Principles of Mechanical Measurement

Dr. Dipankar N. Basu
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

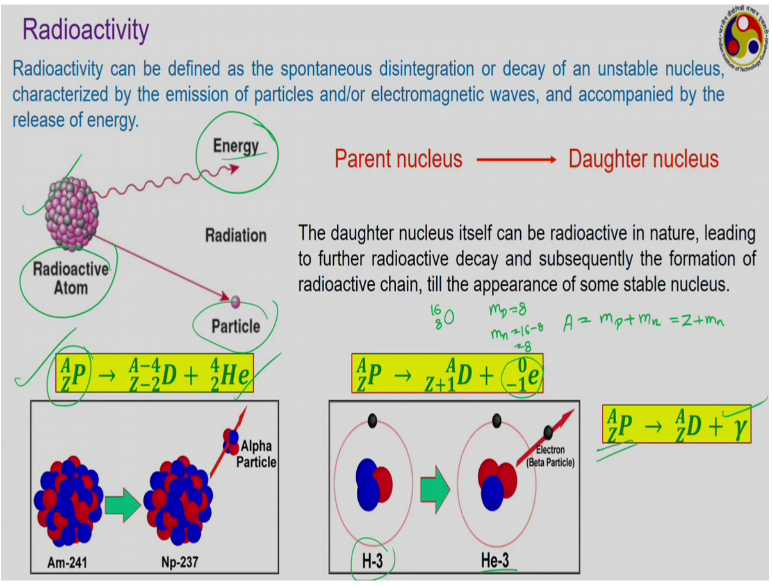
Module - 12
Special Topics
Lecture - 02
Radioactivity & its biological effects

Hello everyone. Welcome back to this course for one final time, because this is going to be the last lecture on this MOOCS course on Principles of Mechanical Measurement. Now, like I mentioned in the previous lecture this week we are going to discuss about a few special topics, instead of focusing on any particular parameter or I should say discussing the measuring options of any particular parameter. Like in the previous lecture I have briefly discussed about acoustic measurements just given an overview of that, different parameters associated with acoustic measurements and also common options like microphones etcetera for measuring acoustic signals.

Similarly, in today's lecture I shall also be discussing about one very relevant topic and again giving only a very brief overview on that mostly discussing different terminologies and several associated factors with that; and that is radioactivity or radioactive emissions. You know that this is a very hot topic for discussion in the field of energy generation or I should say nuclear energy generation, and also very much relevant in the day to day life active or our day to day activities because we are always exposed to certain kind of radioactive emissions coming from all possible sources from surrounding us. Particularly everyone talks about the radiation coming from the mobile screens or the use of electronic devices or corresponding screens that we keep on using.

And therefore, I thought about adding a brief discussion on radioactivity and radioactive emissions, mostly focusing on different units or measurement units associated with radioactivity and also possible health hazards, which may get caused by different kinds of radioactive emissions and try to quantify them in terms of the parameters that we are going to talk today. I would try to keep it only to an overview discussing very briefly on each of the relevant topic.

(Refer Slide Time: 02:31)



And for the first term that I have here towards this is radioactivity itself. All of you may have some idea about this particular term that is radioactivity and you may be knowing that radioactivity can be defined as, the spontaneous disintegration or decay of an unstable nucleus. Here this spontaneous term is very important, here we are talking about the nucleus decaying or disintegrating into some smaller nucleus or so or and ejecting also if your other particles all by itself. And not being subjected to some kind of external influence.

So, the term spontaneous disintegration is the one that characterizes radioactivity, and it also separates it out from different kinds of other possible nuclear reactions. And radioactive decay of an unstable nucleus is always characterized by the emission of particles and or electromagnetic waves and generally accompanied by the release of huge amount of energy.

I am not going to the detailed of the energy production, but just to give you an overview or you I am sure all of you know that whenever a particle goes for such kind of radioactive decay. Then if I show you a picture like this and an unstable nucleus or radioactive atom often called a radio nuclei, that goes through some kind of spontaneous decay producing particles generally more than one number of particles having smaller nucleus and also releasing energy.

The one this one is known as the parent nucleus and the products from there they are known as daughter nucleus. Now, quite often the total mass of the daughter nuclei and also the combined mass of all the particles, that are rejected during an radioactive decay is less than the total mass of the parent nucleus itself.

And the difference in that mass though that may be an extremely small number from our real life point of view, but following the theory of relativity that can lead to the formation of huge amount of energy or I should say the mass gets converted to energy, and the magnitude of that energy can be estimated using e equal to mc squared. So, c being a large number a very small value of m can often lead to huge amount of energy production and that is a fundamental principle of nuclear energy production.

So, any kind of radioactive decay of an unstable nucleus always associated with the release of energy, and also the production of smaller nucleus or daughter nucleus of smaller size and ejection of electromagnetic waves and a few other particles. And the daughter nucleus itself can also be radioactive in nature, leading to further radioactive decay and their way formation of radioactive chains; till the appearance of some stable daughter nucleus. Now, if you think about the periodic table then, the particles which is having large atomic number, generally we talk about atomic number of 82 onwards atomic number means number of photons that is present inside a nucleus.

So, when you are talking about a par at nucleus having an atomic number of 82 or higher generally most of those nucleus are unstable in nature. 82 is for led so but not all the isotopes of laser radioactive, but some of the isotopes of lead bismuth is having an atomic number of 83, they are unstables and from 84 onwards almost all the nucleus are unstable. So, they can go for radioactive atom.

So, the our focus is primarily on this energy which is getting released during and radioactive emission and therefore, whenever you are talking about any kind of radioactive energy emission, we are talking about atoms or nucleus having very high atomic number; generally greater than 82 or it greater than 81. Now, radioactive decay can be of several kinds, this is the one of the most common kind of radioactive decay, where here it refers to the parent nucleus here A is the atomic number Z is the mass number.

