Elements of Ocean Engineering
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Lecture - 2
Physical Oceanography – I

So, welcome to the first lecture on physical oceanography. So, there we have series of lectures in physical oceanography. So, this is physical oceanography – 1.

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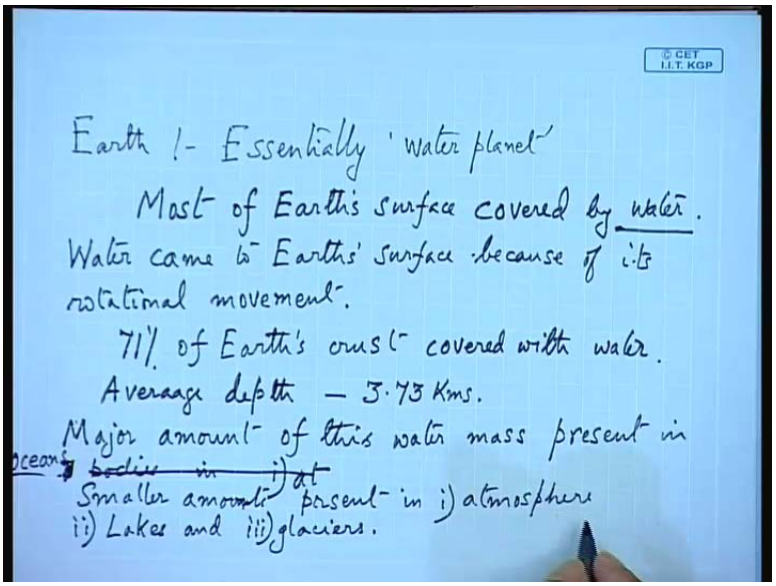

Now, earth may be noted. It is essentially a water planet. Earth is essentially what is termed as water planet. So, that is most of the earth's surface is covered by, so most of earth's surface is covered by water. So, water is a very important ingredient in the elements, which make up or the constituents of the earth. So, in fact, it is… Water is also… Water actually came to the surface, water came to earth's surface, because of its rotational movement. And water as you know, it is being lighter than the soil or the rocks, which make up the earth. So, it started floating on the crust of the earth; it came to the surface. Now, 71 percent of the earth's crust, actually, the amount of coverage is 71 percent of earth's crust.

So, you will be surprised to know that, 71 percent of earth's crust is covered with water. Now, average depth of this water mass is 3.73 kilometers. So, that is the average depth of the oceans. So, we are confronted with the sort of cover over the crust of the earth. Now,

this major amount of this water mass, this is present in namely in 3 bodies. So, this is present in 3 bodies. So, namely, that is in… First is atmosphere, major amount of this water mass is present in oceans; you can write, so there is a small mistake, it is present in oceans. And smaller amounts… So, these smaller amounts are present in atmosphere; then lakes, and glaciers. So, the large portion of this 71 percent of the earth's crust is covered by the oceans; and the smaller amounts there to be found in atmosphere, lakes and glaciers.

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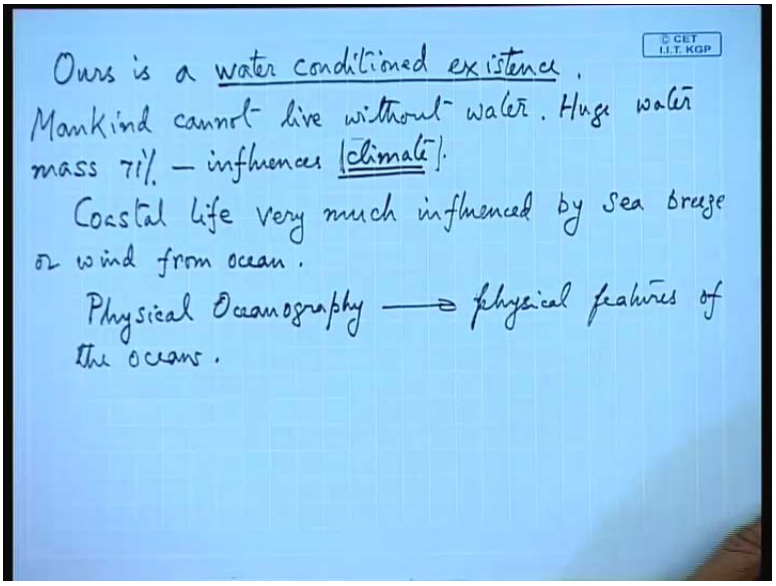

Now, because of this large water mass say almost, which is covering 71 percent of the earth; so ours is a water conditioned existence. So, water conditioned existence. So, that is, Mankind cannot leave without water. So, ours is basically a water conditioned existence. Mankind – obviously, everyone knows – cannot leave without water. So, this is the first inference from a water conditioned existence.

