Introduction to Uncertainty Analysis and Experimentation
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Module - 01
Outline, Introduction
Lecture - 01
Course outline, Introduction

Welcome to this course, on Introduction to Uncertainty Analysis and Experimentation. My name is Sunil Kale, and I am a Professor of Mechanical Engineering at IIT, Delhi. This is our first lecture and in this I will give a broad outline of what this course is all about. So, this is module 1 which is Outline and Introduction. And the first lecture in this module is an overview of this course and what is it that we are going to learn.

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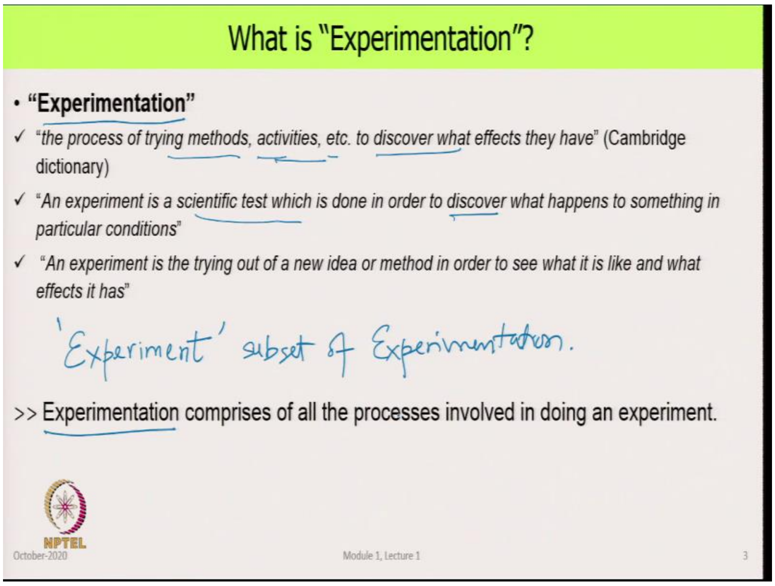

The title of this course has two words, uncertainty analysis and experimentation. So, we first ask the question. "What do we mean by experimentation?" And here I have listed three definitions which says, the first one says that experimentation is the process of trying methods, activities etcetera to discover what effects they have.

This definition is from the Cambridge dictionary. So, what we are saying is that, we are doing something and wanting to study the effect it has and this whole process of doing this. This is what is defined as experimentation. Another definition, that an experiment is a scientific test which is done in order to discover what happens to something, when there is a particular change or a particular condition.

So, this is what we typically understand in science and engineering that we have something, where we change some parameter and see what effect it has on something else. So, the do act of doing it is the experiment, but the entire process of trying methods, activities etcetera is experimentation.

(The experiment) And another definition (of) the experiment is the trying out of a new idea or method, in order to see what it is like and what effect it has. So, we have defined two things, one is experimentation and the second is experiment. And we have seen the difference between the two, in the sense that experiment is something where we do something to study the effect. But, experimentation is the process of doing everything related to that experiment in order to make it a success.

So, the difference again is that experimentation comprises of all the processes involved in doing an experiment. What we are saying is that the experiment is a subset of the processes of experimentation. So, what we have seen here is that doing an experiment is a subset of the processes of experimentation. That means, that experimentation has many more things going with it of which doing the experiment and taking data is just one part. So, that is the basic definition.

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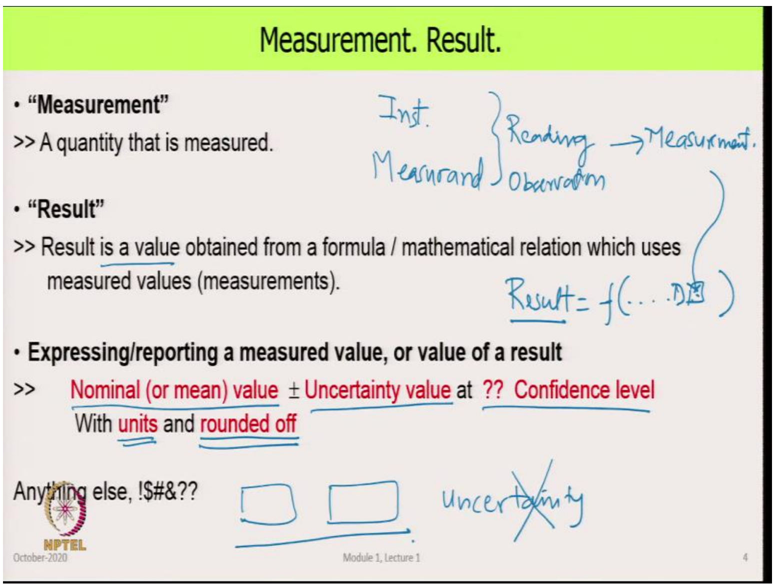

Now, fundamental to doing experimental work are two things (namely) making a measurement, and then getting a result. So, in the context of this course here is what we have. Measurement we mean that it is a quantity that is being measured. So, we are taking a particular data from an instrument by seeing what is the value of it? The result in this context is that it is a value obtained from a formula or a mathematical relation, which uses measured values or measurements or data.