Now what is a mass number it refers to the number of photons, plus number of neutrons present inside the nucleus or together they are called the number of nucleons present inside this or sorry. Here A is the mass number and Z is the atomic number therefore, we can also add this one as Z plus number of nucleus. Like for example, if we take a symbol this is generally the common way we write this, we write something like 8 o 16 that refers to an oxygen nucleus having atomic number of 8 and a mass number of 16.

Therefore, the number of photons if m we refer to number, then that will be equal to 8 and number of neutron in this will be 16 minus 8 that is equal to 8. So, these are common way represent any kind of nucleus and whenever a radioactive nucleus undergoes this particular decay it leads to the production of and helium isotope.

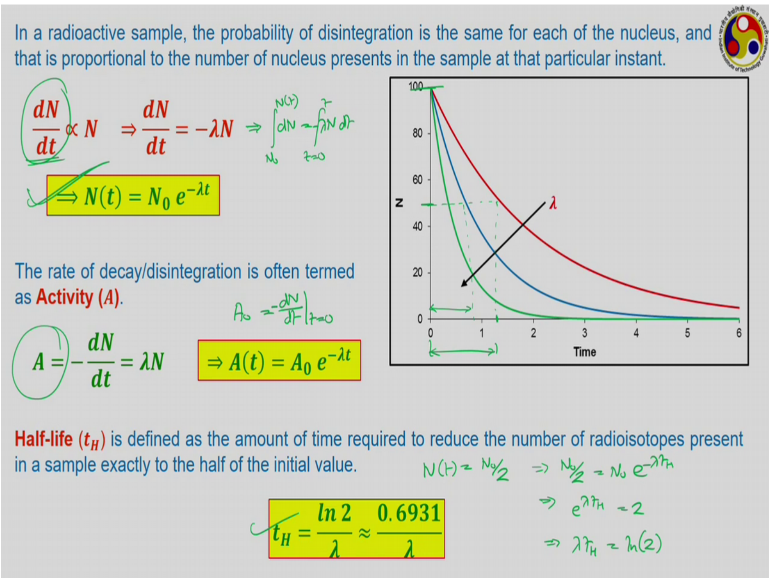
This helium particle is often called an alpha particle and therefore, this particular radioactive decay is called alpha decay. So, this is the representation of this A m is American. So, we are an American nucleus having a mass number of 241 leads to an alpha goes for an alpha decay producing neptunium, having mass number of 237 and atomic number 2 less than American. There is another kind of very popular radioactive nucleus a very common radioactive nucleus is that of beta decay.

Where actually there is a production of one electron, electron is designated as a minus 1 is 0 because it does not have a mass or its mass is negligible, but it has a 1 unit of negative charge. So, like here H 3 or tritium hydrogen 3, I sort of going for an electron decay or often called the beta decay producing helium 3 isotope. This is another kind of radioactive emission called the gamma decay, which had gamma is only an electromagnetic radiation.

So, there is no change in the atomic or mass number of the isotope or I should say the parent and, daughter isotope are having the same and atomic number and mass numbers. But there is a metal at a lower energy level because the excess energy of this parent is being released in the form of this gamma radiation.

So, these are some common type of radioactive decay that we generally identify, there can be several other kinds of radioactive decay possible, but there is no need for us to go for any further reaction. Further discussion into this as our interest is mostly on the energy produced during radioactivity, so this particular one is of large interest to us and even the helium or alpha decay is also important; because this is generally heavier isotope therefore, can carry lots of a large amount of kinetic energy with it.

(Refer Slide Time: 09:34)



Now, in a radioactive sample the probability of disintegration is the same for each of the nucleus and that is generally found to be proportional to the total number of nucleus present in the sample at a particular instant. Therefore, if N is the total number of nucleus present in a particular sample then the probability of the disintegration that is the rate at which the number of nucleus is going to change. This d N dt is proportional to the number of nucleus in itself or introducing a constant of proportionality, we have d N dt equal to minus lambda N a lambda is called the decay constant and this minus sign is coming because the number of nucleus or N is decreasing.

We can easily solve this one that is over a particular period of time if we solve this or before that this is the thing that we are talking about; if suppose initial number of nucleus is 100, then with time it keeps on decreasing continuously following in this particular nature.

And corresponding mathematical equation after solving this is a form like this, which you can easily obtained by performing an integration something like minus lambda N dt integrating this over time t equal to 0 to some t at t equal to 0 N 0 is a number of nucleus and N of t will gives to this particular equation and exponential profile. So, we can get the number of nucleus is exponentially decreasing and it can become 0, only after infinite period of time, but depending on the value of lambda it can decrease very very quickly.

Quite often the term or from energy use point of view that term we are more interested in is called activity. Activity is nothing, but this rate of decay. That is this particular thing itself. So, or the minus of that as the number of nucleus is increasing decreasing always. So, A is equal to minus d N dt is equal to lambda N and by combining with this equation so we can also write this as A equal to A naught into e to the power minus lambda t; where A naught is the initial activity that is the rate of disintegration at t equal to 0.