So, we cannot live without water; that everybody knows. The other most important thing is that, this huge water mass… So, this is very very important – this huge water mass – 71 percent influences climate. So, this affects all of us. So, there are two important things: one is the source of water for the mankind, which is supplied from lakes, rivers, oceans to some extent. And, the influence of this water body of the oceanic waters on climate. So, this is very crucial. Climate actually influences the lives of the people; not only mankind, who are living along the coast, but also inverts. So, coastal life is very

much influenced by sea breeze or wind from oceans. So, the costal climate is very much distinct from climate, which is more landward or inside the land or continental climate.

So, this is the direct influence of the ocean on the climate. So, this is one important difference, which most of us will find. So, climate is influenced by the oceans. Now, we are starting our sediments of ocean engineering with the physical oceanography as which the meaning of this term physical or rather physical oceanography means the features; or, rather it is the physical features of the oceans. So, what are the… We should know what are the physical features of the oceans? So, oceans on the top, we can see that, there are waves.

So, that is visible to the naked eye. But, if we go to the depths of the oceans, there of course there will be no waves. So, there we will find the physical ((Refer Time: 09:19)) that is, the ocean flow, the oceans beds, sea bed, etcetera; what are the features. So, those will influence the… They are called the physical part coming under the term of physical oceanography. So, physical oceanography is very important if one has to do anything in the ocean.

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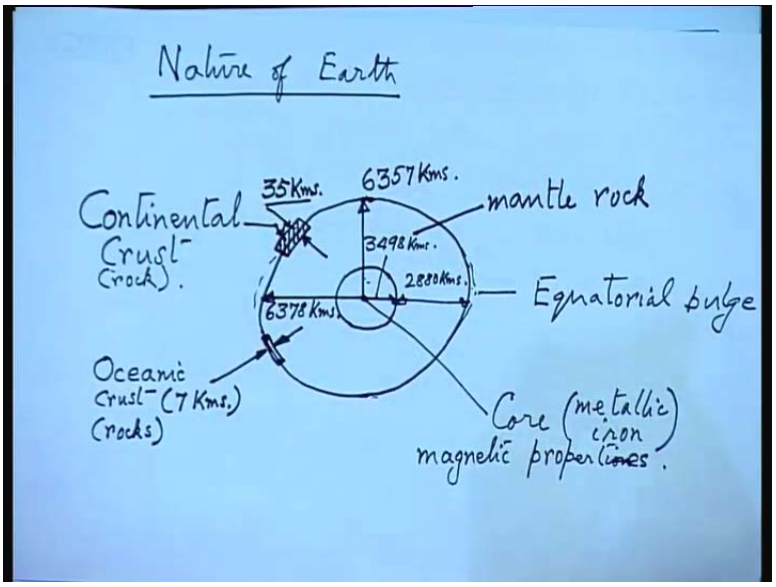

Now, before we go to deeper into this subject of physical oceanography, we should have a look into what is the nature of the earth. So, this I think is covered in most of the geography books. So, you will find the physical nature of earth. So, one has to start with the physical aspects of the earth itself in order to have a deeper gross understanding of

the oceans. So, actually, we cannot… The earth is comprised mainly of the continent, that is, the continental crust and the oceans or the oceanic crust. So, in that way, you will be surprised that, the earth is also not stable; earth is actually spinning on its own axis. And, because of this, it is causing lot of motions in the oceans. So, that one will come across the ((Refer Time: 10:54)) effect and all that; one has to study that. So, those create circulation in the water mass, that is, the currents.

Now, besides this, you will find that, coming to the physical nature of the earth, that is, what are the physical properties, you can… The earth actually you will be surprised is not exactly round or exactly circular in shape, but it is somewhat elliptical. As you can see from this figure, there is… The inner one is called the core. And, on top of this core, you have a cover or a mantle. So, this is called a mantle rock. So, here from this diagram, you can observe that, the core is very securely ensconced inside the mantle rock.

So, this is the basic physical nature of the earth. Of course, I am unable to draw… This is somewhat circular. But, you will see along the hemisphere or near the equator, there is what is called a bulge. This figure is somewhat… Since I am drawing by hand, it is not coming; but it will have a bulge near the equator. So, that is called an equatorial bulge. So, because of the rotation of the earth and the rocks; because of the centrifugal forces, it tries to go outside from the center of the earth. So, that is called the equatorial… This is called the equatorial bulge.

And, inside this, you will have a core. So, this is core rocks. So, this is essentially consists of metals. So, this is metallic iron. So, the core consists of iron; so meteoric iron. And, this core actually essentially gives the earth its magnetic properties. So, magnetic properties of the earth, that is, the… t-i-e-s, so magnetic north, magnetic south, the magnetic axis; the earth is essentially a magnet because of the metallic core. Now, on top of this metallic core, you have the shroud, which is called a mantle rock. So, mantle rock actually covers the core. Now, on top of this… This is a huge rock mass. And, on top of this, you have the… This is the… We are mostly interested in these two types of crusts. So, you have a continental crust.

