Non-conventional Energy Resources
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Lecture - 01
Renewable Energy Technologies

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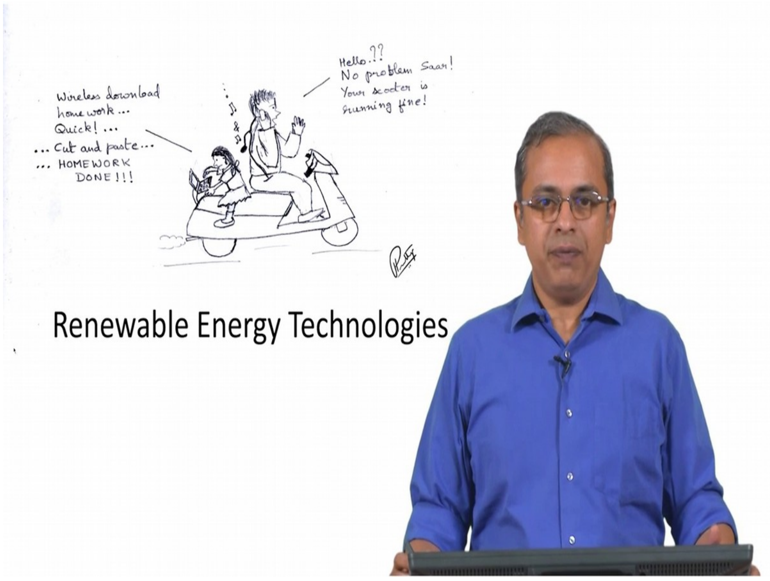

Hello, welcome to this course on Renewable Energy Technologies. You could also think of this as a course on a non-conventional energy sources. This is intended as a 40 hour course, which in a typical engineering curriculum would be about a 3 credit course. So, that's the intention. It is aimed primarily at PG students, but a typical you know higher semester undergraduate student can also benefit from it. So, you can think of it as a an elective course in energy related technologies or if energy is your core activity, then this would be a good core course for you.

So, one of the reasons we have a course like this is the fact that a lot of technologies today that we use, that we all use extensively use different forms of energy and energy sources. So in fact, I don't think you may, you would have realized this, but let's say you go to a room and let's say you go to a meeting or you even in your classroom you are just seated in your classroom, let's say there are 30 students in the class, you will be surprised to note that in that class of say 30 students, the number of portable energy sources that are sitting in that room that are present in that room is actually more than 30. In fact, chances are you have about 60 portable energy sources within that room, mostly because typically many of us have wrist watches and many of us have mobile phones.

So, actually right now I don’t have one, but in principle you would have a wrist watch and a mobile phone most of us would be carrying these 2 items. So, in a typical gathering that you see, whatever the number of people that you see a quick guess is that you have about twice as many energy sources sitting in that room. So, in any social gathering you have more energy sources seated there or present there than you actually have people present there okay. So, that’s the extent to which energy sources have invaded our lives or are pervasive in our lives. They have invaded because we have allowed them to invade us, but that is the way we are sorry that is the extent to which it exists in our society. Naturally it is a topic that is of great interest for all of us to understand what are these sources, what are the possibilities that we have with these sources and what can we do with it.

You can see in this cartoon out here of course, many safety rules are being violated in this cartoon here, there’s a person possibly a father driving with hands of the wheels of the steering handle of a scooter, and there is a little girl seated at the back doing her homework. But I think it quite clearly indicates to you the extent to which we have gotten use to mobile technology. So, you have some music going on here, you have a homework going on here; you have a telephone in operation here and a conversation that’s going on. So, a lot of things that are on at this point in time, and it’s all happening in the same location. And this is not at all unusual it happens in all our lives we are doing one activity while at the same time we are trying to do some other activity, may or may not be a safe thing to do, but that’s what we do these days.

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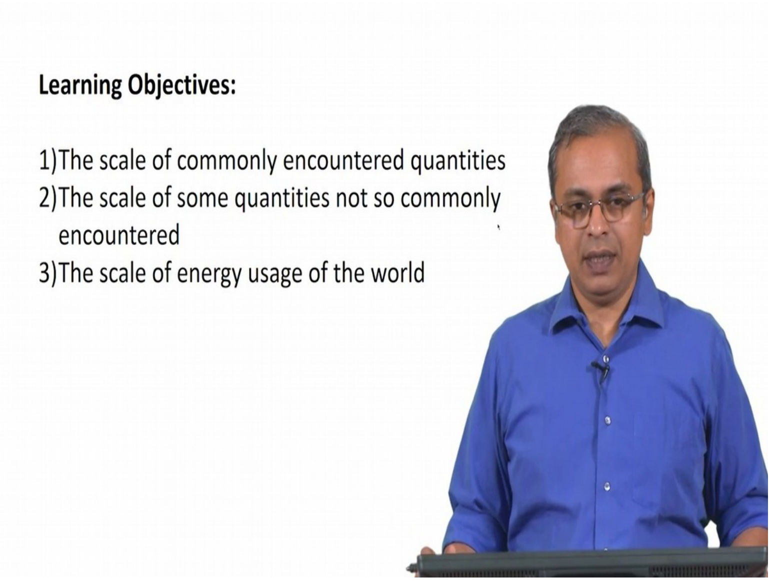

So, in this class we have some learning objectives; for this class as we go through this set of content that we will look at our learning objectives in this class are to look at the scale of commonly encountered quantities, and you will see a wide range of things that we use particularly in the context of energy, and what kind of scale of a energy are we talking about, what's the kind of scale of power we are talking about and these are kinds of things that I think it would be interesting to get a feel for.

You will also get an idea of the scale of some quantities that are not so commonly encountered. Primarily to give you a sense of the scale of all the quantities that are present because we use some quantities commonly and we don't quite realize where they stack up against other quantities that we do not necessarily encounter on a daily basis. So, this is to just give you some you know overall picture so that you understand what you are dealing with when you pick some object and you try to analyze it. And in the context of these scales the primary purpose is to talk about the use of energy in the world.

So, we would like to understand what is the scale of energy usage in the world; because if you are talking of a renewable energy technologies or non-conventional energy sources. At some level these make sense only if you are willing to talk about the scale of energy usage in the world and whether or not these new technologies that you are trying to work with will actually address the scale of usage and therefore, it is of great interest to understand the scale of energy usage in the world okay. So, it's in this context that we will look at a scale of various quantities, commonly encountered, not so commonly encountered and of course, in that context we will see this scale of energy usage in the world.

So, these are all the learning objectives for this module.

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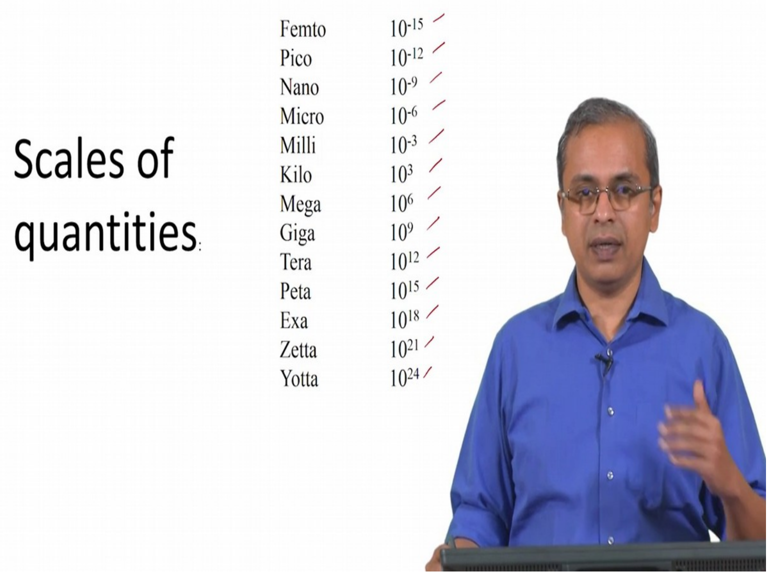

So, just to give you an idea before we get into specific examples. So, here are terminologies that we would use for a variety of different quantities we would prefix these to various quantities to understand the scale of that quantity. So, for example, Femto would refer to something that is in the 10 power minus 15 range, Pico would be 10 power minus 12, Nano is 10 power minus 9, Micro is 10 power minus 6, Milli is 10 power minus 3, Kilo is 10 power 3, Mega is 10 power 6, Giga is 10 power 9, Tera is 10 power 12, Peta is 10 power 15, Exa is 10 power 18, Zetta is 10 power 21 and we have Yotta which is 10 power 24. So, this is a wide range of quantities here. So, you can see here 1 2 3 4 5 6 7 8 9 10 11 12 13, I have about 13 quantities here, and I am going to show you some examples of technologies and examples where we use them, and sometimes they are technologies sometimes they are just quantities that we discuss in the context of science and of the world and so, in that context we will see these quantities and scale of quantities that occur in this you know this scale that you see here.