So, what we are saying is in a lab, we go or in an industry, we go we look at an instrument, we see what it is going to measure that is the measurand, from there we see a reading. That is what we will call either a reading or an observation, and this is our measurement. And then we have a formula, where the result is some function of various things of which this measurements one, two or more are some parts and using this calculation we get another number which we call the result. So, you can call it result or result value.

And after doing all these the idea of this whole course, is that whether it is a measurement or a result it is not that we are expressing only one number, but as we are seeing in this statement here. That we report a measured value or a result value as a combination of first a nominal or mean value, which is the average value, plus minus another value, which is the uncertainty associated with this value at a particular confidence level that is our decision.

And all of these is done with two very important prerequisites that we always specify the units. And we report the value to a particular number of significant places by doing the round off. So, this is what we will learn in this course is, how do I get the nominal value, how do I get the uncertainty, how do I report it at a confidence level, what is the basis for round off, and of course, units will always be there.

If we do anything else and we say that our measurement is this number and we put some number there, or our result is this value and we do not have the uncertainty in it. If we do not report this, then these things mean nothing. Without the uncertainty the reported value cannot be interpreted, inferences that are drawn on such numbers are erroneous and that is why this whole course is so essential.

So, now, we go back to the (basic) other word in the title. What do we mean by uncertainty and what do we mean by uncertainty analysis?

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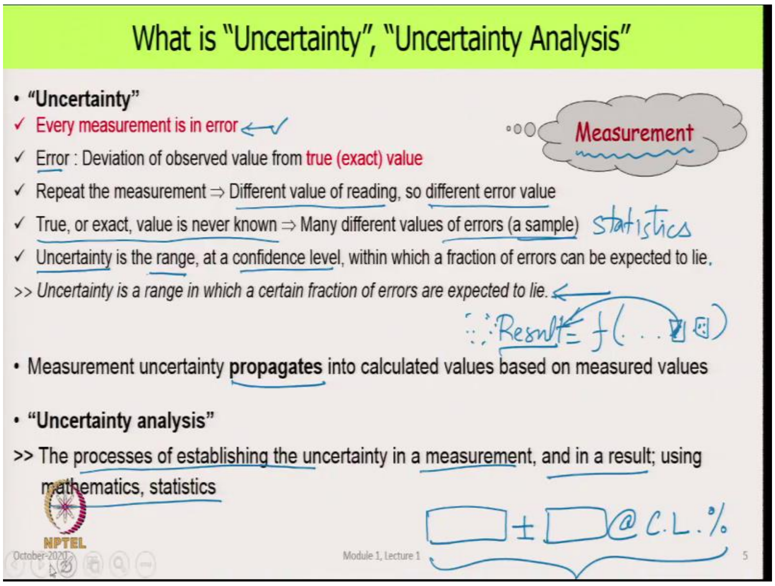

First to talk of uncertainty, we have to have a measurement. So, that is our first prerequisite and we just saw what measurement was. And with this here is a set of arguments that we will go through. First every measurement is in error this is the truth, there is no such thing as exact measurement. The question next is now what do we mean by error?

So, the error is deviation of the observed value from the true or exact value. So, that is error and every measurement has an error. Then, if we repeat the measurement either ourselves or somebody else does it we will get a different value of the reading, which means that there will be a different value of the error every time we make a measurement.

So, that is the thing that is happening. The next truth is that the true and exact value is never known, no matter what we are measuring, we never get the true value of that measurand we never get the exact value. Whether it is to one significant place or ten significant places, we do not know the exact value.

However, it has some fixed value and what it does is that when we subtract the reading that we have from the (value) exact value, we get the error. And since there are many different measure values that are coming in we have a large number of errors and that (set of errors) is called as sample. And this is where statistics starts to come in.

So, now what we have if we make lot of measurements, we get lot of errors the question is "Are we going to report the error or we report something else?" Error cannot be reported because the exact value is not known. So, we take recourse to what we call uncertainty. Uncertainty draws its legitimacy from the statistics of the sample of errors, and it is the range at a particular confidence level within which a fraction of errors can be expected to lie.