So, there is a… Proportional to the mantle rock, you will find… This is called the continental crust. Now, from this diagram, you can see that, this continental crust is actually floating on the mantle rock. And, if one wants to know what is the radius? The

equatorial radius is 6378 kilometers. So, this is near the equator. And so I told you, there is an equatorial bulge. So, because of this bulge, the radius at the equator is somewhat more than the radius at the poles. So, you are… At the poles, you have… Or, the polar radius is slightly less. So, this is 6357 kilometers. So, you can see there is the difference in the radii of the earth; so 6378 and 6357. Although it is very small; but it is still there.

So, from this, we can find out, that is, the radius of the core. Core is itself 3498 kilometers. So, in the core radius… So, this is 3498. And, the mantle thickness is 2880 kilometers. So, you can see that, the core is actually… The radius is more than the thickness of the mantle. But, the mantle rock is also quite significant. So, here we find that, the continental crust is essentially floating on the mantle rock.

Now, the part of the continental crust, which goes into the ocean – it forms another crust, which is called oceanic crust. So, this oceanic crust is relatively young; that means it has grown from the continental crust. So, this continental crust is the depth. There is… The depth is 35 kilometers. So, this is the layer of the continental rocks; that means the rocks, which make up the continent; the depth is 35 kilometers; whereas, the oceanic crust, which has been formed relatively new or young.

So, we say that, this is the oceanic crust. But, the thickness of this crust is very less compared to the continental crust. So, oceanic crust is only 7 kilometers in depth – only 7 kilometers. Now, oceanic crust is they are also rocks; continental crust is also rocks. Now, these do not consist of any water mass. So, these are rocks and these are also rocks. So, on the mantle rock, we can divide the continental crust and the oceanic crusts.

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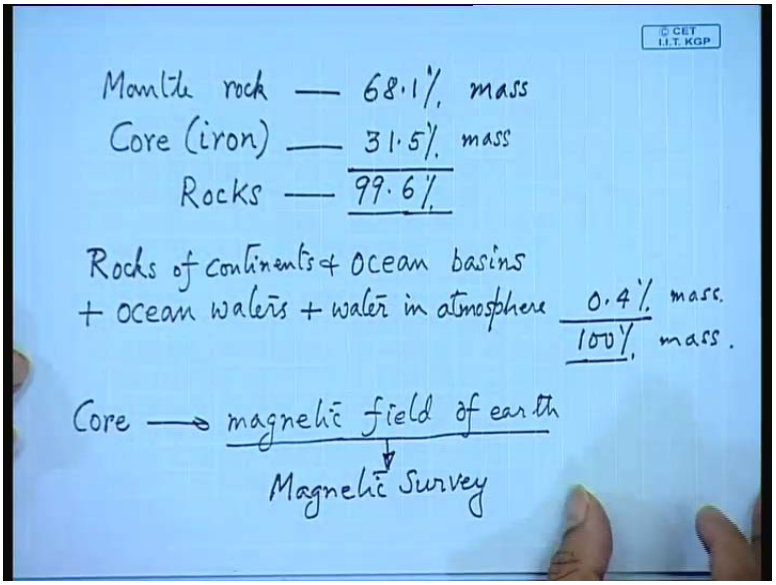

Now, if you take the percentage-wise break up of this mass, you will find mantle rock constitutes 68.1 percent of the mass of the earth. So, these are the mantle rocks. So, mantle rocks constitute 68.1 percent mass. So, next we come after this is the core rock or the core. Now, the core constitutes of 31.5 percent of the mass; the total mass of the earth. So, these are… So, if you add this, most of the mass of the earth… So, this comes to 99.6 percent is made up of rocks. So, 99.6 percent of the earth's mass is made up of rocks. Now, what remain is the rocks, which are not covered in the mantle or in the core. So, they form what is called the rocks of the continents.

So, that is constituting the continental crust, which is floating on the mantle rock. So, core is… You can see from this diagram that, this core is different from the mantle. And, on the mantle also, you have the continental and oceanic crust. Now, see this together. So, we can write that, rocks of continents and ocean basins – now, basins is the lowest… Basin means it is the lowest part of the ocean; that is, the horizontal plane right at the bottom of the ocean; that is, on the sea floor, on the ocean floor. So, that is called the ocean basins. So, rocks present on the continents and on the oceans basins plus the waters in the ocean. So, we can write ocean waters plus water in atmosphere.

So, water in atmosphere. Now, these constitute only 0.4 percent of the total mass of the earth. So, here one adds 99.6 plus 0.4. We get the total mass, that is, 100 percent of the

mass. So, here from this break up, we can see the earth actually constitutes a… A large part of the earth is constituted by the core and the mantle rocks. Here small part of the mass; there is hardly 0.4 percent, is occupied by the continents and waters. Now, the core that I have told you, that is, the core of the earth is essentially made of iron, which the core givers us the magnetic properties. So, these are the… I have already told you; the magnetic field of the earth is generated by the core – magnetic field of earth.