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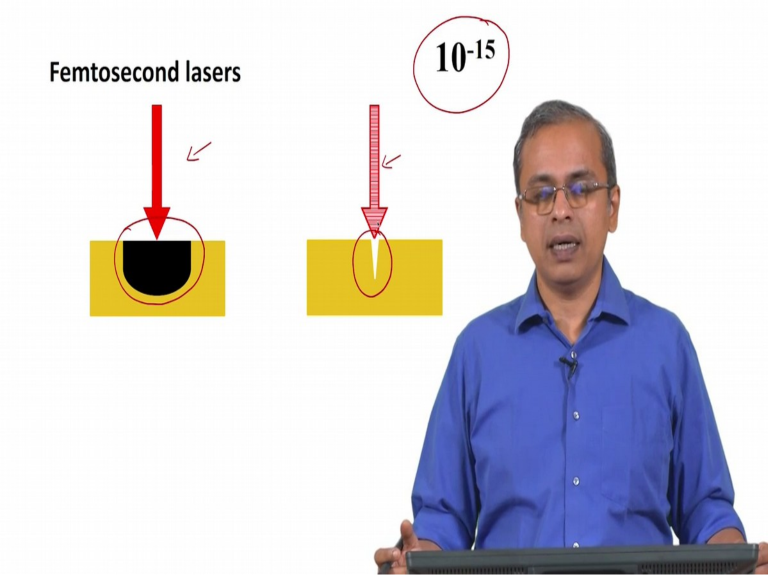

So, we will begin at the bottom end of this spectrum, and then move work our way up. So, you have a quantity that is the 10 power minus 15. So, there are technologies today that use quantities that are in the 10 power minus 15 range. So, if you actually go to certain specialized medical facilities, they do have a certain lasers referred to as Femtosecond lasers okay. So, Femtosecond lasers are laser which are on for 10 power minus 15th of a second and then they go off.

So, normally, for example, if you look at a laser that is that you see here for example. So, this is a laser that is on for a significant period of time continuously. The implication of it is that, if you have some if you are trying to clean up some location you want to destroy some particular tissue then the region over which this laser takes impacts that tissue; is fairly large. You see this region here this entire region is affected by this laser, because it is continuously on there is a certain amount of heat associated with it, there is a certain amount of shockwaves associated with it, all of that impact as fairly significant region.

Now, if you want to be precise and you want to say specifically clean up a particular location which has some infection, which can let's say can be treated using a laser then you don't want the neighboring tissues to be affected. So, you want exactly the specific location that you want impacted to be impacted by that laser, and all the surrounding issues surrounding tissues to not be impacted by that laser. So, to do that they do a pulsed laser, which is on for a fraction of a second, then off for a fraction of a second, on for a fraction of a second, off for a fraction of a second, typically it is on for this 10 power minus 15th of a second. So, that is this range over which it is on. So, this range laser that you see here is pulsed, it’s not continuous it’s pulsed it’s on and off and on and off and the impact of it is that you can see there is a much narrower region, over which the impact of that laser is felt. And this is a technology that is being tried out and being examined and to some degree being used to work on regions where at a very narrow location needs to be handled by that laser.

So, and what that region is and what that base material is could be a variety of different things, but that’s the purpose of it. You just want that location to be impacted nothing else to be impacted okay. So, this is one.

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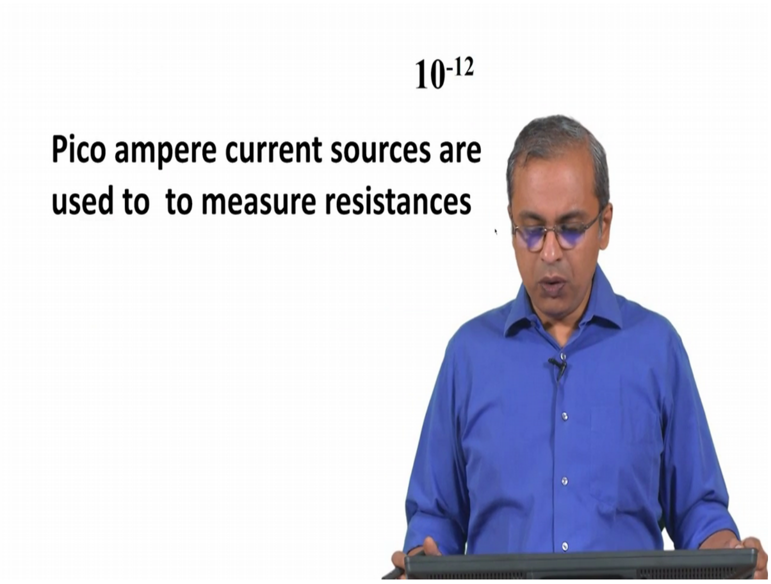

So, we will go up to 10 power minus 12. So, we are going up in energy and we will look at a particular kind of instrument that is actually quite commonly available in laboratories at various places where they deal with the current sources.

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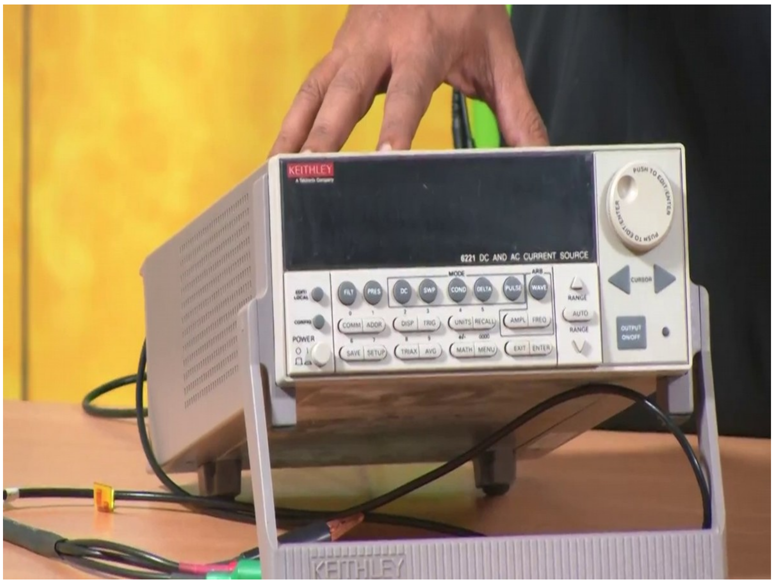

So, you see here a power source, this is a fairly sophisticated power supply it is there in labs where you are trying to make very precise measurements of current voltage and therefore, resistance of specific samples. So, in this can send out current in the range of pico amps. So, this is say 10 power minus 12 amp current and or instruments such as these can do that therefore, you can make a very precise current of very low value being sent into a circuit, which is possibly a very sensitive circuit and then you can make a measurement of say a resistance, some other quantity from that circuit.

So, these as I said are in good electronics laboratories, you have such high precision power supplies that are present, and they help us make such measurements.

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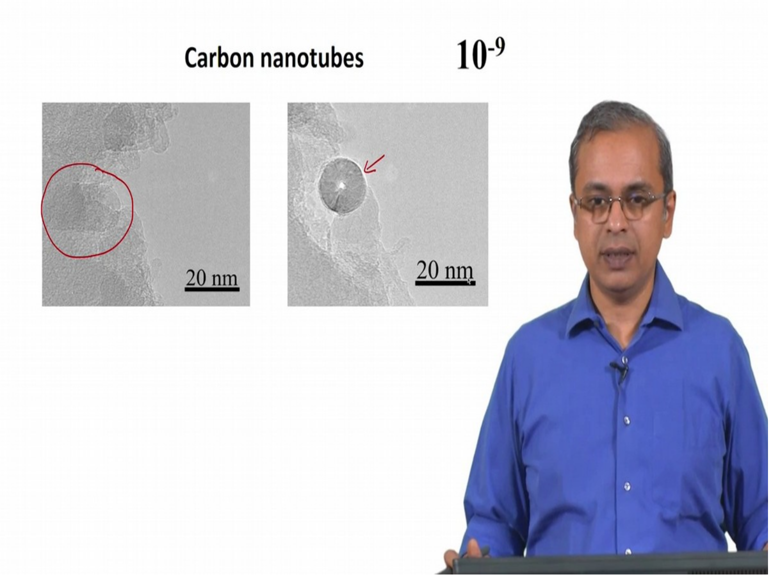

We will now look at the next level of a scale of quantity which is in the 10 power minus 9 range, and that is a very famous range of quantities to be associated with these days because that is where nanotechnology is.

If you look at material science around the world almost all researchers now work with materials that are classified as nanomaterials and that simply means the size scale of that materials is in the 10 power minus 9 meters range. It turns out that for nanomaterials, it is not the specific number that matters, but a certain set of values which have to be in this roughly in the nanometer scale range, and then for every given property the precise value at which that property starts acting different and shows you a nano effect maybe a different value. So, it's not that it's always 10 power minus 9, it could be 10 into 10 power minus 9. So, in another words 10 nanometers or 20 nanometers or 100 nanometers at which you see the effect, but basically the effect is that, when you go down in size scale usually the properties change in some gradual manner and then when you go down to really small size scales such as this nanometer size scale, the properties change in a dramatically different manner. And therefore, the same material now gives you a dramatically different property and that is the phenomenon that people are trying to exploit or build on, when they work on nanotechnology and nanomaterials.