So, we said that errors are spread their whole value is so much from this value to this value. If a certain fraction of those errors say two thirds or 90 percent or 99 percent lie in (your) a certain band, that band is what we call as the uncertainty. And that gives us this definition of uncertainty; that uncertainty is a range in which a certain fraction of errors are expected to lie.

So, the every measurement got an error; and as we saw a few minutes back, we said that we compute a result as a function of many things of which some of these are our measured values. So, what it tells us? This has error, this has error which means that if we do a calculation based on two numbers which have errors, the result will also have an error. So, the result is not exact.

So, depending on what values you used here you got a different value of the result. So, you end up getting a lot of values of the result and now, we ask “How do I report the result?” So, this process we are doing a calculation with a measurement that is in error, leading to an error in result and consequently the uncertainty in these leading to an uncertainty in the result is (which) what is called propagation of uncertainty.

That means, measurement uncertainty propagates into calculated values, which came from measured parameters. Uncertainty analysis; so, this was about uncertainty. Now we say what is this whole world of uncertainty analysis. So, these were two aspects of it uncertainty analysis has got everything else that makes this thing happen.

So, this is the process of establishing the uncertainty in a measurement, that is one part of uncertainty analysis and seeing how it propagates into the result. And the tools we use for doing this process are based on mathematics and statistics. So, uncertainty analysis is that process using mathematics and statistics by which we establish uncertainty in a measurement, and we compute that and define what is the uncertainty in the result.

That finally, gives us the thing that we were looking for that whether it was a measurement or a result, we have a nominal value plus minus the uncertainty at a certain confidence level, this is our answer this one. That is the whole objective of all reporting of all experimental work. Now, we go back and say that this course has two words - uncertainty analysis and experimentation.

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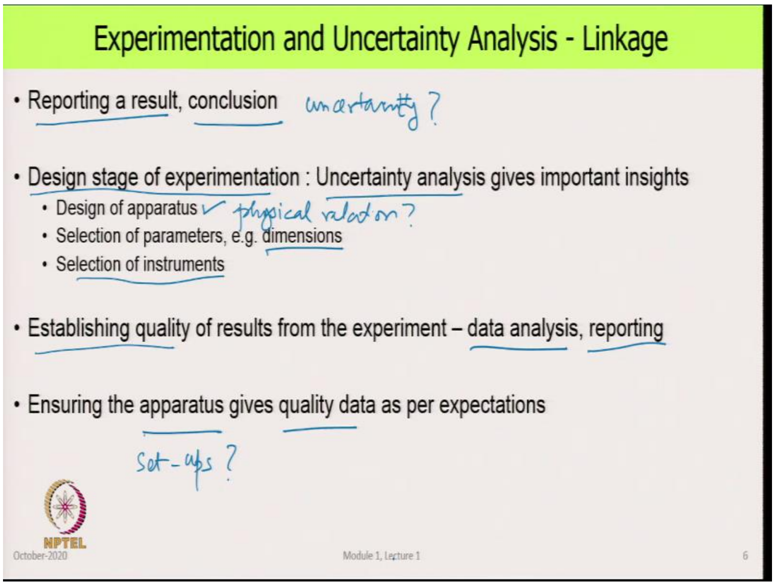

So, we saw that experimentation is the process of doing a lot of things of which experiment is one thing. Uncertainty analysis is something which tells us that measurements are not exact.

So, how do we report a value? The question is what is the linkage between these two? First of all, in the whole process of experimentation in the end, we want to report a result and draw conclusions based on it. This is possible only when we know what the uncertainty at different points is.

So, (they) we have various stages of experimentation, at each stage uncertainty comes into play. A very quick overview of this we will take a few instances the design stage of experimentation. When we look at experimentation, we will look at various stages of experimentation in more detail right now, let us say that I am looking at that stage where I want to design the experiment.

I have an open mind, I have lot of possibilities, I can have different sizes, I can do different instruments, I can have various strategies of data collection how should I do it. Is there a good scientific way to zero in on some possibilities which are more desirable than others? So, that is the design stage of an experiment.

So, with uncertainty analysis we can get great help in designing the apparatus. For example, what should be its shape and size and what is the physical basis of doing it, including what is the physical relation on which we will calculate the result? Uncertainty analysis helps us in deciding that, once we have decided what sort of an experiment - we want to make, how big should it be, what should be its dimensions, which is the best way, it should it be very small, very big, what?

Uncertainty analysis tells us that there will be some of these combinations which are better than others stick with those. Uncertainty analysis helps us in a very major way in tell telling us which instruments we should put. So, there are some instances, how uncertainty analysis helps us at the design stage of experimentation. Now, suppose we did the experiment got the data, and now we are doing calculations and drawing conclusions based on it.