Now, this is used in… There is this very important from our point of... Those of us, who are studying the ocean engineering, this magnetic field is used in what is called… Later on, we will come to know; this is called magnetic survey – magnetic survey methods by which one finds out the amount of oil in the reservoir and the nature of the rocks, etcetera. So, that uses the magnetic properties of the earth, which are generated from this – essentially, the iron core. And, the other survey, which utilizes the mass of the earth; mass of the earth consists of these mantles and the core rocks. So, that gives us the gravimetric field.

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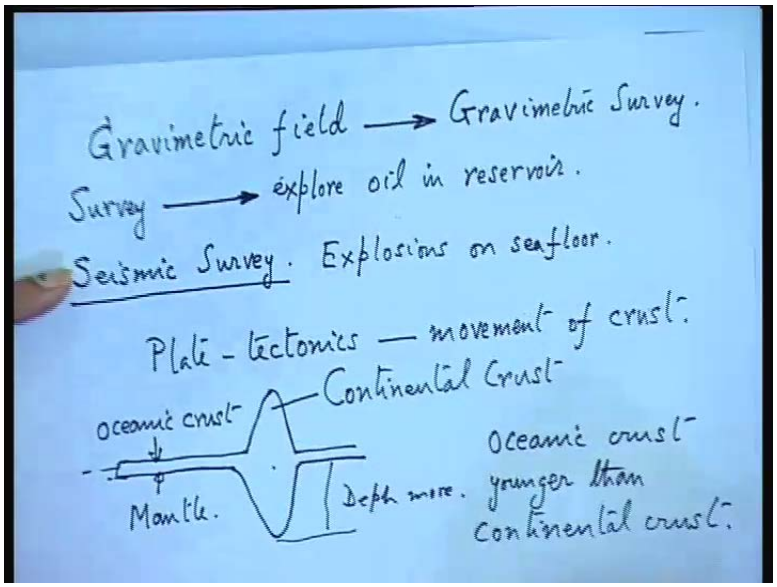

Gravimetric field – so now, there are very sensititive instruments, which studies the nature of the gravitational fields generated by the mass of the earth. So, gravimetric field is generated and this gives us what is called the gravimetric survey. These are two important survey methods, which are used in ocean engineering. So, gravimetric survey. Now, there are… In order to survey the oil… Survey I mean essentially we are… Our

point of interest or our major area of interest is in order to gauge the quantity of oil in the reservoir. Survey means explore oil in reservoir. So, this is very important for there if one goes into the ocean engineering. So, one…

Now, since drilling for oil is very costly and it is also time consuming affair. So, one has to before take the decision to drill for oil below the sea surface, one has to have a map of the oil reservoir. So, this is done by both the gravity survey, gravimetric field and also the magnetic survey. And, after this is done, there is another survey, which is called seismic survey. So, this actually there are explosions. Seismic means explosions are generated on the seafloor. And, the return path of the sound is measured. So, this is nutshell, what is called the seismic survey.

So, before one, any company or anybody goes to drill for oil, he must satisfy himself that, whether by all these three surveys, that is, the gravimetric survey, the magnetic survey, then seismic survey that, the oil in the reservoir is exploitable; that is, it is economically feasible to extract that amount of oil from the reservoir down below the ocean surface; which is of course is a very costly affair. So, when one ventures out into the sea or one tries to explore oil; so previously, one has to undertake survey. And then after this survey procedure is completed or finished, then you try to dig out or try to take out what is called the soil samples and explore the chemical composition of the soil in order to make yourself more certain.

So, this is the point, which I wanted to stress in physical oceanography. So, these are the parts of the earth. So, you have the equatorial bulge and then the mantle core rocks and continental oceanic crust. Now, here you will find that, the… Preciously, I have told that, these continental and oceanic crust – if you can see from this diagram that, they are essentially floating on the mantle rock; so that means they are not fixed. First of all, you see the earth… If one wants to know, there is always changing… Its position is always changing with time. First of all, it is spinning about its own axis and also it is going along the elliptical path with the sun on one of the foci. So, it is always changing. So, the continental crust also – it is not fixed to the mantle, where it is floating.

So, this also… There is movement on the continental crust. So, also the oceanic crust also, there is movements. So, those are not… You will be surprised to know that, these are not static; but these are actually floating. And, one crust – they also can go against

the movement on another crust and then you will have… So, earthquakes will emanate and volcanoes and all these things will go on. So, there is a dynamic situation, which one faces when one studies, what is called in plate-tectonics. Of course this is the realm of the geologists or the seismic engineer, but because of the movement of the crust. So, essentially, this is movement of the crust. So, this is another branch of study in seismology.

So, plate-tectonic, because the plate-tectonic has come, because of the movements of the continental and the oceanic crust, so that is a separate branch. Now, here actually if one studies the continental crust we can see the… The reason I told that it is floating on the mantle rock, one will find that, where you have large mountains; large mountains if one studies on the continental crust, that is, on the land; and below this, you will find a large portion, which is below the mantle, which is going deep inside the mantle rock. So, this is the continental crust, and because the continental crust is floating on the mantle rock…

So, this part actually is below the mantle rock. Why? The reason is wherever you will find the large portion of the continental crust protruding above; it has to be supported by buoyancy. Since this is floating, any floating body has to be supported by buoyancy. So, this… Because the continental crust is more Here; so the rock formation, which goes below inside the mantle, that is, the continental rock, is also deeper, because of the increased weight in this region.