So, that is a size scale of 10 power minus 9. So, you see here an electron micrograph which actually shows you carbon nanotube head on. So, you are seeing straight down the tube to the tube axis is perpendicular to the screen and you are seeing that carbon nanotube and that same nanotube is been tilted here a little bit. So, you see it slightly tilted here. So, you do see something like a tube that has been tilted on its axis that is shown there. So, that same tube is now on your right you see the complete tube, and on the left you see the tube that has been tilted. So, this is the nanomaterial size scale.

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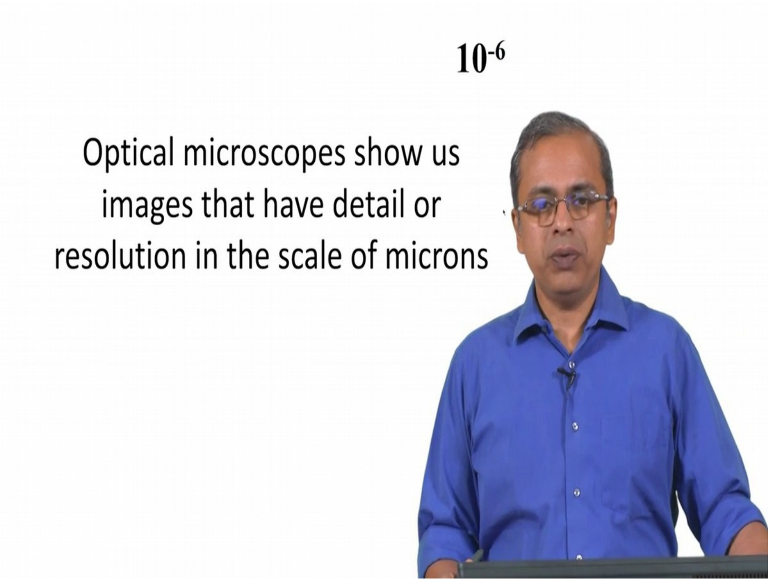

Okay although, nanomaterials are of great interest to us, significant amount of science and engineering has been done in the using optical microscopes, which typically means that you are using optical you know visible light to do all the investigations and a typical optical microscope gives you what you would refer to as micrographs. And those micrographs have the detail, the level of detail that is shown in those micrographs is in the size scale of microns or 10 power minus 6 meters.

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So, that is the kind of size scale in which we see it. And this is often there in almost most of the laboratories that you see, you may have a sophisticated version of an optical microscope even in your school you may have a in high schools you may have optical microscopes, in engineering colleges you will have optical microscopes, maybe dental colleges you will have optical microscopes, many places we use many you know fields of science and engineering, we use optical microscopes and they are all giving us images in with the resolution in being in microns.

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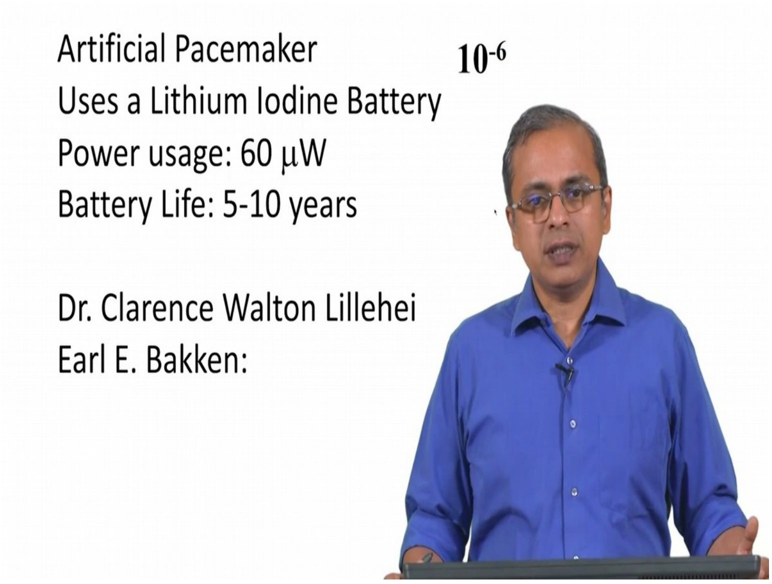

If you also stick to this 10 power minus 6 you know regime of scale, then there are interesting products that exist in this size scale. So, for example, there is this thing referred to as the artificial pacemaker. So, if you see most of us in fact, all of us have in our heart a tissue which is referred to as the pacemaker.

So, this is the tissue that decides how fast our heart operates. So, it is the one that keeps the heartbeat going at a certain rate, and it is the tissue that is taking a lot of input from the rest of the body. So, let’s say you go for a slow jog or you are doing some running or you are playing some squash etcetera, then your body is sensing that it needs more energy, it needs the blood circulation to be faster etcetera. So, that faster heartbeat is generated using this pacemaker. This pacemaker which exists in our heart then sends out signals to the various chambers of the heart, and the rate at which it sends that signal decides the rate at which the heart beats. So, that’s the way in which the system works.

Now, for some number of people the pacemaker does not work properly. So, they may have various issues. So, for example, even though they are trying to do some exercise, the heartbeat may not pick up its rate it may continue to stay at the low rate then they struggle because; that means, their body is not getting the oxygen at the rate at which it should the rest of the all the tissues in the body are not getting oxygen at the rate at which they should and so the body begins to struggle.

So, to deal with this situation, we basically have this thing called the artificial pacemaker and the credit for that is given to doctor Lillehei and Earl Bakken. So, Earl Bakken was in fact, responsible for these companies called Metronic and so, lot of interesting things have been done through this company, and certainly doctor Lillehei was the principle person who enabled this technology of an artificial pacemaker to become possible.

So, the artificial pacemaker in olden days in say 40 years or so ago, 40-50 years ago used to be one large object that had to stay even parts of it had to stay outside the body, and was extremely cumbersome and completely disrupted the operation of the people who use those pacemakers. Today the pacemakers have become very small, and you actually have a the typical pacemaker these days is a very small is coin shaped pacemaker it’s only about say the size of a I mean modern in Indian currency a 5 rupee coin or a typical such coin which is just somewhat that big and can be installed within the body.

So, it actually uses extremely tiny amounts of current and it is in this current that is the power it is using is in the scale 10 power minus 6, you can see here that it has it's only going to use about 60 microwatts and the typical lifetime of the battery with such low power usage is about 5 to 10 years. So, for 5 to 10 years once it is installed in the person's body, they do not need to do anything further till the till the battery starts acting up and then they have to do something to change the battery.

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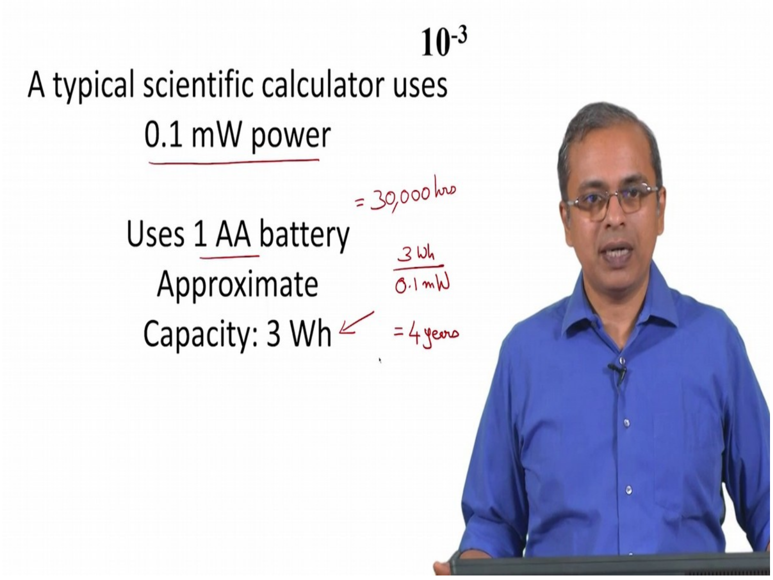

So, let's go up in scale again. So, we are now at the level of milli quantity of some sort and so a typical scientific calculator for example, which many students going to engineering colleges would possess, is typically using power in the scale of 0.1 milli watt. Interestingly it also uses just a single AA battery, which is approximately having a capacity of about 3 watt hours.

So, now if you take this 3 watt hours and divide it by this 0.1 milli watt power that is being consumed, it implies that this battery can run for about 30,000 hours. So, that simply 3 watt hours divided by milli watts 0.1 milli watts that should get you your 30,000 hours and if you take a typical year, a year has about 8000 plus hours. So, 30,000 hours is roughly about 4 years. So, this is roughly equal to 4 years approximately okay, 4 years. So, if you buy a scientific calculator on the day that you join your undergraduate program and you put a fresh double a battery in it, if everything works fine and you know it, it doesn't leak or other problems don't happen to happen with the battery chances are when you graduate you will run out of the battery and you can move on with your career. So, this is the you know interesting way in which this quantity lines up with your engineering curriculum with a by coincidence or some other purpose behind it I cannot say it for sure, but it seems to lineup with your engineering curriculum very nicely.