What does uncertainty analysis have to do with it? What we are doing is that at this phase, which is data analysis and then finally, when we report our result, in the paper or a thesis or a decision form. We are say doing taking uncertainty to establish the quality of the results from the experiment. So, we say that this result was this much plus minus this much, that result was this much plus minus this much. In light of these variabilities what conclusion can I draw.

Another example of use of uncertainty analysis is ensuring that the apparatus gives quality data as per expectations. We will see as the course goes on and you can also look up various standards and experimental setups, that not every setup is as good as anything else. Particularly when it comes for certification, quality assurance, performance testing, there are various levels at which one can do that experiment. It involves various different types of apparatus, although the end result may be the same.

Uncertainty analysis tells us that different types of setups or apparatus, what sort of uncertainties can you expect, which tells you how good that particular setup really is? So, these are some of the instances of the inter linkage between uncertainty analysis and experimentation. We will come back to experimentation in a later module. Now, we will look at uncertainty analysis in little more detail.

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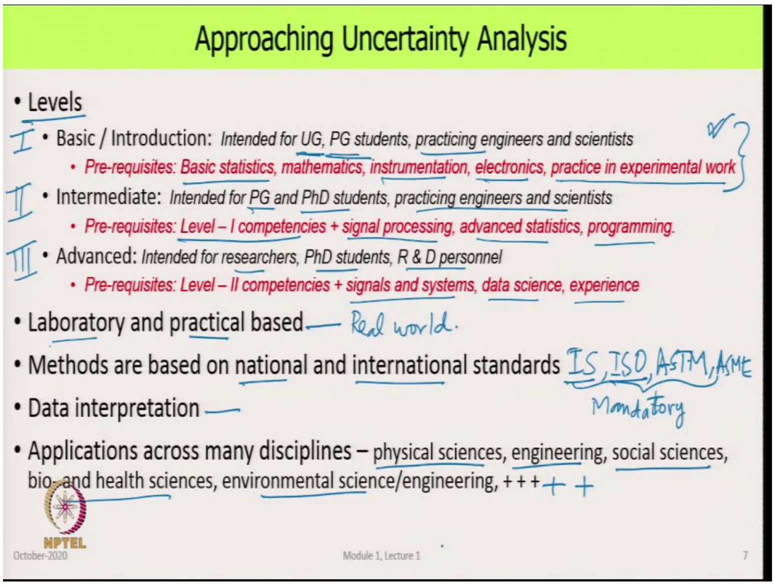

The first thing is, what is the broad approach, to this whole field of uncertainty analysis? This entire body of knowledge is very vast and it is not possible to either take it in one course of say a semester duration or it is not even advisable that the same material be taught to everybody. By everybody I mean an undergraduate student in science and engineering or a master's level student, or a researcher a PhD student or may be somebody in industry who is doing this.

So, based on these two criteria the course has been planned in three levels. Level I, which is what this particular course is basic and introduction. To the concepts and methods of uncertainty analysis, it is focused at undergraduate students beginning post graduates, master's students and some PhD students and it will have benefit to practicing engineers and scientists. So, if someone does not know anything about this subject this is the good place to start.

You (can we) will see that at the end of the course what you will be able to do, and how it benefits. In doing this course we assume that who is studying this course, has a good grounding on basic statistics and mathematics particularly calculus. You need to have a good idea of instrumentation at least some idea of what are the parameters that are measured, what are the instruments used for making those measurements.

And even if you do not have an extensive experience on that, as we go on in this course, we will have problems, assignments, projects, coming up where you will have to go to the web look up new instruments and see what all is there for us to use.

You need to have some basic understanding of electronics. These days if you see any instrument, any device, any gadget at home, everything has electronics in it; whether it is your cell phone, whether it is a touch screen, everywhere there is electronics, where digital data is flowing doing some operations and making some things happen. This has become an integral part of most instruments.

So, we need to understand some basic electronics. Now, in these COVID times if you go anywhere they are using a small instrument to measure the temperature of your skin. But that is another instrument, it has uncertainty with it and it has electronics in it. So, get some idea of how that thing works this is what we need to know.

And it is essential to have some experience in experimental work. If you do not have any experience in experimental work well we will keep giving ideas, where you can do a small experiment yourself and see how what we are learning gets applied to what we are what practical things are.

So, this is level I and in this 8-week course, we will reach a certain level where you will have a decent idea of what is it that we are doing, how we are doing and what is the outcome of this. This is adequate for most undergraduate experimental work and also for many post graduate works. After studying that (you) would be (able to study) the second level of course, which is I have called as the intermediate level.

