good one in Russia. In India, we do not have yet a tidal power generating plant, but there are places that are very suitable for it, I will come to it. For example, let me show you one map.

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Can you see the map on the screen? Yeah, I am showing the map of the West coast from a school atlas. Now, notice that there are, there is one important creek here below Gujarat and above Maharashtra. Here, this is called the gulf of Khambhat or earlier this used to be called Gulf of Cambay. This is the place where you see a large creek, right. It is going in and this is the place where a large, a good number of rivers meet. So, this is one place where you have very large tidal variation and this is a place which is considered to be very suitable. There is another place, where is it? The blown up picture is not there, so let me show the smaller picture.

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Here, below Calcutta, what is this place called? The Sunderbans, right and the Sunderbans experience very high tidal variations. So, there have been proposals of establishing tidal power plants in the Sunderbans, but there is a specific topographical problem there. The Sunderbans delta is still in the process of formation which means that the islands that are there, they are still forming and in some cases some are eroding off. So, sometimes you will see there is an island, 10 years later you will find there is no island there and a place where there is nothing, suddenly there will be island formed and that happens over periods of years, you know.

Suddenly people find that the place under which they are standing that is no longer there. So, it is still in the process of formation and people have to be displaced like over the last 20 years, some 70,000 people had to be displaced, because the islands vanished which means that it is still a forming landmass and in such cases, any major civil construction may disrupt the path ways, channels through which the water flows and that may have a devastating effect on the rest of the landmass and it so happens that the Sunderbans is the largest, largest eco system, natural eco system with mangroves.

Mangrove is a specific kind of tree. Mangrove forests are very, very rare and wherever mangrove forests are there, their protection is of utmost importance; specific kind of trees that grow in saline water, that have roots, that roots can breathe, so this kind of specific eco system is there. So, people are very concerned about the protection of the mangroves and protection, of course of the tiger; specific flora and fauna that are there in a specific place. That is why even though the Sunderbans are good place for tidal power generation, it is not considered to be a suitable place because of the environmental reasons. So, the only place that we can look at in India is the Gulf of Cambay, all right.

Fine, in the next class, we will talk about the actual ways of tidal power generation. But remember, when you talk about tidal power generation, obviously the turbines that you use for tidal power generation have to be a low head turbine, because we are talking about heads of the order of say, 1 meter, 2 meter. In the open sea it is 2 feet only, in those specific estuaries it may enhance to say 2 meters, but not much, not much more. In contrast to the hydel power plants that you have been taught about, we have talked about the hydel power plants, right, we had talked about the high head plants, medium head plants and the low head plants. What were the low head plants we talked about? The specific designs where you have very low head, see, for the very low head, for the medium head or towards the lower side, you have the propeller type turbines.

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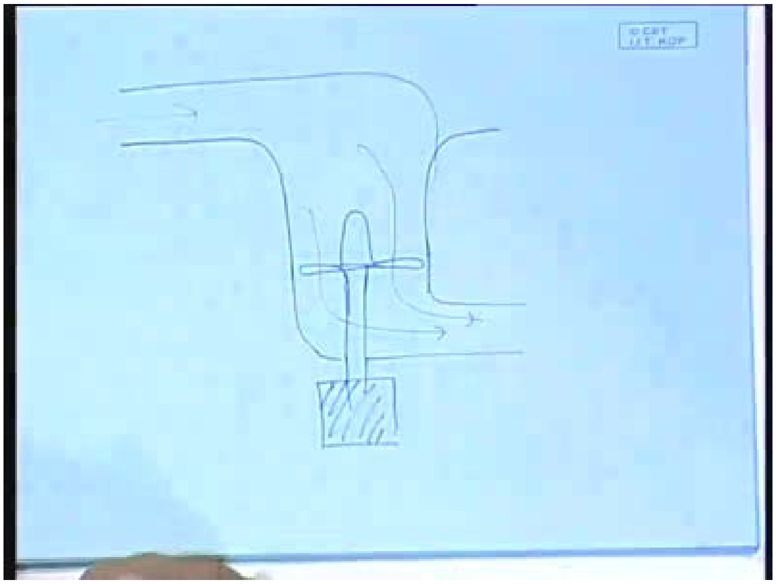

Propeller type turbines, often they look like this. Here you have the propeller and here you have the passage of water to go out and here you can have the generator, all right. So, you have, the passes …. like this. These are the sort of reasonably low head turbines, these are reaction turbines. The ones that look like propeller, water flows and it is vertical axis turbine. But notice that, because it is vertical axis, these are very widely available, because it is a vertical axis, the generator can be placed outside the water. One of the major problems in turbine design, how to place the generator, has to be placed outside the water, but because it is, it is vertical axis, it has to have, it has to have this much of head difference and obviously, this head difference is larger than about 1 meter or 2 meters. So, even this kind of design is not suitable for tidal power generation.