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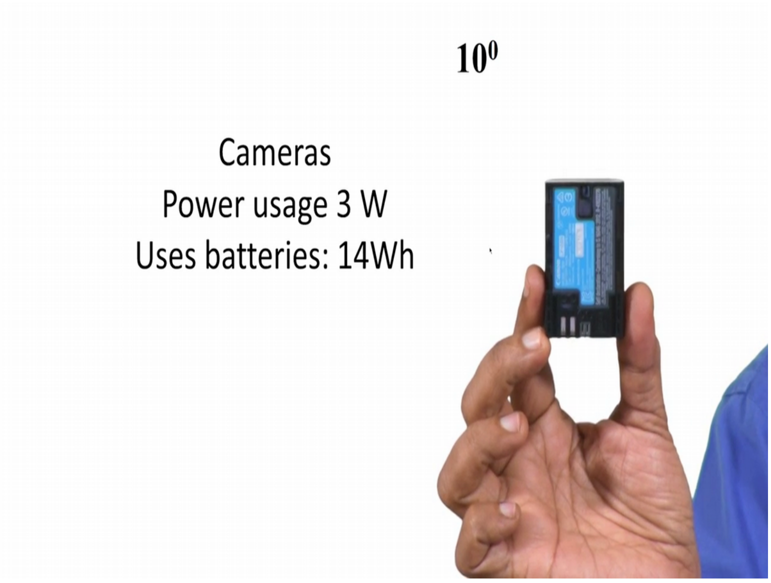

10 power 0. So, 10 power 0 is basically a quantity which is in the unit place. So, to speak and. So, typical cameras for example, use batteries and those batteries are using about 3 watts of power typical battery is something like this a small battery, which would sit in typical cameras that we may have. And if you look at what is written in this battery here you will find that it will say somewhere here that it is about 14 milli, 14 watt hours is the kind of you know energy that’s available in it, and that it is consuming about 3 watts of power. Which basically means that it can operate for about typically this kind of a battery will operate for about 4 hours, 4 and a half hours of operation is possible which will allow you to take you know that is continuous operation if you basically. So, you can take a video with it, you can take you know several hundreds of photographs using it. So, that’s the kind of usage that this battery is capable of, and it enables you to operate your camera like that and this is pretty common place at this point in time.

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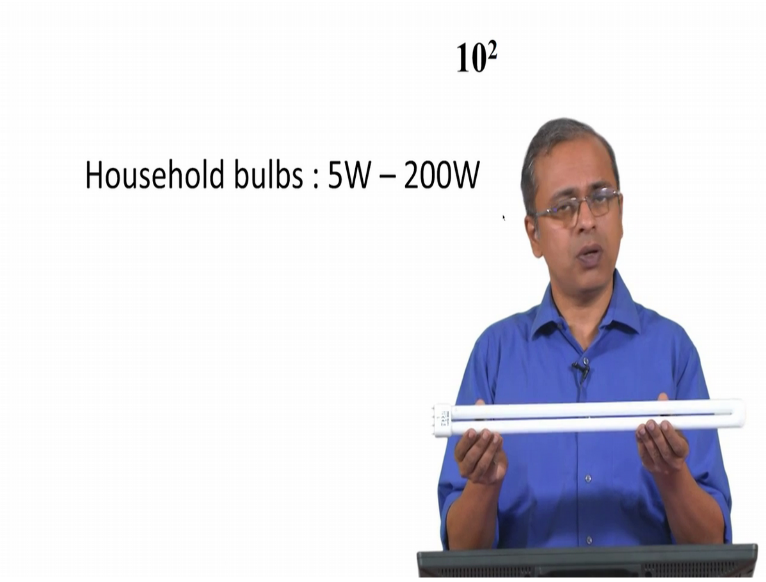

The next level of quantity is in the let's say in the scale of tens to hundreds of units of some nature, and common again common quantity that you would encounter in day to day setting to the power used by household bulbs. So a typical household bulb that you would see which looks something like this, different kinds of bulbs are available these days some are incandescent, some are fluorescent type of bulbs you also have LED type of bulbs. So, wide range of bulbs all of which use totally different kinds of I mean amounts of energy and they are becoming more and more efficient, but typically you are looking at power usage which is tens of watts is the kind of power usage that you will have for units of this nature.

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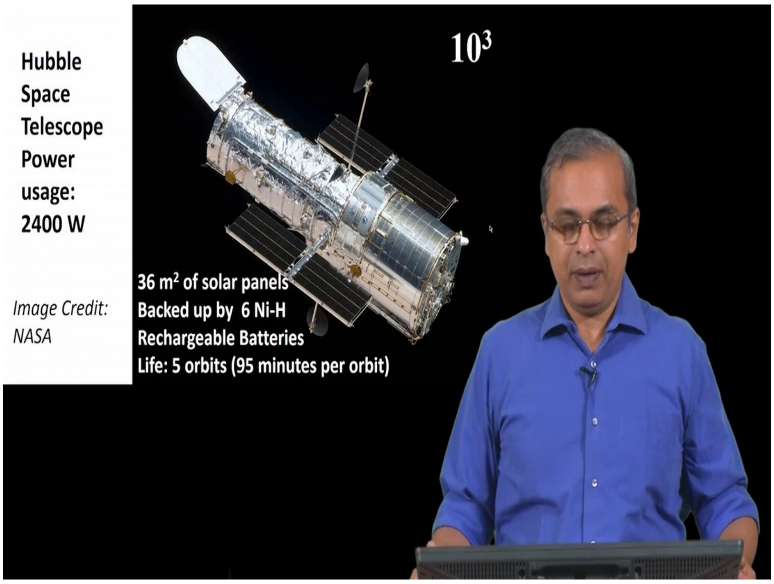

The next scale of power usage interestingly and very fascinatingly, you go up in space from few 100 watts, if you go to say a few thousands watts 2400 watts in this case you are now dealing with the kind of power that is being used by the Hubble space telescope.

So, this, images courtesy of NASA and you can see here there are solar panels in this telescope as are present with almost any you know satellite that is out there in space, and typical power usage is about 2400 watts. And you will see that you know this has been designed very interestingly the kind of amount of solar panels that are present and the fact that each of those batteries has a certain capacity, ensures that you can actually run about 5 orbits with the battery setup present. So, you can get 95 minutes it takes about 95 minutes per orbit and the batteries that are present will take care of this unit for about 5 orbits, but in any case they are backed up by solar panels. So, this is the kind of you know they have had to balance the weight of this of the battery pack and the solar panel pack and you know balance that weight against the amount of energy they would like to require, the amount of you know downtime that they would like to cover, in case there is some problem with the solar panel, how much time they would like to cover using the batteries and things like that.

In addition to providing coverage during the time, that the satellite is actually sitting in the on the dark side of earth. So, it's not receiving direct sunlight. So, at that point the solar panels are not going to help or assist powering that the space telescope. So, they will have to depend on the battery pack, to help them power the telescope. So, for both those things both routine operation as well as a backup you need batteries, and they are all you know giving power in this range of about 10 power 3 watts 2400 watts.

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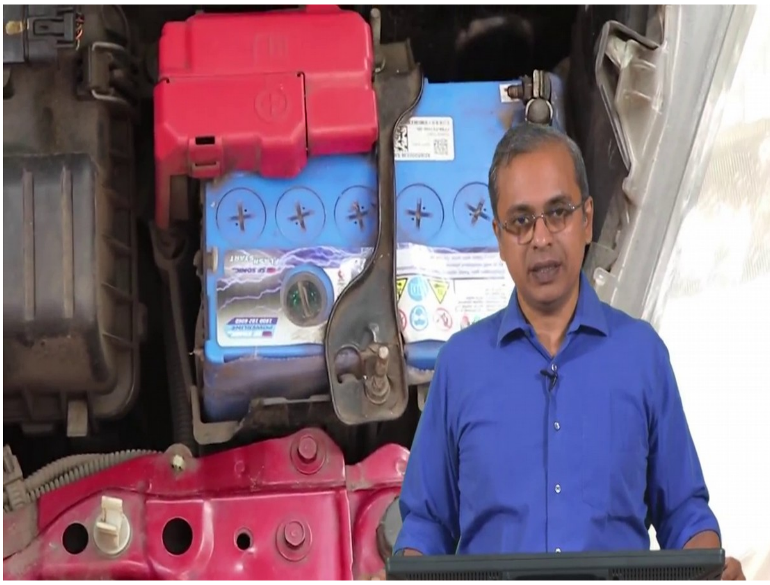

From something out in space, something very sophisticated and out in space, if you come back down to earth to something very common place, which is there in almost any modern city in any modern house is an automobiles. Something that’s present in most of our modern houses is automobiles and in automobiles you have batteries. These are the batteries that that are powering your car the moment you turn the ignition.