Now, here we go to focus on largely for post-graduate and PhD students, practicing engineers and scientists and researchers. And what do we do in this course? We learn more advanced topics related to these, what we have studied. In fact, there are many topics which we will not study in this course the form part of level II course.

To take level II, we need to have a prerequisite, which is level I competencies which is all of these and all the knowledge that you have gained in level I. Along with that we learn more on signal processing, some topics in advanced statistics, and some programming. So, this takes us to a level where we are pretty much on top of the field as it is being practiced. The advanced level, which is level III is intended for researchers some PhD students and R and D personnel and people who design and make standards.

We look at topics and methods which go well beyond what is there in level II. The prerequisites for this are level II competencies, which is everything we learnt in level II plus some knowledge of signals and systems data science and a lot of experience. Right now, this course that is being offered is right here, we are looking at level I.

A thing about uncertainty analysis it is that it is extensively, if not exclusively laboratory and practice based. It is not something which is theoretical abstract. Yes, the calculations the concepts could be like that, but ultimately we use that as a method or a tool to come back and say well what is happening in the real world?

The next feature of uncertainty analysis is that, while it started of 50 years ago as something that researchers were looking at. Gradually it has become extensively used in national and international standards. In India, we have the Indian Standards, IS, made by the Bureau of Indian Standards. India is one of the founding countries of the ISO International Standards Organization and a whole bunch of other standards.

These are important because not just in doing research, but also in reporting industrial data, industries extensively follow these standards. It is like these (are) have become almost like they are mandatory. If you do not follow these standards no one takes you seriously these standards have evolved a lot and they also give the complete logic, methods and processes of doing uncertainty analysis.

So, in this course we will extensively look at some of these standards and also standards that come from other standard bodies like ASTM or ASME. And based on these we will learn what are the methods of doing uncertainty analysis. The issue of data interpretation which is after the result has been obtained that we will not look at in this course.

But we end at that point, where we have established the uncertainty in result and measurement and said “Well now, the next stage is to draw conclusions” which has to be done separately; we do not look at that in this course. The final feature of uncertainty analysis is that this is not a course which is related to one branch, one discipline or one subject.

What we will learn is a very broad based extensive general theory of uncertainty analysis applicable to everything. And so, what we have is that who can benefit from it. It is applicable to physical sciences, all disciplines of engineering, many aspects of social sciences, bio and health sciences, environmental science and engineering and you can add many more to it.

Uncertainty is an inherent aspect of every measurement, whether it is your blood pressure or anything else; and as we are even seeing these days, various tests for COVID 19 detection. Some have high accuracy, some have low accuracy that is what is uncertainty all about.

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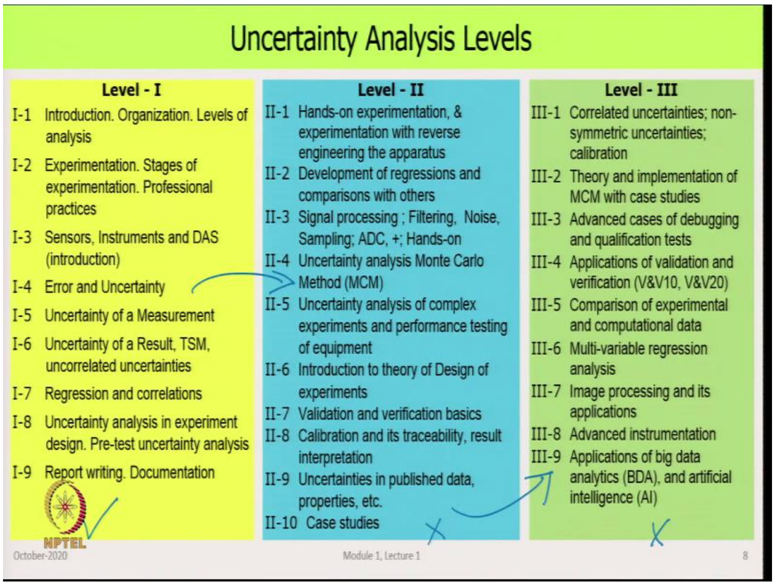

This slide very quickly tells you the topics in levels I, II and III. Right now, I will not go into the detail of it they are all listed in the notes, and we will come back to it later on. Level II and III (is) are not right now on our menu. We are looking at level I and what is written here I will come back to it in the later slide.

But, what it tells you is that there is a gradation of knowledge, where this is the basic one which is a prerequisite for going there, which is a prerequisite for going there. That is the important thing to note here and you can see here there are various issues coming from mathematics, statistics, electronics, signals processing, various types of hardware everything is coming into this.