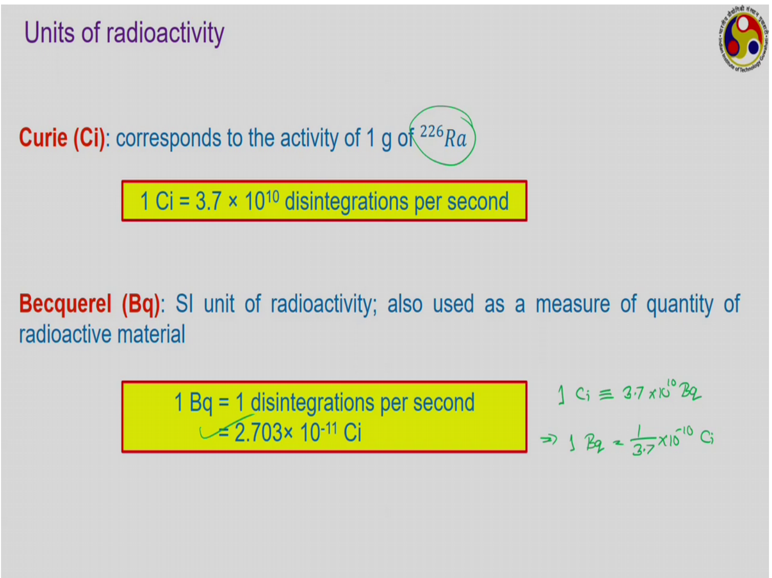
This activity is the one that we are most interested in because for most of the known radio nuclei we generally know what kind of radioactive reaction it is undergoes. And therefore, we know that what kind of emission we can expect from a nucleus whether it will be gamma radiation or alpha radiation or beta radiation. Now, our job is to know total number of disintegration that is going on over a particular period of time and once we know that, then we can easily calculate the total amount of energy release, because we already know the nature of each of such releases.

So, we have to know the activity before while for judging the radioactive nature or I should say the radioactive effect that a particular nuclear nucleus can produce. Another parameter that is a very much importance here is half life, half life is the amount of defined as the amount of time required to reduce the total number of radioisotopes present in a particular sample to half of its original value. Like a look at the curve that I have shown here initial number of isotopes was 100. So, the time at time t equal to 0 and half of that is 50. So, the time it takes to reach this half value like, if we go for the first sample that I red one colored one then it is somewhere here.

So, it is reaching half life somewhere here for this. So, this particular period is the half life for that particular red colored sample. Whereas, a particle which is having a higher value of lambda see here, this half life will be this one for the blue colored sample and it is definitely much smaller compared to this. Now how can you estimate the value of the half life? Here going back to this equation if we put N t is equal to N naught by 2, then what we have? N naught by 2 is equal to N naught into e to the power minus lambda into t H or t half which gives us this particular equation.

That is if we solve this then e to the power lambda t H is equal to 2 that is lambda t H is equal to log of 2 which gives t H equal to log of 2 upon lambda or 0.6931 upon lambda. So the half life is inversely proportional to the decay constant, which is very much logical. If the decay rate is higher half life will be smaller lesser time will be taken to reach to that half mark half in mark. Now our interest now goes back to this A and the units of radioactivity are defined in terms of this A activity.

(Refer Slide Time: 14:28)



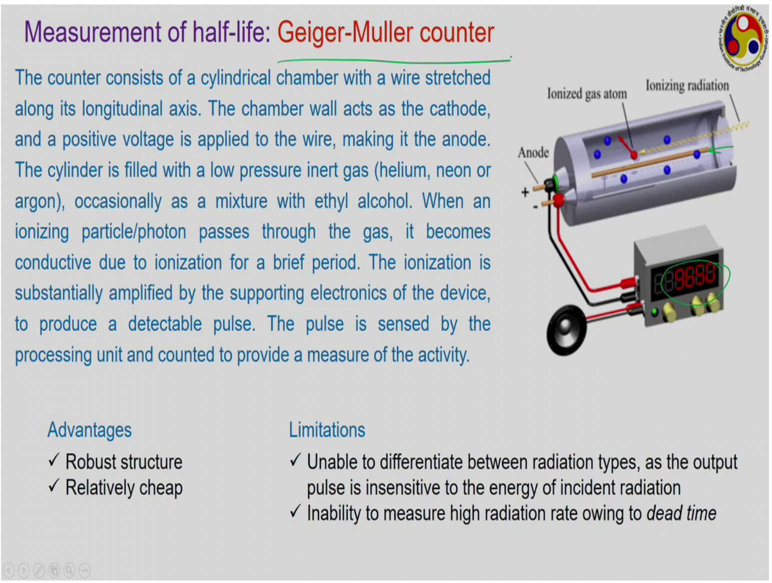
So, the most common or the standard SI unit or I should not say SI unit the most commonly used unit for radioactivity is Curie, base top one definitely the name of the first person who properly formulated the theory of radioactivity even coined the term radioactivity as well. The Curie familiar Pierre Curie and Madame Curie, now if 1 Curie corresponds to the activity of one gram of radium 226, which generally comes to be 3.7 into 10 to the power 10 number of disintegrations per second.

So, this particular radium sample then 1 gram of radium sample that, number of disintegrations or radioactive decayed undergoes in, 1 second of time that is depend as 1 Curie. But it is a nearly a very large number to deal with so quite often the laser unit or the SI unit of radio activities Becquerel. Becquerel actually Henry Becquerel is actually the first person, who observed this phenomenon of radioactivity, but failed to under understand the underlying physics for this which was later explored by Curie family.

So, Becquerel is the SI unit of radioactivity it is also a measure of the quantity of radioactive material 1 Becquerel is just one disintegrations per second. Therefore, 1 Curie is actually 3.7 into 10 to the power 10 number of Becquerel's or as shown here, 1 Becquerel is 1 by 3.7 into 10 to the power minus 10 Curie or 2.703 into 10 to the power minus 11 Curie.

So, these are SI units of radioactivity based upon which we measure the potential of any radioactive elements. And whenever you are talking about radioactive decay not from one in nuclear isotopes, but even from any other sources also generally these are the units in terms of which we measure the same.

(Refer Slide Time: 16:24)



And this is the instrument which is most commonly used for measurement of radioactivity it is called the Geiger Muller counter. Now just look at the picture that I am given here, it consists of a cylindrical chamber like shown here with a wire stretched along its longitudinal axis.