So, this is why the depth will be more here, rather than the depth here. So, here of course, one can see that, the layer of the continental crust is rather thin. But, here it is thicker or more. So, here it has to be supported more by more of the buoyancy force. And, this can only be achieved by larger sinkage of the continental crust. So, here we can see the depth more. So, this is one example to show that, the continental crust is floating on the mantle. So, here the continental crust – it has come thinner and it is going outwards. So, this is called the oceanic crust. So, continental crust actually expands towards the sea.

Now, here actually towards the land of course, it does not have any room to expand. So, it can only expand towards the sea. And, that is the one of the reason why the oceanic crust is younger than the continental crust. So, one influence we can get from this diagram is that, oceanic crust… Now, in the oceans, one does not find large mountains.

So, that is why the oceanic crusts are relatively shallower than the continental crust. So, oceanic crust is younger than continental crusts.

So, this is one important influence we can have from this. So, this is coming to the rock formations on the continental crust and also on the oceanic crust. And, this ocean, that is, the ocean what – if we measure it relative to the depth of the continental crust, that is, the mantle rock and the continental and the oceanic rocks; so it is the mantle rock, which one can observe from this diagram is – this is 2880 kilometers. Now, compared to this, the oceans, that is, the depth of the ocean is hardly… The average depth is hardly from 3 to 4 kilometers.

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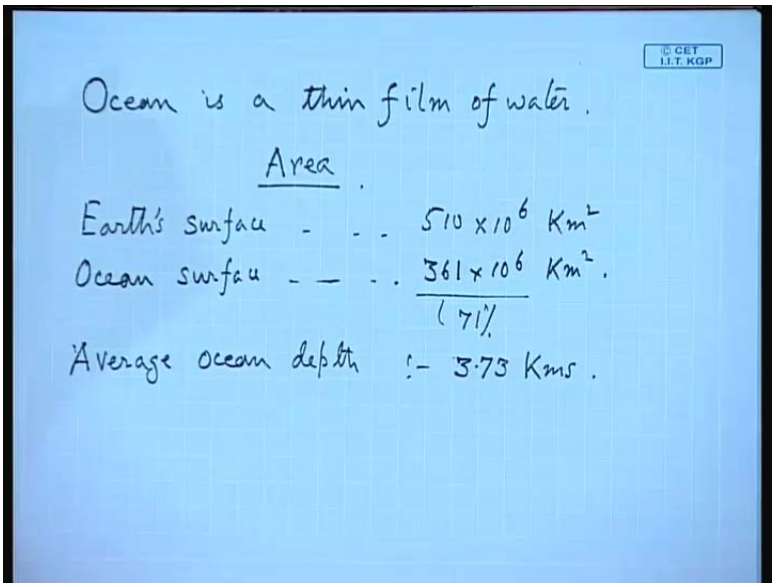

So, ocean is basically a thin film of water. Ocean is a thin film of water. Now, if one acquires the data – the area or the spatial data; once finds out that, the earth's surface. So, earth surface is 510 into 10 to the power 6 square kilometers; or, rather I can write kilometers square. Whereas, the ocean surface – so this is 361 into 10 to the power 6 kilometers square. So, this I think… Average I think if we work out, this is 71 percent – 71 percent of the total earth's surface. 71 of I think 510 will give us somewhere near this 361 figure. Now, the average ocean depth; so average ocean depth – this is 3.73 kilometers. So, with this, the 361 kilometers – multiply this by 3.73. So, one can get a rough idea of the water mass.

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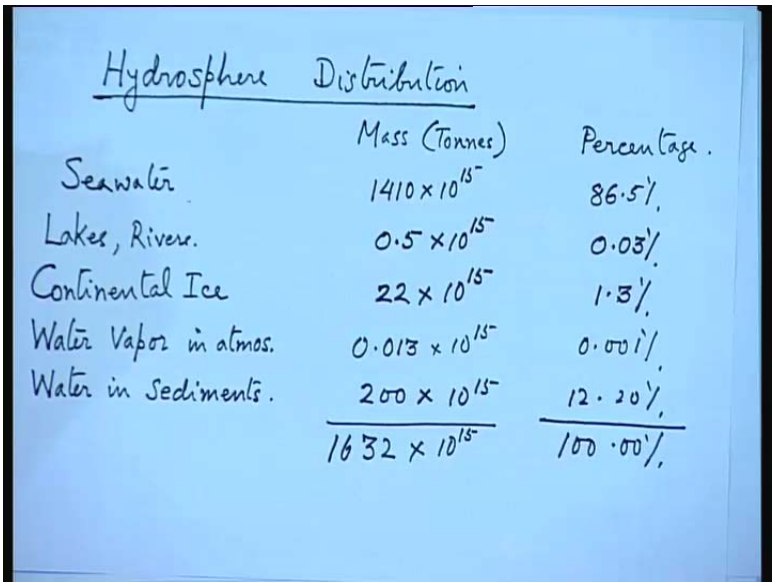