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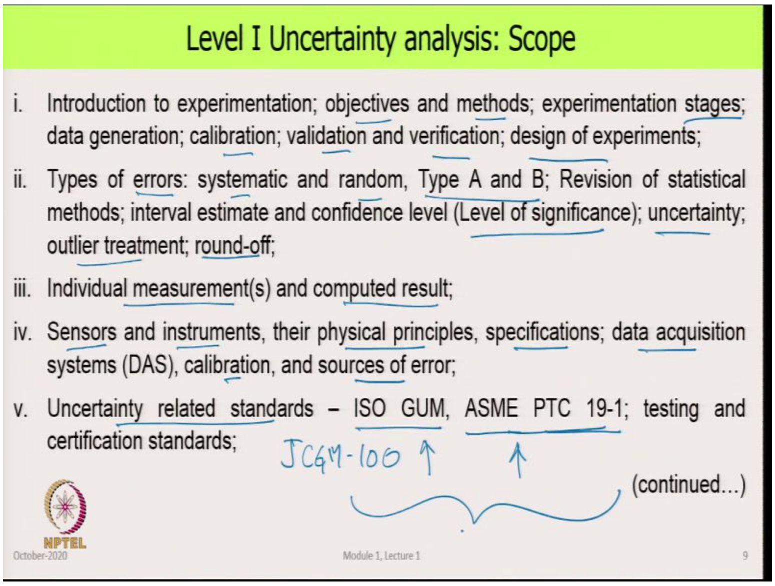

Now, we will focus on level I which is this course 8 weeks and we start by saying in this course what is our scope, what do we plan to do in these 8 weeks. We will begin by introduction to experimentation, what are the objectives and methods, what are the stages of experimentation and various issues like what is calibration, validation, verification and design of experiments.

Then, we will learn about errors which we will classify them as systematic or random errors or Type A or type B errors. We will look at statistical methods, revise various concepts and use that to develop, the uncertainty. Using statistics we will also revisit or learn about outlier treatment and the basis of doing round off. We will look at two things, first we will look at individual measurements and then we will look at a computed result.

In the course we will also touch upon sensors and instruments, we will not go into details of these because this is not a course on instrumentation. But, we will pick out certain things about the instrument which are relevant to uncertainty analysis; for that we will learn their physical principles; see what the specifications tell us because, most instruments is something that we buy.

There are very few (instruments) that we make ourselves most instruments are bought out what is it how that you are buying; that is what specifications are all about. We will look at data acquisition systems DAS and also look at calibration and sources of error in the instrument.

We will do we will get lot of familiarity with uncertainty related standards the two most important ones that we will extensively use in this course is ISO GUM, GUM this is actually JCGM 100, which is called Guide to the Expression of Uncertainty in Measurement. And the second one is ASME, American Society of Mechanical Engineers, Performance Test Code 19 dash 1. And these two standards between them are the basic standards used by almost the entire scientific and technical community.

For example, ISO GUM was not just developed by engineers, but by physicists, chemists, and a whole bunch of other professional bodies which are the biggest in the world, they all got together and made this standard. But, they all thought that this is how we should be reporting experimental data. Similarly, although this is American Society of Mechanical Engineers, the performance test code is applicable for testing of aircraft engines.

So, it used in aeronautical aerospace industry it basic standard in many chemical industries, many standards related to chemicals industry and practically everything else. So, in a way we can say that these two are the foundational standards or the mother standards of a whole bunch of things that happens in science and engineering.

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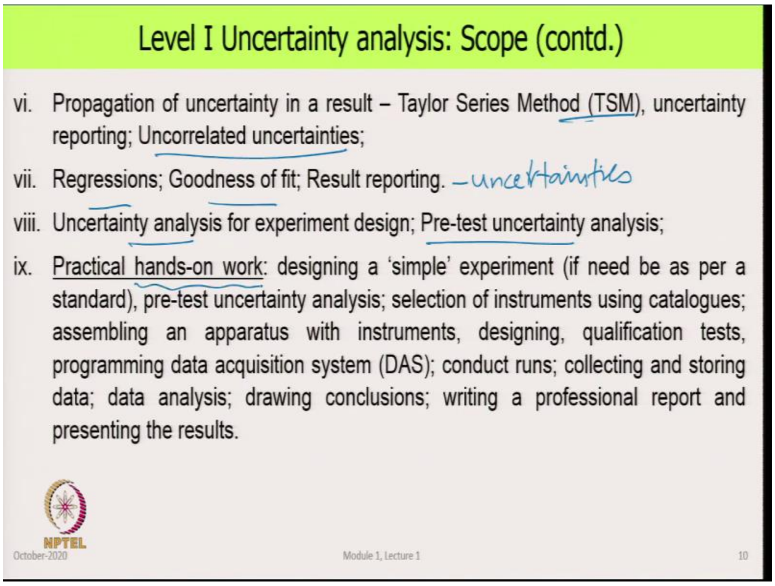

Then, we will look at propagation of uncertainty in a result, but we will study one method which is called the Taylor Series Method TSM. And we learn how to do uncertainty reporting and what are uncorrelated uncertainties. This course is confining itself to a sub class which is uncorrelated uncertainties.