What is done is there are two designs that are generally used.

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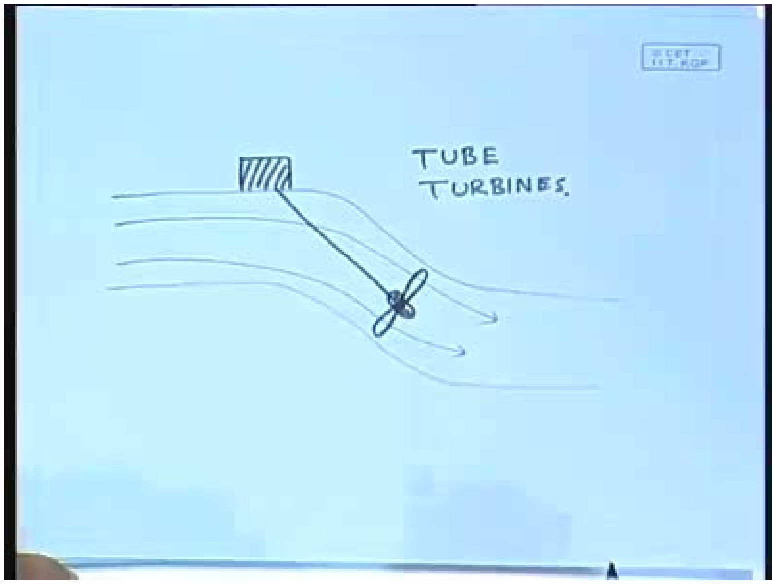

One is where the channel is not exactly vertical but it is something like this and the turbine is situated here and the shaft goes like this and the turbine is situated here. Obviously, that will allow the use of a larger, of a smaller head. These are called the tube turbines. So, there the head is smaller than the vertical axis turbine. So, this can work in lesser head.

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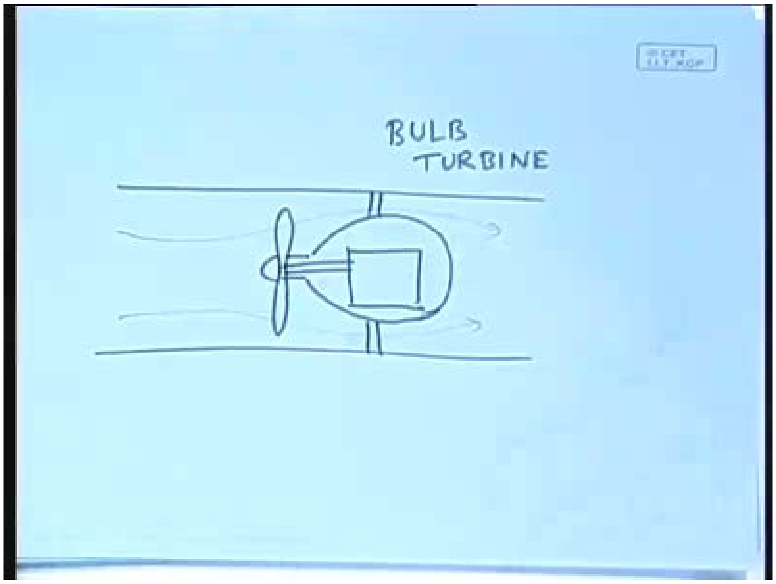

There is another design, I will just quickly draw; that is absolutely horizontal flow. You have the … and then you have a large bulb, the water type bulb in which you have the generator and this is connected like this. The water flows. In this case, it is a water type bulb in which the generator is placed. So, it is called the bulb turbine. So, in case of the tidal power generation either the tube turbine or the bulb turbine is used. That is all for today, we will continue in the next class.