Now, the hydrosphere distribution or the water distribution – their total water distribution if we can break down, this is called hydrosphere distribution. Now, actually for our case, that is, the ocean engineer is only for his knowledge; but he need not do detail study on the amount of the seawater and the water in the lakes, rivers, oceans, and the dynamics, etcetera. So, those are taken care of by the meteorologists and those who study the circulation patterns of these water mass. So, they are most interested in the relative masses of these waters. But, anyway, just to have one's curiosity – just for curiosity sake; for information sake, you can write the seawater is 1410 into 10 to the power 15.

So, this mass is given in tones. Now, the sea water is the maximum percentage if you can see from this chart. So, this is percentagewise, this constitutes 86.5 percent of the hydrosphere. Hydrosphere is the total water inside the earth. So, seawater constitutes 86.5 percent of the total water mass. Next is the lakes – water in the lakes and rivers. So, the total mass is very small compared to 1410 or 1410 – this is only 0.5. So, this 0.5 is 10 to the power 15; and this constitutes only 0.03 percent – lakes and rivers. Now, next you will be surprised that, continental ice – now, what is this continental ice? So, this continental ice is the ice in the Arctic and Antarctic regions. So, those are the continental ice. And, they make up the substantial amount of the water mass. So, this is next to the seawater.

So, this is 22 multiplied by 10 to the power 15. So, this is… Percentagewise, this is 1.3 percent. So, we can imagine that, the continental ice present on the poles is more than what is present in the lakes and rivers. So, it is huge water mass melts. Those of us, who are now afraid of global warming – so they can increase the water in the oceans. So, next is the water… After continental ice, one comes across the water vapor. So, water vapor in atmosphere – so this atmosphere besides air, it has water vapor. And, if the water vapor is saturated, then of course there is precipitation or rainfall.

So, this… Also, this is 0.013. So, all this is into 10 to the power 15; and this is only 0.001 percent. Then after this is the water in the sedimentary rocks or water in sediments. So, sediments is on the sea floor; or, below the lakes and rivers, sediments… So, these are also quite substantial, that is, this is somewhat 200 multiplied by 10 to the power 15. So, this is 12.2 percent. Whereas, the total if you make up; so this is 100 percent. So, from this chart, one can see that, the maximum amount of water is in the seas of course.

And then next is water in sediments. Continental ice is also substantial – 1.3 percent. So, water in sediments actually – for us… For the ocean engineer, this is also very important because of the reason is, that is, if you want to have any foundation on the ocean itself or on the sea, that is, one come across; one has to do foundation in the sediments, which are saturated in water.

Foundation has to be designed or structures have to be designed in the ocean on sediments, which are basically saturated with water; unlike in land, you may have dry sediments. But, in the oceans, it is wet sediments or saturated sediments with water. So, these are the two types of sediments, which we will find is different from land and water. So, their total mass you can write down; you can add up all these. And, this comes to 1632 multiplied by 10 to the power 15. So, this is the hydrosphere distribution. So, this is just for our knowledge.

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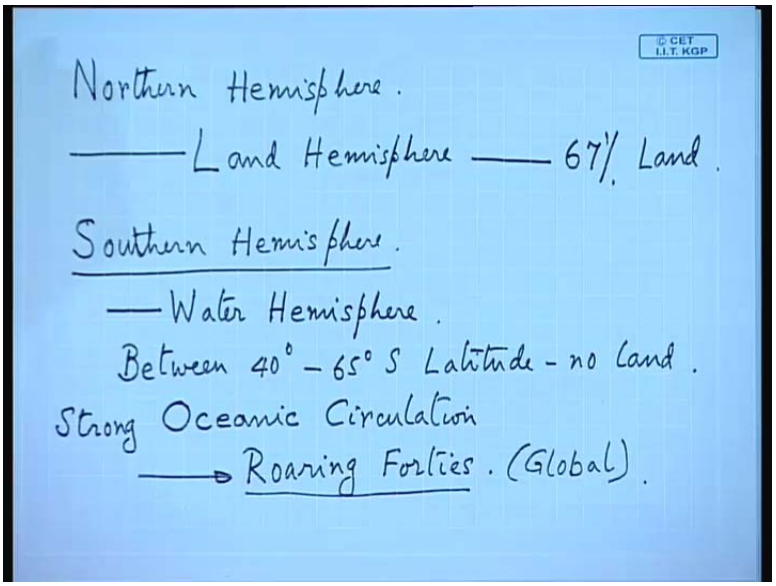

And, the other part that I wanted to tell you is the distribution of these ocean waters. You will find that, the northern hemisphere, that is, the portion of the earth, which is above the equator. So, that is the northern hemisphere. Now, northern hemisphere – it is essentially a land hemisphere. There is… Most of the continents of the earth – they are located in the northern hemisphere. So, this constitutes 67 percent of the land. So, the northern hemisphere is 60 percent of the land; whereas, this southern hemisphere is absolutely a water hemisphere. So, in the northern hemisphere, 67 percent of the northern hemisphere area is covered by land. Now, in the southern hemisphere, hardly you will find that. So, essentially, the southern hemisphere is a water hemisphere.