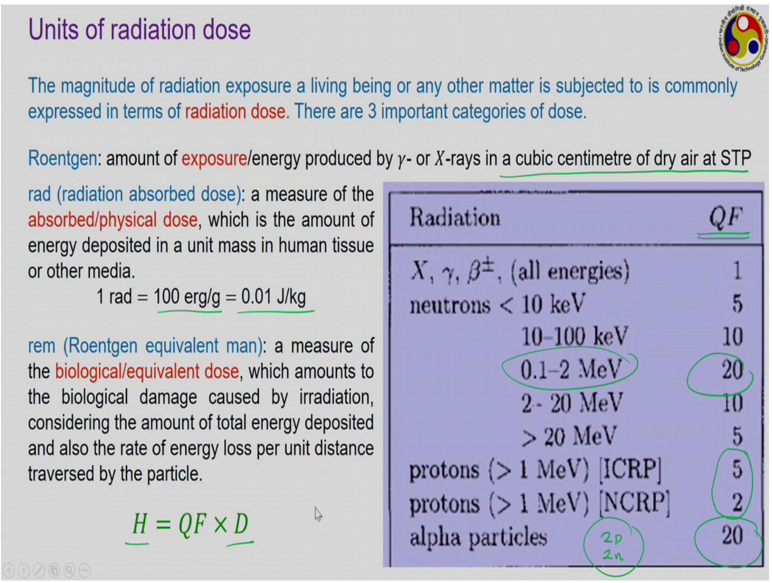
Now, this is the wire that I am talking about you have a wire stretched longitudinal axis the cylinder wall acts as the cathode; and the wire as the anode the positive voltage is applied to the wire, so it can act as a anode where is the wall is connected to some negative terminal so the wall is the cathode in this case. Now, the cylinder is filled with some kind of inert gas maintained at a very low pressure can be helium neon or even nitrogen, also occasionally it can is mixed with the ethyl alcohol to increase the sensitivity of the instrument.

Now, when an ionizing part a particle something like a photon or any other kind of energy, ionized particle that passes through this gas it becomes conductive due to ionization for a very very brief period, which can be sensed with the corresponding circuitry. This ionization is substantially amplified by this current the electronic circuitry to produce a detectable pulse this pulse is sensed by a processing unit which is here.

And accordingly it provides a commissar for the activity that is over a particular period of time the total number of pulse it has recorded. Say if this is the pulse then the number of pulse divided by the time is definitely going to be the act radioactivity, the activity of that particular sample. It is the advantage of this particular counter is it is a robot structure and it is not very costly it is relatively cheap quite proven technology. And easily available limitations is it is unable to sorry it cannot differentiate between the radioactive radiation types, that is whether the radiation is coming from alpha rays or gamma rays it is not able to distinguish as the output pulse is insensitive to the energy of the incident radiation.

It can just sense whether there is energy coming in or not, but what is the magnitude of energy what is the characteristic or source of that energy it does not give any idea. Also you know when its own date time that is the time it takes between two circuit the minimum time it requires between two successive readings, because of that it also cannot measure very high rate of radiation. Still this particular counter is a most common device for measurement of radiation or particularly nuclear radiation.

(Refer Slide Time: 18:50)



Now, the one that we are more concern nowadays about is the health hazard caused by the radiation. And whenever you are talking about the health hazard that can be the result of any kind of radioactive emission, then just the units of Curie or Becquerel and not sufficient rather we have to identify some other unit which can relate the radioactivity in terms of the health hazards or health effects. The magnitude of radiation exposure a living person or any other matter is subjected to is commonly expressed in terms of the radiation dose.

So, radiation dose refers to the radiation exposure one human being or some something else generally characterized in terms of human being only; the magnitude of radiation it is exposed to that is the radiation dose. And there are three kinds of definitions of this radiation dose first is roentgen have you heard the name roentgen.

He is an inventor of X-ray, which is originally used to be called the roentgen ray or roentgen ray, but now we are it is more popularly called the X-ray because that is the name that he used. Now, roentgen is an unit which is the amount of exposure energy produced by gamma or X-rays in a cubic centimeter of dry air at STP. Just look at the definition properly we are giving a particular volume that is 1 cubic centimeter of dry air at standard temperature and pressure. So, we are talking about a given volume given pressure temperatures we are talking about a particular mass of dry air means no moisture present there. Then the amount of energy or exposure produced by gamma or X rays in that is a measure of roentgen. Second is rad or radiation absorbed dose, you know rad is a short form radiation absorbed dose it is a measure of the absorbed dose which is the amount of energy deposited in a unit mass of human tissue or other media.

So, one rad corresponds to 100 arc per gram or 0.01 and joule per kg that is see if I provide you 1 kg of human tissue and the because of this radiation 0.01 and joule amount of energy is being deposited into; that means, the total energy content of that, 1 kg of human tissue increases of a 0.01 joule. Then that the corresponding physical dose or absorbed dose is called rad radiation absorbed dose.

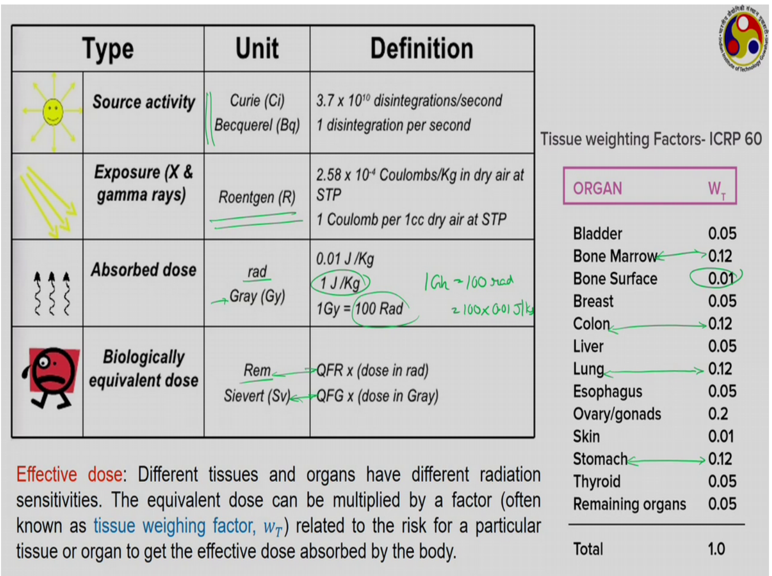
And then add in there the next one is rem, roentgen equivalent mean or roentgen equivalent man, it is a measure of the biological equivalent dose which amounts to the biological damage caused by irradiation considering the amount of total energy deposited, and also the rate of energy loss per unit distance travelled traverse by the particle. The response to different organs of our body are different against the same radiation and therefore, we also have to take into consideration how much biological damage this irradiation is causing.