Then, we will look at some basics of regression and goodness of fit in the light of uncertainties. Some of you may have learned these things, but now you will say “I am making a regression based on certain measurements, which have certain uncertainty what is the uncertainty in my regression? This is what we look at. We will have a glance on how uncertainty analysis can be used for experiment design, and in particular we will learn and do some examples on what is called pre-test uncertainty analysis.

That means, in the stages before I make a setup or before I go to take a measurement, what uncertainty analysis can I do and how can I benefit from it. And finally, uncertainty analysis as I have already mentioned is completely about hands on work, many aspects to it we will look at it as we go in the course.

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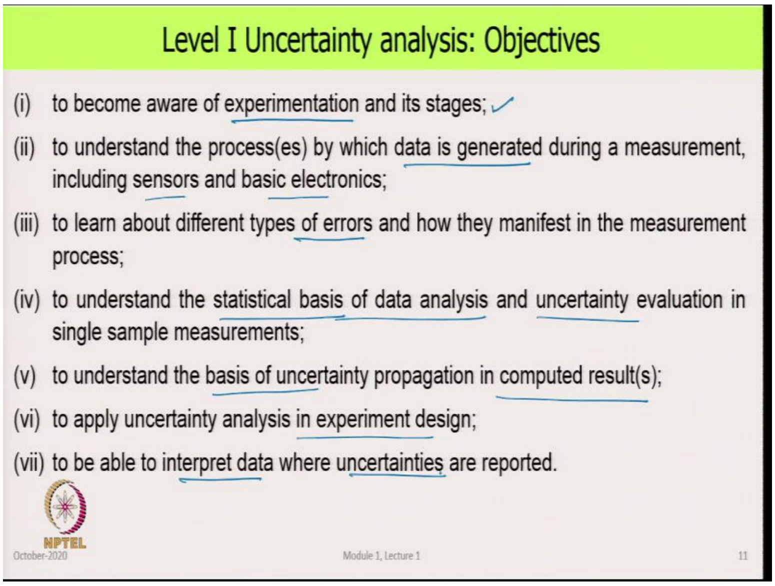

So, the objectives of this course are to become aware of experimentation and its various stages. So, this is experimentation to understand the processes by which data is generated during a measurement and how sensors and electronics affect it.

The third objective is to learn about different types of errors and how they manifest themselves in the measurement process. Then, we will understand the statistical basis of data analysis and uncertainty evaluation. We will also our objective is also to understand the basis of uncertainty propagation in computed results.

We will also see how to apply uncertainty analysis in experiment design. And the objective is that you should be able to interpret data, where uncertainties are reported. Somebody else reports the data and says my this data is this much plus minus this much, but how do you interpret it in a consistent way as to what that person is trying to say that is this thing.

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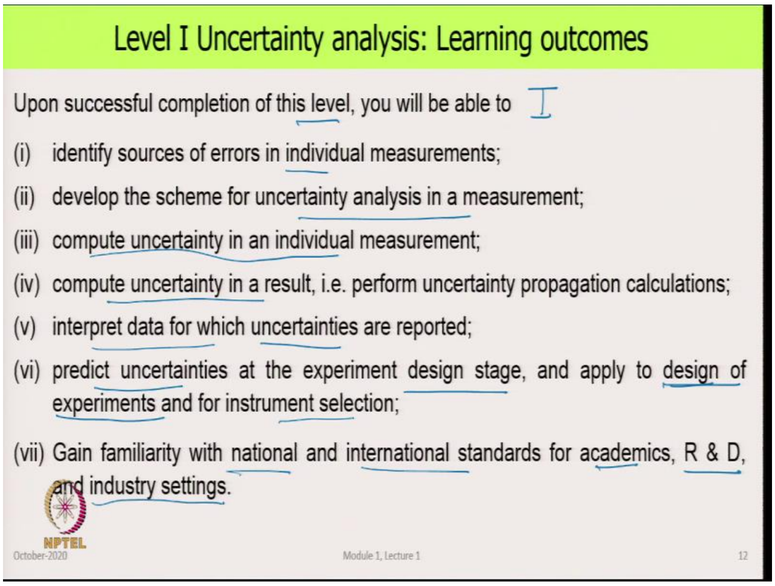

Now, we come to the learning outcomes of this course, which means that when you have finished this course what will you be able to do? Here are various items that have been listed. So, upon successful completion of this level which is our level I, you will be able to identify sources of errors in individual measurements, you will be able to develop the scheme for uncertainty analysis in a measurement, a very systematic way.