Now, there is no land between 40 degrees. So, between 40 degrees to 65 degree south latitude, there is no land. Now, because of this reason, at this – between 40 degree and 65 degree, there is a huge amount of ocean current, which causes a global circulation. So, there is a strong oceanic circulation. So, this is called the roaring forties. So, if one visits the Antarctica region, near the Antarctica, you can come across the roaring forties. So, that means this region is very active as far as wind and currents are concerned. So, they are called the roaring forties and they cause a global circulation. And, this actually influences global climate. So, this current is called the roaring forties. So, this is the ocean circulation influencing world climate. So, this is just an example.

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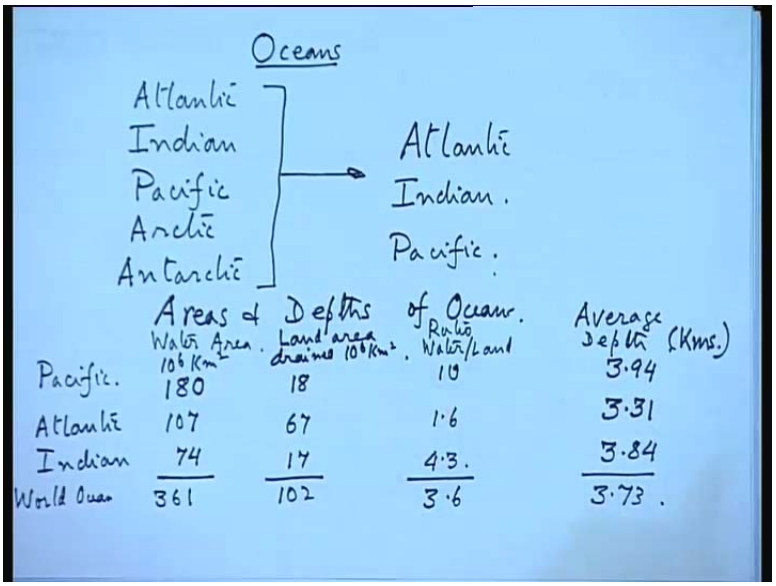

Now, if one wants to go further, then the oceans can be divided into number of parts. So, oceans – Atlantic; then you have the Indian Ocean; then Pacific, Arctic; last is the Antarctic. So, these are how many? 3, 4, 5. Now, for all geophysical study or oceanographic studies, actually these five oceans can be clubbed together into three oceans. You can combine these water bodies into Atlantic. For study purpose, you can write this Atlantic, then Indian and Pacific. So, these five oceans can be combined and they can be segregated only three oceans: this is Atlantic, Indian and Pacific ocean for our oceanography or ocean engineering studies.

Now, this is areas and depths of oceans. So, that we have already divided these five oceans into the three oceans. So, we will write only the three. So, first is the Pacific; so the water area. Now, the water area is given in 10 to the power 6 kilometers square. So, pacific is 180. So, it should be come down. And, next is Atlantic; Atlantic water area is 107. And, the Indian Ocean is smaller than the Atlantic. So, this is 74. And, total World Ocean you have 361. So, this gives us the coverage of the Atlantic, Indian and the Pacific Ocean.

Now, the land area, that is, the coastal area – land area drained. So, this is also 10 to the power of 6 kilometer square. So, the adjacent land area is 18; and this is 67; and this is 17. So, land area affected by these oceans are 18, 67 and 17. And, if one takes ratio of water is to land – the area wise. So, this will give 180 by 18. So, this is 10. So, this is

roughly will be 1.6 times; and the water is to… Then this is 4.3. So, from this diagram, we see that, the pacific is the largest water area with respect to the land. Next is the Indian Ocean area. So, Indian Ocean area – we have the continents, that is, the large portion of the coasts are affected by the ocean waters. Of course Atlantic is – area wise, it is less. Now, average depth if one comes cross; so average depth is…

The Pacific is 3… This is kilometers. Average depth in kilometers is 3.94; there it is 3.31; and this is 3.84. Now, we can see that, this ratio – water is to land. So, here we can add this with 3.6 also; and this is 3.73. So, in our country actually, large portion of the coastal area is drained by the Indian Ocean. So, that we should not neglect; and also the average depth is also quite high – 3.84; it is almost near the Atlantic. So, this gives us some of the physical aspects.