And that will depend upon the total amount of time, the inner radiation is allowed to amount of energy that is getting definitely total amount of energy that is deposited on the tissue. And secondly, the rate at which the rate of energy loss per unit distance traversed by the particle we did not have tissue; these two combined general is given in terms of something known as quality factor.

This QF different particles has different kinds of quality factors like X-ray gamma rays or the beta particles they are generally very light very low mass or like X-rays and gamma rays are electromagnetic radiations or electromagnetic waves and therefore, they does not have any mass beta particles we are talking about as electrons which have a negligible mass, that is why they have very low quality factor it given the magnitude of 1.

Neutrons are much heavier compared to electrons and therefore, they have certain quality factor and that keeps on increasing with energy to become maximum around this 0.1 2 mev level. And with further increase in this further increasing, the kinetic energy of the neutron, it keeps on decreasing the quality factor. Protons can have quality factor in this range depending upon two different classifications; and alpha particles are much heavier because every alpha particle contains 2 protons and 2 neutrons. So, 4 times the mass of any new your proton or neutron therefore, total damn called damage is can cause is also much higher and even a quality factor of 20. The rem is therefore, measured here H is the rem is measured as the rad which is D into the quality factor. So, the total amount of energy that is getting deposited in a human tissue what kind of reaction that is going to produce or response from the tissue that depends upon the tissue itself. And also on the nature of the energy or emitted radiation accordingly we are defining this rad and rem.

(Refer Slide Time: 23:40)



So, if we combine all these units the source activity from whether the radiation is getting produced that unit is qd or Becquerel. Now, how much exposure and human tissue is subjected to? That is called roentgen, which is given a measure 2.58 into 2 minus 4 4 coulomb per kg of air in dry.

Kg of dry air at STP then we are talking about the absorbed dose measured in terms of rad and biological equivalent dose measured in terms of rem. Now, but rad and rem they are actually the useful units, but not assign units properly so it is gray and Sievert. Now 1 gray corresponds to 100 rad and as we know one rad is 0.01 joule per kg. So, 1 1 gray is 100 rad that is 100 into 0.01 joule per kg that is 1 joule per kg like this.

Similarly, rem biological equivalent dose is always the absorb dose multiplies the quality factors. So, if you are multiplying the absorb dose given in terms of rad with the quality factor, then you are getting rem whereas, when we are having the absorbing in terms of gray then we are multiplying that with the corresponding quality factor we are getting sievert.

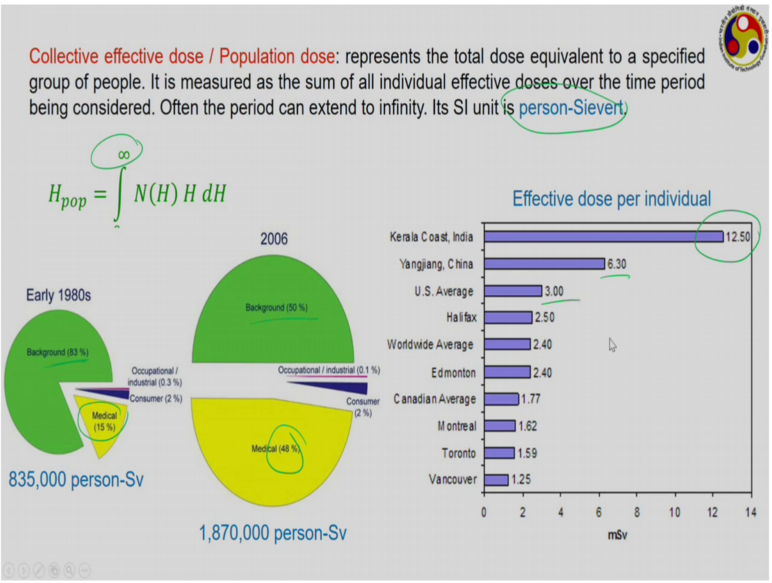
So, this two are corresponding to each other; effective dose different tissues and organs have different kinds of radiation sensitivity different kinds of response. The equivalent dose can be manipulated by effector often on this tissue weighing factor related to that is for a particular tissue or organ to get effective dose, absorbed by the body.

And these are the tissue weighing factors and you can clearly see some of the tissues are very much unaffected or some of the organs. Like the bone surface is a very less effect on this or our skin a much smaller effect of radiation whereas, there are certain other organs where the effect is very strong. Like on the internal organ like colon there can be very strong effect on the stomach, we can have very strong effect of radiation and certain a same on the lungs they have very high this tissue weighing factor. And accordingly they are the most sensitive to this like bone marrow is another example of having point one to tissue weighing factor. So, these are very sensitive to any kind of radiation.

Therefore in a nutshell what we are trying to say is that, just how much radiation you are exposed to that alone does not matter rather depends on two things. Firstly, from where the radiation is coming, what is the nature of this radiation? Means the radiation is coming in the form of a gamma radiation or alpha radiation accordingly, its quality factor varies. And therefore, this biological equivalent dose can be viewed as like the potential for the radiation to cause some harm.

And now this is going to fall on some cut particular organ and the response of that organ is also not the same for all the organs, some of the organs are highly sensitive and some of the like the bone marrow or like the stomach where certain organs like our skin are very less sensitive.