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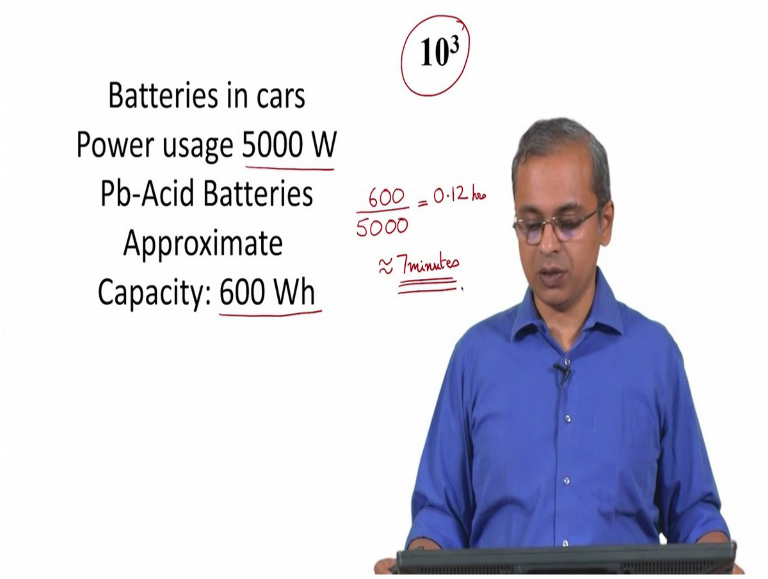

Interestingly, if you see this is also in the 10 power 3 power range so in fact, in terms of scale, this power usage is identical to the power usage in a Hubble space telescope.

So, you would never imagine that that something. So, sophisticated as a Hubble space telescope uses just the same amount of power as you use when you crank your car. When you just turn on the car and you just turn the ignition on the car you are using the same amount of power as the Hubble space telescope and so, you can see here this is actually a battery where that can put out 5000 watts, but its capacity is not very high you only have about 600 watt hours. So, if you divide this 600, you will get about 0.12 hours. So, 0.12 is what you will get. So, 0.6 by 5 is what you will get and that is 0.12 hours. So, that is about approximately 7 minutes.

So, in other words if you try cranking your car repeatedly let’s say there is some problem starting your car, you keep on trying to crank your car again and again and again if you keep doing this for about 7, 5 to 10 minutes somewhere in that timeframe, your battery will run out of energy and that’s exactly what happens, when you hear your neighbors car struggling and then they are struggling with it for some time and then you suddenly find after about say 5 10 minutes there are there is nothing that’s happening They are just turning the ignition and barely anything is happening in that car you won’t hear any you know attempt by the car to try to startup. So, that’s only about 7 minutes timeframe that you have there, typically if your car is running fine, then you will only need a few seconds not even few seconds you will probably need a fraction of a second to get your car started. So, these 7 minutes is more than adequate. So, this is actually a very large number this 7 minutes in that context.

But if there is a problem with the car if you are under cold conditions, then this 7 minutes you may start ending hitting the boundary of this 7 minutes. But to summarize on this slide I just wanted to further indicate that you know this is the same amount of power usage as a Hubble space telescope.

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On this screen here you see an example of a vehicle where they have attempted to use lead acid batteries to power it and it's a small van can carry maybe say 20 people, and it uses power in the range of kilowatts. 10s of kilowatts, 20 kilowatt pack is what you see here power capability is 20 kilowatts. So, that puts you in the 10 power 4 power scale.

So, again this is also relatively common place, you will see let's say in your university or lab they may be trying experiments, where they trying to power some you know small 3 wheeler or 4 wheeler using batteries, if you examine what is going on there in terms of what power is going to be delivered, chances are you are looking at power in this scale; you can see here battery capacity is 30 kilowatt hours. So, again if you do a small calculation here you have 30 kilowatt hours, divided by 20 kilowatts. So, you will get approximately 1.5 hours 1.5 hours this battery can run for about 1 and half hours. So, let's say the vehicle is running at about say on average about 30 kilometers an hour. Let's say that is the average speed. So, you are looking at approximately say 45 kilometers. So, a range of about 45 kilometers is what you are looking at that is again, you know typical of you know small scale efforts to do electric vehicles hybrid vehicles etcetera.

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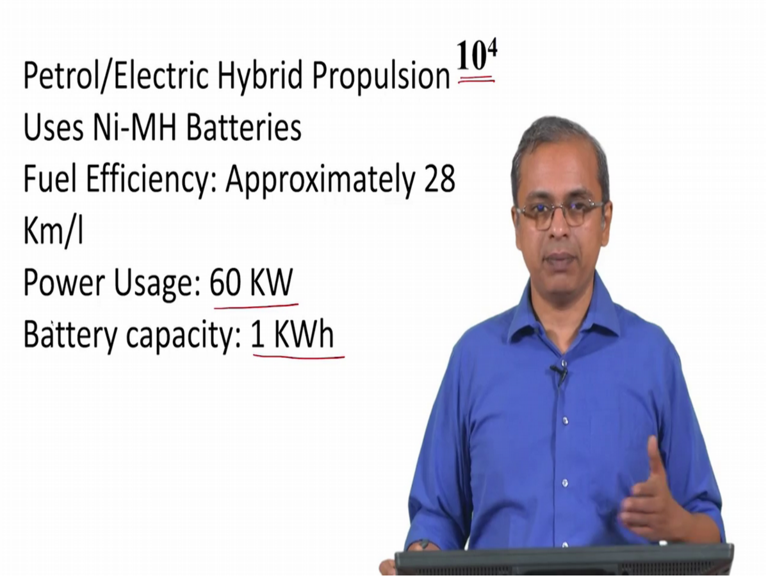

Also of similar power usage 10 power 4 or more sophisticated vehicles, which may use a combination of petrol engines as well as electric hybrid propulsion systems and so, they also use in tens of kilowatts power, but they may actually have much smaller battery packs because their intention is to actually run the petrol engine at its best operating point and then to keep up a continuous charging of a battery pack. So, they need a much smaller battery, which takes care of variable loads while the petrol engine continues to operate at a constant operating point which is its best operating point. So, this is just one mode of operation for you know hybrid vehicle, which is using both petrol as well as an electric propulsion system. There are wide range of other modes of operation where they you know optimize power from one source versus power from the other source. So, and you can also try something different. So, nothing requires you to just follow this, this is just an example of how somebody might try it out.

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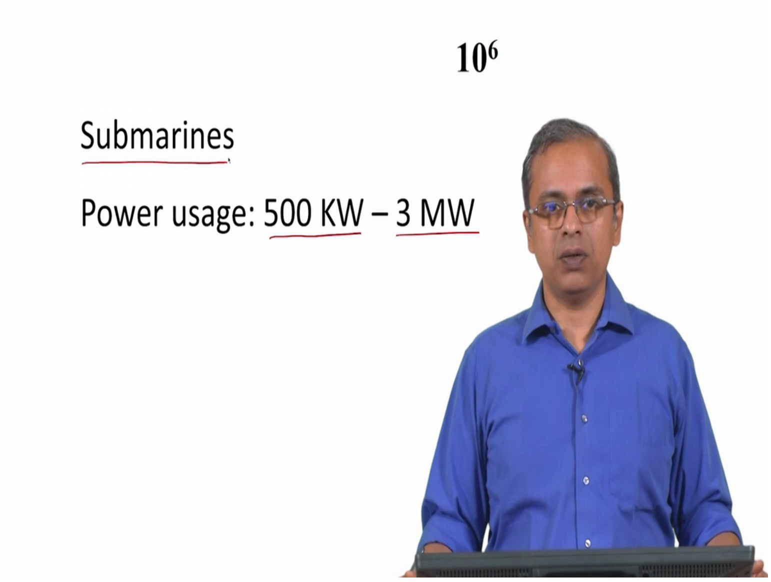

So, we have come to a scale of 10 power 4, if we go up in scale to 10 power 6, then you come across this kind of power usage in large capacity you know transport and one interesting place where you may see this kind of power usage which is in the you know in the megawatts range. So, this is a megawatts, hundreds of kilowatts to megawatts and this kind of a power usage and is used in some is kind in large vehicles of the nature of submarines. Of course, as you know submarines are you know typically only military vehicles, we do not have them for the most part for you know public use there are a few which are there for entertainment etcetera, but they are not common place certainly not common place for the general public and so, getting enough information about them is actually quite difficult and quite this is scarce scarcity of information. So, this is just the scale of a quantity involved with such equipment and that’s just all that we can find out about such a you know vehicles that are available.

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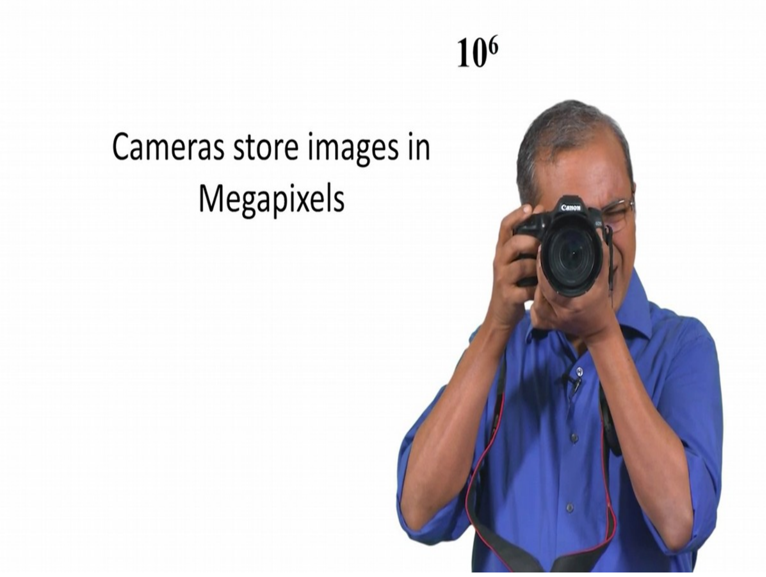

Also of a similar scale of quantity is the kind of storage that exist in our modern day cameras. So, for example, this is a modern day camera which many of us might have, and this typically will have images stored in its disk and the typical kind of resolution with which it stores, requires the total number of pixels to be in the scale of megapixels. So, with a camera like this if I look at you, and take an image and I am now taken an image you watching this video it is stored here in megapixels right.