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In the last class we have understood why tides occur and in that process we have seen that the tides are mainly caused by the effect of moon. The effect of the sun is there, but the effect of the moon is 2.2 times stronger than the effect of the sun. So, when we consider the tides, we will essentially consider lunar tides and we have understood that within a lunar day, there are two high tides and two low tides. Therefore, two full tidal cycles in a lunar day remember, which means 24 hours 48 minutes. The solar day and lunar day are bit different, because if the moon were static, then we would see, as the Earth rotates around its axis we see it come back exactly 24 hours later, but since moon itself is moving, therefore it comes back to the position 24 hours 48 minutes later. So, that is a lunar day. In a lunar day therefore, they would be two high tides and two low tides.

The effect of the solar tide would be only to enhance or to cancel a part of the lunar tide. So, that is how we would understand it. So, whenever, from now onwards, when we talk about the tidal cycle, we will essentially mean the lunar cycle. We have also understood that the open sea has only about 2 feet of tidal variation, which is very small and that is enhanced by the specific topography of certain coastal sites and that is why in various parts of the coastline we will find tidal variation going to different heights and there are specific places where the tidal oscillation, natural tidal oscillation and the ingoing water and outgoing water that kind of cycle they match and there is a resonance and there you find very high tidal variation and that can go as high as 30 feet and naturally, we have to utilize those particular sites where you have a large tidal variation; but not only that, there is another thing that you have to consider.

How actually would you utilize the tidal energy? Essentially, you somehow have to confine the water that goes in during the high tide and allow it to pass through turbine, right. In order to do that, therefore you need to construct a dam, so that the water cannot naturally go out without going through the turbine.

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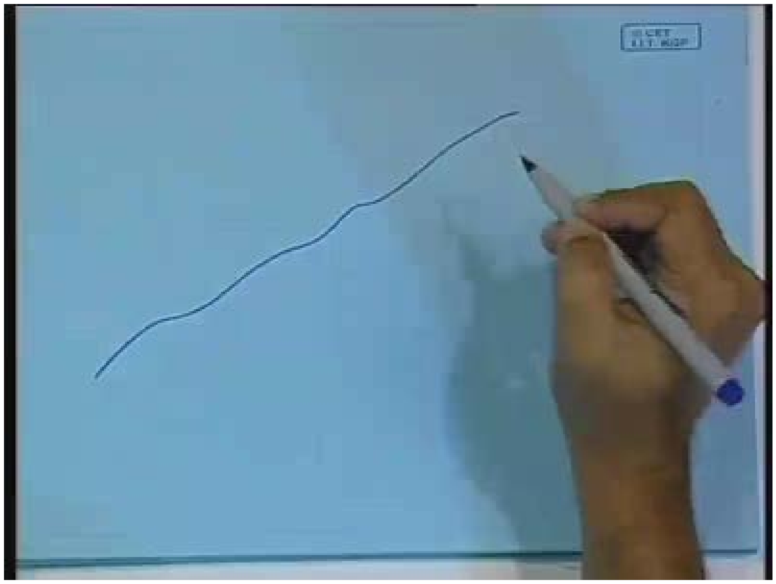

So, suppose this is a coastline, but before that let us get back to the particular site characteristics. It is here.

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Notice, we were yesterday talking about this site, the Gulf of Cambay or the Gulf of Khambhat. Notice that it is estuary of many rivers and it has an elongated part and it is possible to construct dams here, somewhere here. But still, if you notice the sizes, the size of the dam that would be necessary is 25 to 30 kilometers, very large. Naturally, that would entail a very large capital expenditure, even though the amount of water that would be enclosed is very large. So, it has been estimated that this site has a power generation capacity of close to 5000 megawatts, huge, but still the problem is that the capital expenditure is also huge, due to which the country has not yet been able to establish such a tidal power plant. But, it is a very large tidal power generation site that is possible.

So, notice that you have, you can put the dam somewhere here or here or here depending on how much you can spend and depending on that you will have different amounts of energy made available, because different amount, different sizes of basins can be created. Unfortunately in India, the other sites that are possible are not very good tidal generation sites, because a tidal head is not all that high or the coastline is rather flat rather than having that kind of estuary, a structure. The other rivers, there are many rivers, but other rivers do not have that much of tidal variation, except at Sunderbans and Sunderbans has a problem that it is not just one estuary. It is a very, very large number of rivers that is finally meeting the sea; very, very large means there can be something like 50 different rivers going into sea. So, you will need to construct many small dams in many places in order to enclose any amount of water and as I told you, there are environmental objections, which is very justified. That is why that has, that site has not been chosen as yet. So, let us stop here and in the next class we will talk about how to produce continuous power from tidal power generation.

Thank you.