(Refer Slide Time: 26:56)

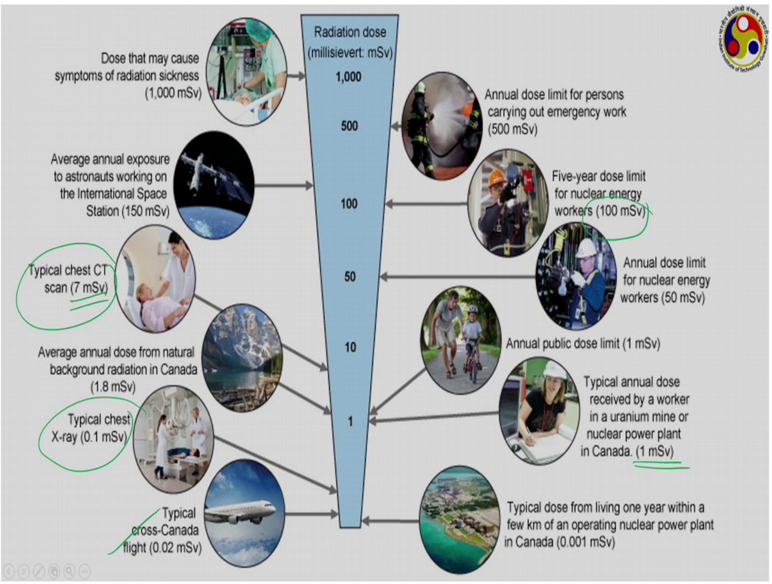


Then we get something called the collective effective dose or population dose where we take the entire population into consideration, it represents a total dose equivalent to a specified group of person it is measured as a sum of all individual effective doses over the time period being considered. And if all the individuals are subjected to same kind of dose then it will be just a product of the total number of persons, into with the number of dose received by per person, that is why it is often measured in terms of persons in Sievert which is given like this where n is the number of population, H is a corresponding dose effective biological effective dose which can vary from person to person.

And infinity here refers to the total number of sample over which you are doing this, because in a population we can have infinite number of persons. In early 80s the effect of background radiation was much larger, for medical instrument it was only very small only about 15 percent. Whereas, in 2006 the background has dropped to 50 percent or actually it has not dropped its quantity remains more or less is the same one has increased a bit, but from medical pot the radiation exposure has gone to very high level.

It was about 0.8 million persons-Sievert whereas, it has become just in 20 odd years it has 1.9 persons million persons Sievert. This these are certain areas, where the effective dose per individual is very high, like the Kerala coast of India has very high effective dose of radiation certain parts of china or US also has very high effective dose for individual.

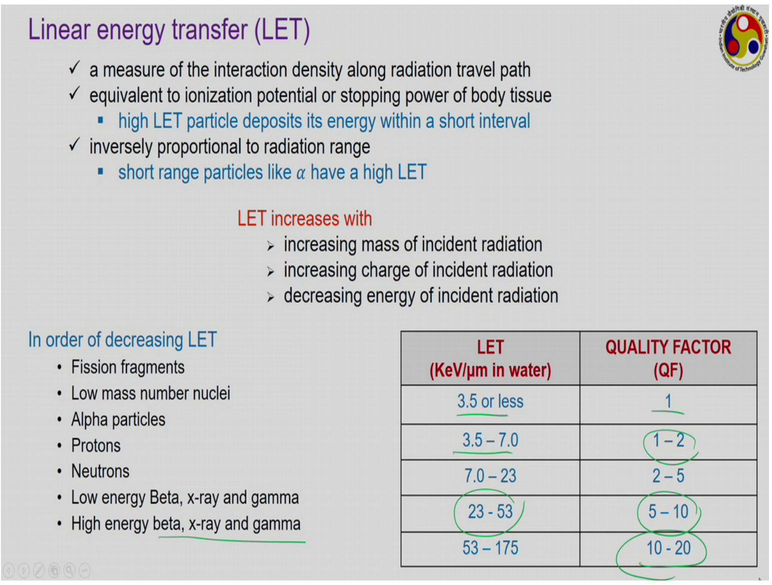
(Refer Slide Time: 28:33)



Now, this is an idea about what we are talking about or rather I should say the biological tool that you just mentioned, we are trying to relate to different kinds of human activities. Like when you are having a typical chest X-ray you are actually getting in dose equivalent to 0.1 millisievert. Whereas, when you are having a chest CT scan it goes up to 7; and if you are going for even higher level some then we can have much higher level of radiation exposure.

This is what the medical term that refers to different medical kind of examinations we are still exposed to different kinds of radiation level, this is not small this is quite large dose. Because, if you compare this is 7 millisievert and correspondingly the total annual dose you see by a worker, which is working in an uranium mine is only 1 millisievert. But this in a certain whereas, when we are considering the and nuclear workers working for working for 5 years in this it can go up to hundred millisievert. So, several common activities like flying or certain medical examinations can still lead to some amount of radiation exposure.