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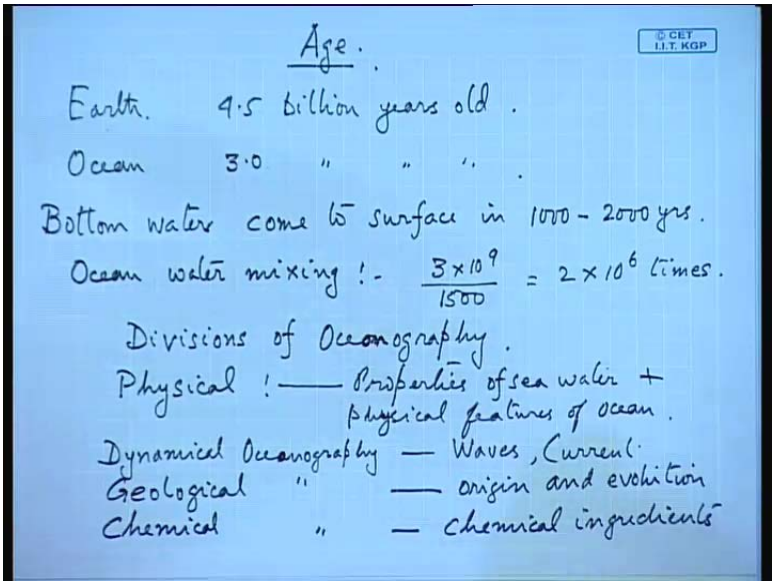

And, coming to the age; so age wise. So, the earth is 4.5 billion years old. Now, oceans – I told you; it is ((Refer Time: 53:39)) younger. So, this is only 3 billion years old. Now, these bottom waters – they come to be surface. Now, this is to be noted – the circulation of the waters depth wise. So, they come to be surface in 1000 to 2000 years. So, this is bottom water circulation. So, this causes what is called ocean water mixing. So, this – if one divides the age, age is 3 billion years. So, this is 3 multiplied by 10 to the power 9. And, average of 1000 to 2000; you take 1500 let us say; take 1500. So, this is 2 into 10 to

the power 6 times. So, this is not small. So, in the total age of the oceans, there has been 2 into 10 to the power 6 times of mixing.

Now, coming to the divisions of oceanography; so here you can divide into physical. So, the one that we are studying right now is called physical oceanography. That deals with the physical features of the oceans; and also, the properties of seawater plus physical features of ocean. So, this part is discussed in physical oceanography. Then of course there is another part of oceanography, which is dynamics of the free surface, that is, the waves and all that. This comes under dynamical oceanography.

So, this basically deals with the waves, etcetera – waves, current. Now, after this, one has geological; so geological oceanography. So, this deals with the origin and evolution of the world's oceans. And, chemical is chemical ingredients or chemical transformation. So, the manganese nodules are caused by the chemical reactions in the seawater. So, those come under the category of chemical oceanography. So, then of course there the marine life is covered under biological oceanography.

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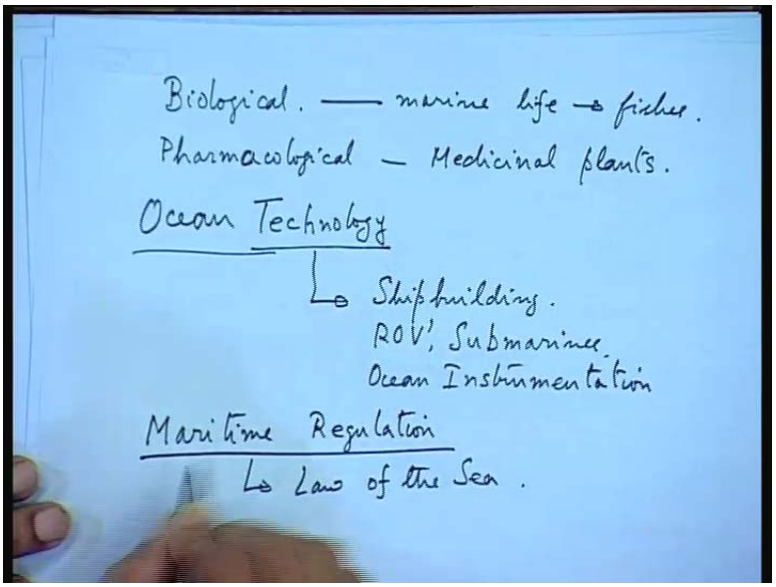

And, biological… Other part is biological and pharmacological. So, this last part deals with the medicinal drugs. So, biological is marine life. So, that is, fishes. There are pharmacological – medicinal plants. So, these are some of the branches of oceanography that one deals with. And then of course, the other technology part has also developed from this – from oceanography. Then the technology part – that also comes under after

1970s onwards, which has developed very rapidly; that is, ship building. Then you have ROV's – remotely operated vehicles, submarines; so these are all developed; then ocean instrumentation.

So, these are the technological part of the ocean engineering. So, this is called ocean technology. And, at the last, we will find maritime regulations. So, this deals with the law of the sea. So, these are the various divisions of physical or rather oceanography that one comes across.

So, thank you; so next class, we will look into the deeper other aspects of the physical oceanography.