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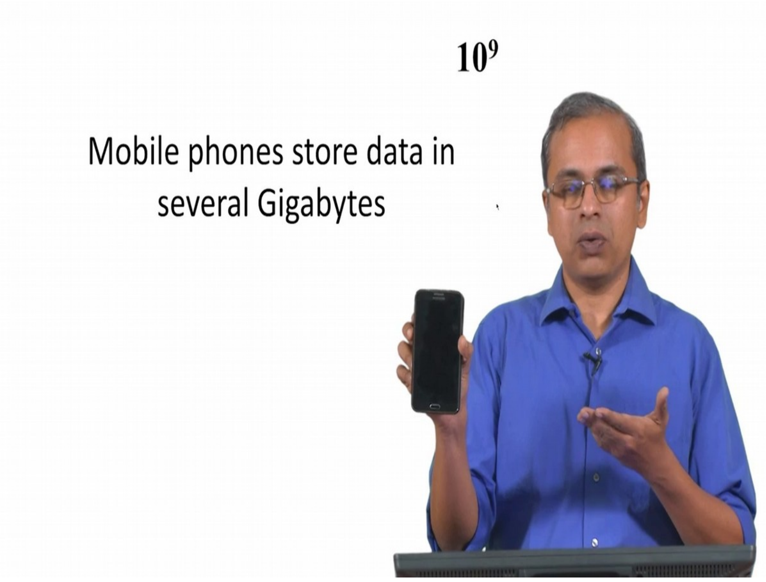

So, again yet another common place equipment, which is using you know some aspect of it is using a quantity which is quite large is moves up move’s us up from you know something in the mega scale to something in the giga scale. So, a common this is a mobile phone many of us have carry mobile phones, which are you know very much of this nature. In fact, this aspect ratio is now pretty common with respect to mobile phones, and if you get any of the modern day mobile phones they have storage in them built in storage, which are you know of the order of 16 GB, 64 GB etcetera.

So, getting this kind of a phone and in fact, chances are most of us already own one in our and have one in our pockets even as we are you know discussing this video or watching this video and ours the storage in it, is in the gigabyte range. So, this is again something that’s pretty common place in today’s world, we are already using quantities in the giga scale. So, we don’t often recognize it, but you can see that there is something in your pocket which is sitting other 10 power 9 range, that is quite something that maybe you have not thought of it in that context.

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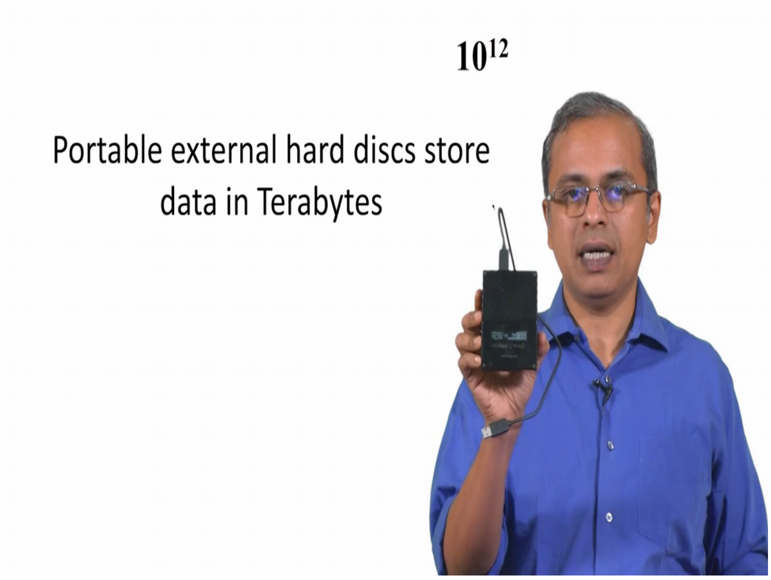

Moving up in size scale some more you reach 10 power 12 and that is tera, that is get referred to as tera again something that is relatively common place many of us are using maybe not everyone of us is using it is the kind of storage that is now available. Cameras the computers in today’s usage are all having hard disks in the terabyte scale. So, for example, this may not seem like much, it’s just a portable external hard disk and it stores data in the terabytes range.

So, this is got let’s say about 2 terabytes of data that can be stored here, and it is quite common place you can go to typical electronic store near you and chances are you can buy one of these. And as you know with passage of time it gets outdated pretty quickly. So, depending on when you are seeing it this may already be an outdated model, but as of now these are the kinds of size scales at which the data is being stored ok.

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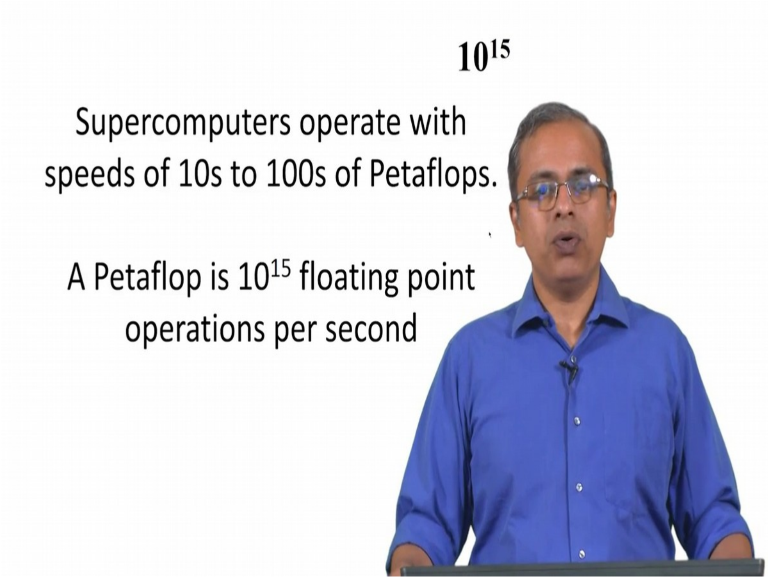

If we go up get again a size scale 10 power 15, then we are looking at supercomputers. Today’s supercomputers as we approach the year 20-20 our operating in hundreds of petaflops. They are called a petaflop is a floating point operation per second the number of floating point operations per second and is indicative of how much of computation can be done using that computer at in unit time and 10 power 15 is the extent to which it is being pushed at this point in time.

And so, you have operate I mean computers that are operating anywhere you know from tens to hundreds of petaflops and these are the kinds of computers that get used for doing our weather analysis for us, when we do weather forecasting and you hear a weather report on the news channels then those weather reports are making a stronger attempt to get the details right their predictions right using forecasting models, and those models are extremely computationally intensive. And, so they need many kinds of operations to happen every second for them to now predict the next moment of weather that might possibly happen and so, they need this level of computation and that's what supercomputers do.

Again supercomputers of course, are not common we don't normally see them even in our universities they are very specialized equipment, and they are always pushing the boundaries of computation.

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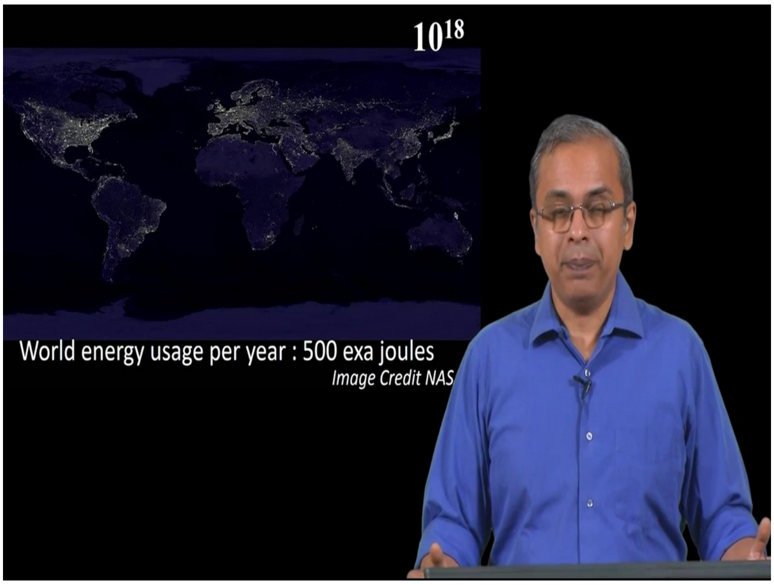

Up in scale one more and that is where we arrive at the energy usage of our planet okay. So, 10 power 18 is a kind of a quantity that is indicated with this prefix exa, e x a exa the world today uses energy in the range of 500 exa joules okay. So, that is a number I think in dealing with the with all the content that we deal with in the course, that is a number that we need to absorb 500 exa joules and you know keep in our mind because as we work on renewable energy technologies, as we try to develop technologies that are non-conventional and are trying to impact say the environment, time to impact the way we live our lives the way we use energy in our lives etcetera, this is a number that we have to keep in mind. Only when we realize that the world uses energy at this scale, if our technologies are in a position to address this level of usage that is when we start actually making an impact on the environment ok.