(Refer Slide Time: 29:49)



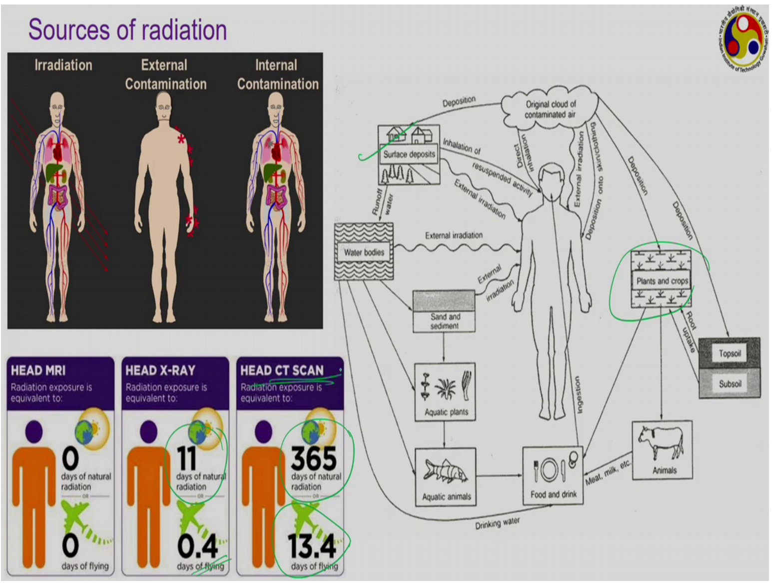
And there we define one final term that is called the Linear Energy Transfer, LET. Linear energy transfer is a measure of the interaction density along radiation travel path, means as the radiation is traveling then how much interest in it can have with the surrounding medium?

It is equivalent to the ionization potential a stopping power of body tissue, high LET particle deposits its energy within a short interval of time. Whereas low LET particle requires larger travel or large longer time to diplos its entire energy; it is inversely proportional to the radiation range like short range particles like alpha I have high LET our LET increases with increasing mass of the incident radiation decreasing charge of incident radiation and decreasing energy content of the incident radiation.

In order of decreasing LET if we express certain particles then generally fission fragments are on or low mass number nuclear very small LET, then it keeps on increasing with alpha particles protons etcetera. And high energy beta X-ray and gamma radiations have much larger LET means they need to travel much longer to deposit the entire energy.

Rather an alpha particle which is heavy and has lots of energy content each can lose all the energy within a short introduction time or short period of time. Generally for particles having a LET of 3.5 or less quality factor is about 1, between 3.5 to 7 it is between 1 to 2 between 23 to 53 it is 5 to 10 and greater than 53, it goes to 10 to 20 that is how we relate the quality factor to different kinds of particles.

(Refer Slide Time: 31:28)

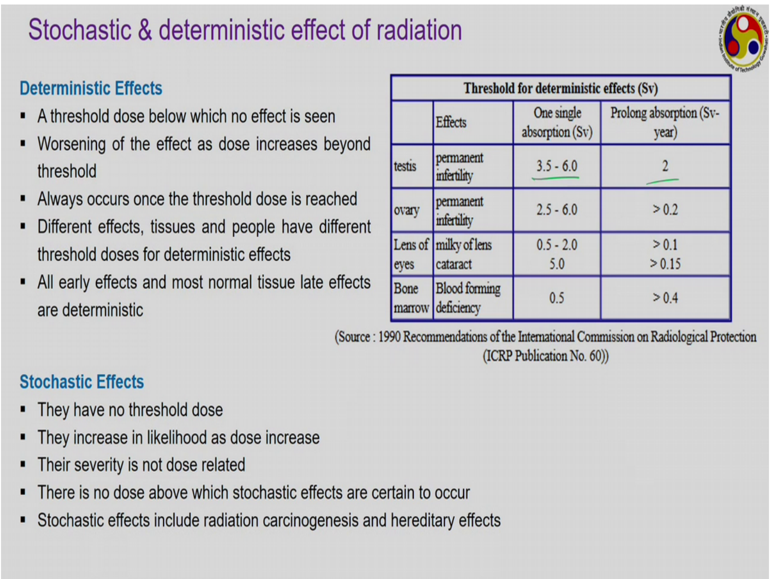


What are the sources of radiation then we are exposed to apart from the nuclear working? We get it from the irradiation coming from the sun, the external contamination or internal contamination coming through some of the foods that we are taking. See this is a more common source like, suppose you have in water body and you have a surface deposit here where we have certain kind of or in a radioactive material stored. So, the water that is running up from there goes to a water body and can lead to the contamination or increase in a nuclear activity level for this water body.

Then what are the things which gets directly contacted by the water body? The sands and sediments are there, aquatic plants directly taking from the water body and aquatic animals. Now, when we are using those for our fooding etcetera, then we are directly getting the corresponding radiation into our body also original cloud of contaminated air can deposit it to the plants and crops from where it can go to the animals or you can go to the soil which is subsequently used for production of foods and drinks. So, there are several ways we can get contaminated by radiation.

Just what I talked about the medical thing, when you are doing an MRI there is hardly any radiation exposure; however, if you are doing a simple head X-ray then it is equivalent to 11 days of natural radiation exposure and 0.4 days of flying. Whereas, when you are having a head CT scan it is equivalent to 1 full years of natural radiation exposure and more than 13 days of flying. So, that is a large dose of radiation that we are talking about.

(Refer Slide Time: 33:11)

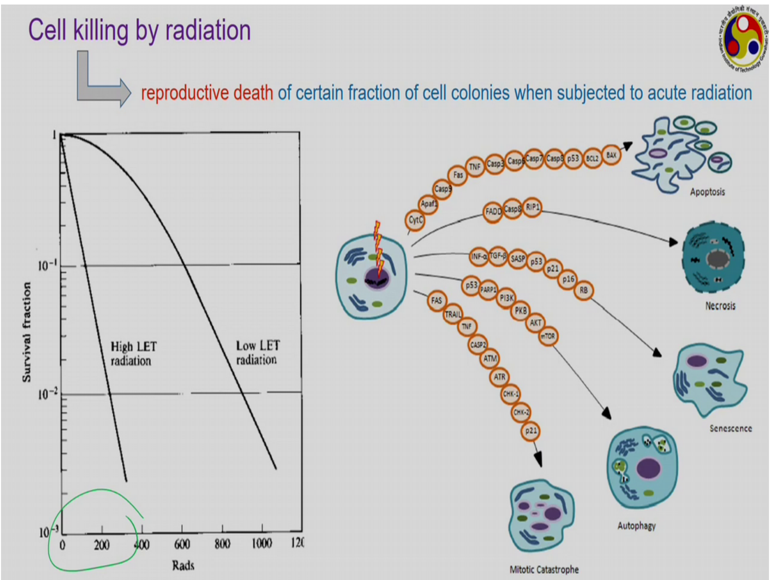


And finally, to relate that to the health hazard, we generally classify the effects of radiation into two categories; one is a stochastic effect other is a deterministic effect. Deterministic effect refers to having a threshold or up to the threshold or in terms of the magnitude of radiation or the quantity of radiation there is hardly any effect; however, once the threshold is crossed threshold is breached. Then the effect starts increasing exponentially once the threshold is reached then only it is going to happen, but beyond the threshold the effect can increase extremely rapidly.

Different effects tissues people have different threshold doses for deterministic effect, all early effects and most normal tissue late effects are deterministic in nature. So, these are some numbers indicating the threshold for deterministic effect, like in one single absorption permanent infertility may happen for 3.5 to 6 sievert whereas, prolong the absorption sievert per year it can be in the range of 2.

The stochastic effect refers to no threshold the increases the likelihood sorry, the hazard dose keeps on increasing and the effect is more likely, but the severity of the effect is not related the dose; it just indicates whether the effect is going to occur or not, but how much it is going to affect the subject? That it does not say there is no dose above which the stochastic effects are certain to occur and this includes the radiation carcinogenesis and hereditary effects. So, once I body is subjected to all human tissues subjected to different kinds of radiation or sustained period of radiation.

(Refer Slide Time: 34:53)



Then it can lead to the killing of ourselves, the reproductive days of certain fraction of cell colonies when subjected to acute radiation. Like for a high LET radiation the survival fraction decreases very quickly within a short span of time whereas, it is much longer for in low LET radiation.

These are the different kinds of effects the human cell can undergo and subjected to radiation, like 5 types of cell modification strategies as shown what possible cell modification like apoptosis, necrosis, senses in auto foggy and mitotic catastrophe each of them has their own reasons of occurrence. But always they lead to some permanent modification in the cell structure or at least the cells which are in immediate vicinity of the affected area.

(Refer Slide Time: 35:44)

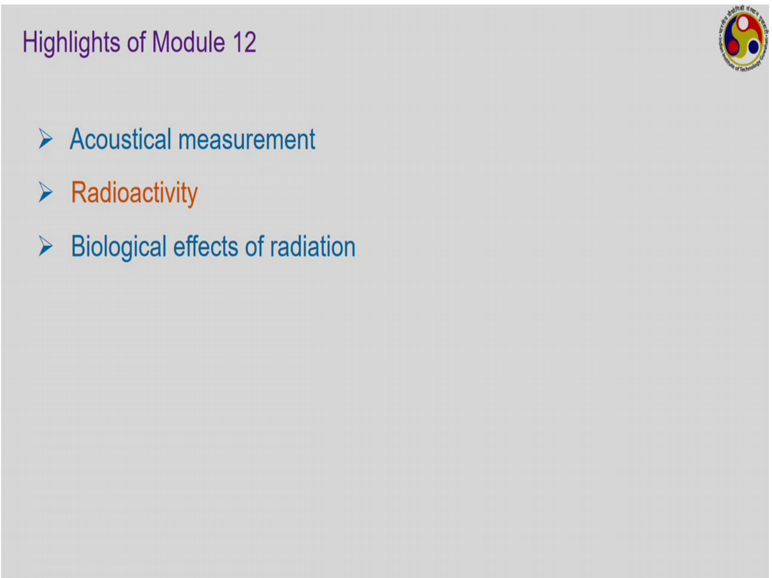
Radioactive effect of foetus

Gestational age	Effect	Threshold dose
0-2 weeks	Death or no consequence	50-100 mGy
2-8 weeks	Congenital anomalies	200 mGy
	Growth retardation	200-250 mGy
	Childhood leukemia	
8-15 weeks	Severe mental retardation	60-310 mGy
	Intellectual deficit	200 mGy
	Microcephaly	200 mGy
16-25 weeks	Severe mental retardation	250-280 mGy

Effect is even more struck for foetus like within gestational age of 0 to 2 weeks, if it threshold value is 50 to 100 milli gray only and they effect may not be any much significant. However, if between 2 to 8 weeks there may be congenital anomalies growth retardation and childhood leukemia, when it is being subjected to 200 or higher milli gray amount of threshold, for 8 to 15 weeks, severe mental retardation intellectual deficit and microcephaly these kind of effects may appear.

Then finally, between 16 to 25 weeks severe mental retardation when it is exposed to a radiation greater than 250 to 280 milli gray. So, that takes us towards the end of this particular module I thought about discussing briefly about different kinds of pollution measuring instruments, but thought that is not going with this topic. So, there is just no point enhancing or extending this lecture just for the sake of it.

(Refer Slide Time: 36:49)



So, in this module we have discussed about the acoustical measurements and we have discussed about radioactivity and biological effects of radiation. So, that takes us to the end of this course. I hope you have enjoyed it, there are different kinds of topics that we have discussed wide variety of subjects that are included in this course because, though we are talking this as mechanical measurement, but we have used extensively with the concepts of electrical engineering on some concepts from electronics certain times the concept of physics.

And therefore, this is a very much in I should say quite intricate as at the same time very much involved part of any engineering discipline. Whatever is your observation please keep on writing to me, I shall be happy to respond to your queries and also any kind of criticism as I shall be happy to accept those who have registered for the examination. Please go through all the assignments properly because some of the questions will be coming directly from the assignment or will be inspired from the assignments well. Some other questions will be a bit new to you. But I can ensure that the question papers will not be very tough. It is just a logical application of whatever you have discussed in this course and so you should do well.

So, at this particular point I would like to say goodbye for one final time, but if any of you need any kind of help not only for this course regarding any other topic also I shall always be happy to be there.

Thank you.