So, if you have technologies which make which are so rarely used, that they are not really making an impact at this scale then that does not help the environment in any great manner. So, but it is also true that any new technology is always going to start at a much smaller scale of operation and then eventually find its way up, but this is a nice target to keep in mind, that you know the world uses energy in the range of exa joules and about 500 exa joules of energy is being used.

This is a very interesting image again the credit for this image goes to NASA, they have taken over 400 images in during the night where they could get a clear sky of various locations of the world. And they have pieced it together and this is actually therefore, you know image that has been pieced together and stitched together so to speak and it shows us the you know say the an indication of how power is being used around the world all those brightly lit places are the places where there is a lot of light that is on during the night and presumably; that means, that there is a lot of energy that's being used there. And the world overall as you can see in this image at this moment, is using about 500 exa joules of energy through a typical year. So, that is a very interesting number to keep in mind, we have now come in quantities from 10 power minus 15 which is a Femto all the way up to exa joules which is 10 power 18 and seen a lot of examples along the way and interestingly when we arrive at this very large number of an exa joule that is where the world is you know situated at this point in time.

Of course, generally if you see historically our energy usage has only been going up. So, you can always expect that this number is going to increase and for I mean reasons that are you know not particularly I would say defendable, to some degree development or the or an indication of a development of a region is associated with the amount of energy that is being used at that region. So, people generally think that, you know there are lot of industries, there are lot of development has happened it also means a lot of energy is being used.

But today this is the kind of energy being used by the world. You can also see from this image, that this energy usage is certainly not uniformly being used, you can see that there are regions in the US which use a lot of energy, you can see that there are lot of regions in Europe that use extensive amount of energy you can see here, some significant amount of energy being used and so, you do see pockets where significant amount of energy is being used. Rest of the world for example, has distinctly lower amounts of energy being used. So, most of Africa is I know almost no energy being used here fair bits of South America are not using much of energy. So, this is the typical scenario that you see in the world, significant amount of energy usage and a significant amount of non uniformity in the amount of energy being used.

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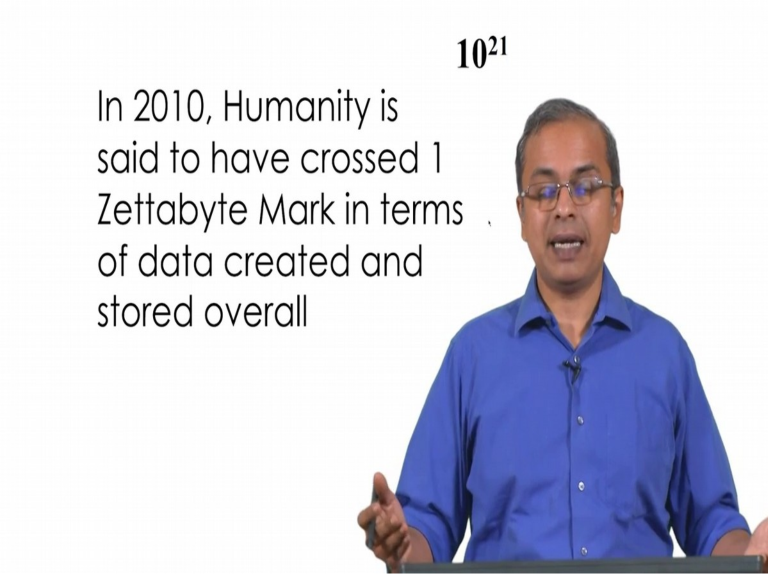

Well, we came upto exa joules, but we don't have to stop there just to give you a sense of scale and show you where we can head with all these quantities. I will just take you up a couple of more steps before we close this discussion. Interestingly you will find that in 2010 humanity is said to have crossed the 1 Zettabyte mark in terms of data created and stored overall okay. So, that is 10 power 21 is the kind of quantity 10 power 21 bytes of data is being generated by the world and is being stored in you know say hard disks or you know cloud storage etcetera and that is the kind of storage.

So, we as humans are already doing something at a scale in this 10 power 21 scale okay. So, that is again you know when we think of numbers you look at the number of zeros that is 21 zeros that are to going to show up in that number you have to you know step back and imagine what we as human beings are doing on this planet. I mean our; you can I mean some ways these are our accomplishments, in some ways these are also the kind of quantities that will always give us some reason for concern because; that means, it impacts various things that we do in the different ways, but we have to get familiar with these quantities.

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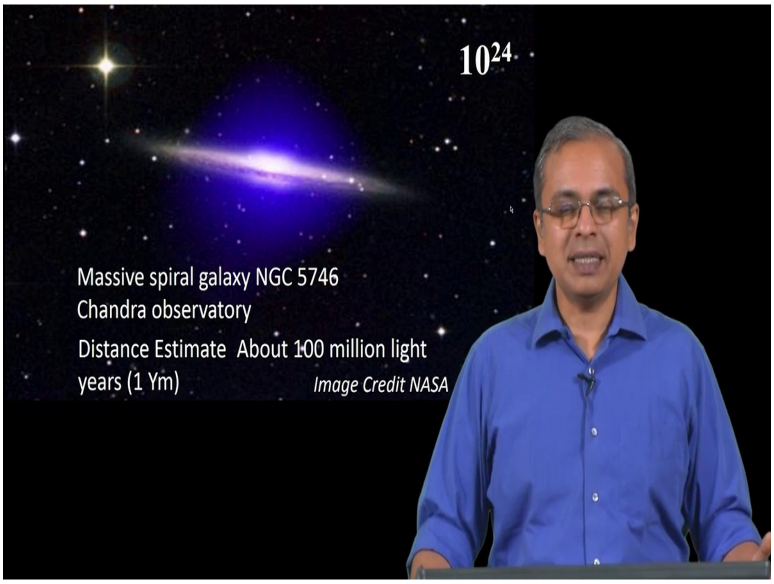

Little bit higher no I mean you can you can understand the scale of what we do when we only when you compare again something in the you know scale of the galaxies and universe, and then you realize where we are in terms of what we are doing. So, if you move up in scale to 10 power 24. So, that is referred to as Yotta, Yotta is the quantity and 100 million light years is equal to 1 Yotta meter. In other words 10 power 24 meters is 100 million light years and this again is an image courtesy of NASA, if you see this galaxy here that is 100 million light years from where we are okay. And just 3 orders of magnitude less than this is the amount of data that we are generating. So, that is the phenomenal thing that we are doing out here and that we need to you know be aware of.

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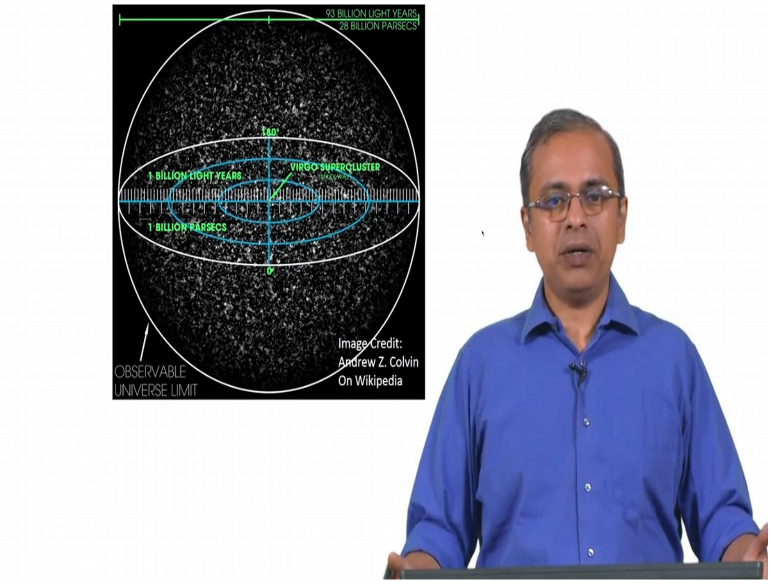

But that's not the end of it this I just wanted to close this presentation with the slide and just follow this up with 2 slides of summary. But this gives you an idea of you know what more is there. I mean we have already come to 10 power 24 that is 100 million light years, but that's not the end of it, this image that you see here is a courtesy of a source in the Wikipedia that is there and credited here and basically it is a simulation that shows you the limit of our observable universe. And you can see here that since I mean we have been receiving light for about 14 point roughly about 14 billion years since the origin of the universe that's the best theory that exists.

This is kind of the scale of you know the observable universe given that it is been, it is expanding, and it's also limited by how long it takes for the light to reach us, and how far the light can travel in the time that is available for it to reach us. So, given all that we are looking at quantities that are in billions of light years and so, that is a scale that is well above you know the 100 million light years that we just spoke about.

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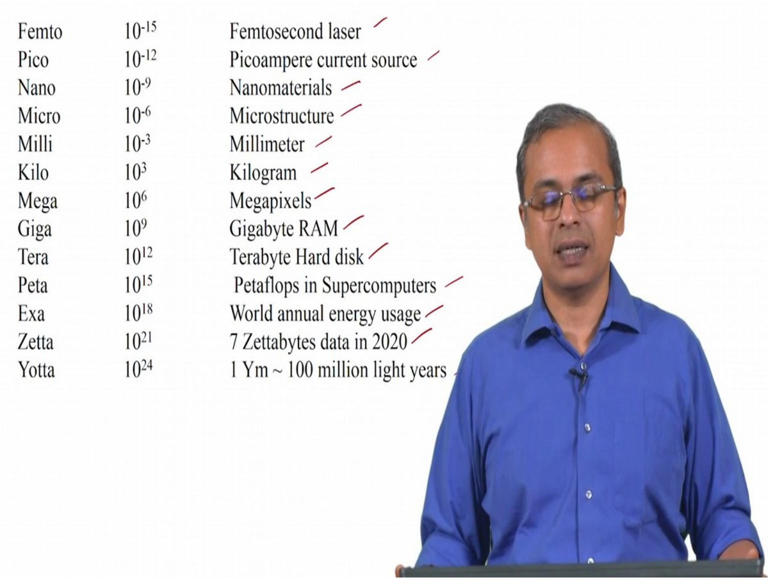

So, I will close this discussion with summary, 2 summary slides here, we just went through this entire sequence of quantities, we looked at 10 power minus 15 which was a Femtosecond laser, we looked at 10 power minus 12 which is a Pico, ampere current source used for electronic applications 10 power minus 9 nano materials, that are being discussed in great detail in science and engineering. 10 power minus 6 is a quantity that will always be with us because almost any scientific endeavor requires us to use the optical microscope quite rigorously, and many times we go to higher forms of microscopes only after we have limited, we have completed what the optical microscope can give us. That typically gives us something referred to as a microstructure, and that has quantities in the size scale of 10 power minus 6.

10 power minus 3 is a millimeter, we are quite familiar with that kilograms of food that we consume or buy at in grocery stores, megapixels the kind of you know resolution with which the images are stored in our modern day cameras. Gigabyte in terms of ram or in terms of hard disk space that exists in say mobile phones, terabyte hard disks that are there is no either in modern day desktop computers or in the removable hard disks that are available. Petaflops, the kind of speed with which supercomputers operate and then exa joules the scale at which the world consumes energy. But going about that is Zettabyte rate at which we are generating data as a community as a world community. So, that is very large amount of a quantity and hundreds of millions of light years the

kinds of distances that are there between us and some of the interesting phenomenon that we observe in the universe.

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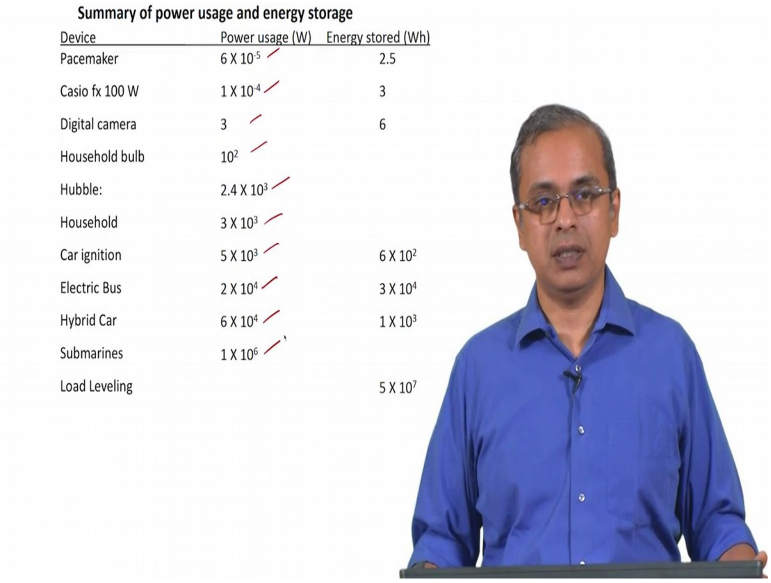

In terms of energy usage again we saw here 10 power minus 5 micro tens of micro watts being used by a pacemaker, a typical scientific calculators in the milli watts the cameras which use power in the scale of watts, household bulbs are in tens to hundreds of watts. The Hubble space telescope which is just an order of magnitude more in usage of power than a common household light bulb operates with the power in the range of few kilowatts 2 point kilowatts is the kind of 2.4 kilowatts is the kind of power usage it uses.

The typical households in fact, use about 3 kilowatts typical households that includes you know having a refrigerator, having a say a washing machine etcetera. So, a typical household actually uses more power than or equal to or little bit more power than a Hubble space telescope. Car ignition when start your car actually consumes more power than a Hubble space telescope at that instant of time. So, that is again a very interesting thing for us to note. Various types of buses that I just showed you I showed you a bus which uses you know tens of kilowatts of power, one of the possible vehicles that use this kind of power is in the tens of a kilowatts and finally, submarines which use power in a you know megawatts.

So, these kinds of quantities exist and they are I mean all around us we are using various technologies which use these quantities and many of these scales that I just showed you now are associated with energy usage.

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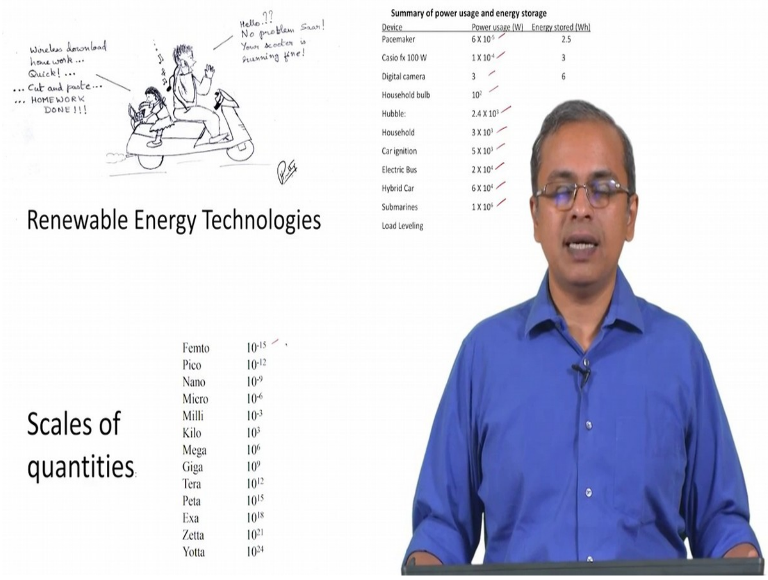

So, with this I will conclude this class, the as I said objective of this class was to look at wide range of quantities which are now available to us either in common place occurrence or are uncommonly encountered by us, but yet exist around us and also to get a sense of the kind of power usage of the world which as I said is about 500 exa joules.

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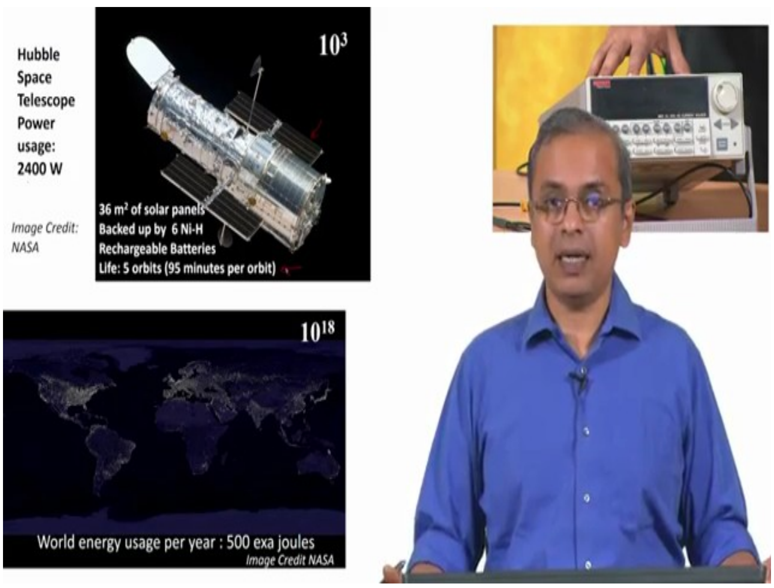

So, with this we will close this class, we will in our future classes we will build on this we will from time to time refer to these quantities and build on it, but particularly we will focus on the energy usage of this world which is 500 exa joules.

Thank you.

KEY WORDS:

Energy Sources; Power; Energy; Energy Scales; Femto; Pico; Nano; Micro; Milli; Watt; Kilo; Mega; Giga; Tera; Peta; Exa; Zeta; Yotta