You will be able to compute uncertainty in an individual measurement using that, you will be able to compute uncertainty in a result. Then you will be able to interpret data for which uncertainties have been reported. And you will be able to predict uncertainties at the experiment design stage and apply that to the design of experiments and instrument selection.

The term design of experiments has a slightly different connotation and people look at it differently. (This) What we will look at or we consider design of experiment as is how do I use uncertainty to make my setup? The design of experiments has a much broader connotation that how do I design, what I will measure, how frequently I will measure, where I will measure that is left to level III.

And finally, here among the learning outcomes, you will gain at the end of this course. Familiarity with national and international standards that are used in academics, research and development and many industry applications.

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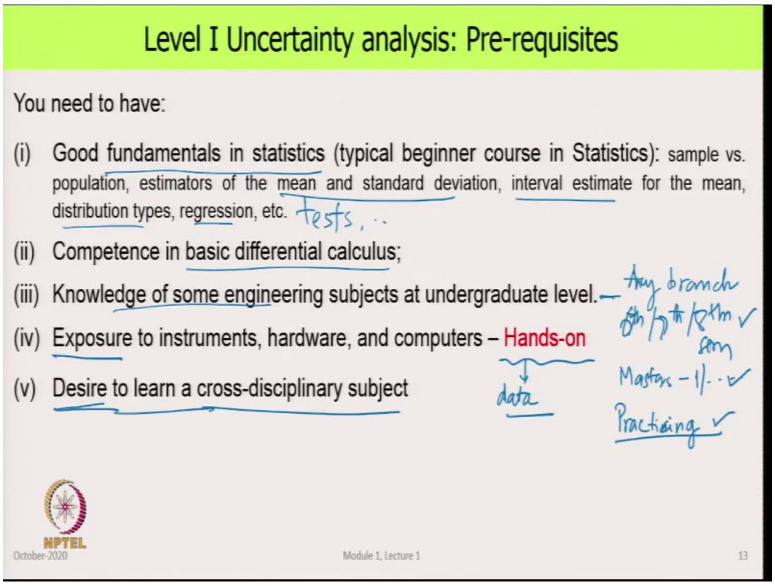

So, these are the learning outcomes of this course. So, that is what you will learn after 8 weeks.

Now, the prerequisites of this course which means what do I expect you to know in order to be able to meaningfully benefit from this course.

You need to have decent fundamentals in statistics a beginning course in statistics. What is sample, what is population, what are estimators of the mean and standard deviation, what is the interval estimate, what are the different types of statistical distributions, what is the regression, what are the different types of tests that are done.

At least this much which is covered in a basic undergraduate first course in statistics is what is required for this course. We need basic competency in differential calculus and that is what you would learn in a typical undergraduate mathematics course in calculus. The third item here is knowledge of some engineering subjects at the undergraduate level.

Now this is very broad-based thing, it does not mean, that you have to be from this discipline or that discipline. You could be from any branch and you could have taken a few courses related to that branch for understanding the subject. Typically, this thing happens in the first 6 semesters. So, if you are in your 6th or 7th undergraduates or 8th semester, you would have had done most of these courses that are required for this uncertainty analysis course.

So, this is ok; if you are a master's student, even if it is your first or second semester or any of the semesters you are ok, you can study this course because you have done most of these undergraduate courses. And same thing with people working and practicing in scientists and engineers.

We expect that most of you have a degree in science or engineering bachelors or masters. So, you have got this basic knowledge you may have forgotten some of it, but we will go back revise a few things from there. We do not need deep knowledge of each and every subject, but we will pick up examples from that and see how experimentation is valid is applicable to that. You need to have some exposure to instruments hardware and computers especially hands on.

That means, you should have worked with something put something together got a measurement. And measurement means you collected lot of data. And the last prerequisite that I have listed here is something very big and philosophical, you should have a desire an excitement to learn something which goes beyond your own subject and which is a cross disciplinary subject.

So, in this course we will take examples from as many disciplines as possible. And you should be open enough and exciting enough that ok, let me learn something from another subject. There must be something new and something interesting in it. And in that sense you will learn something new about another subject, but at the base of it you are learning the practice of uncertainty analysis. So, that is an important thing to have.

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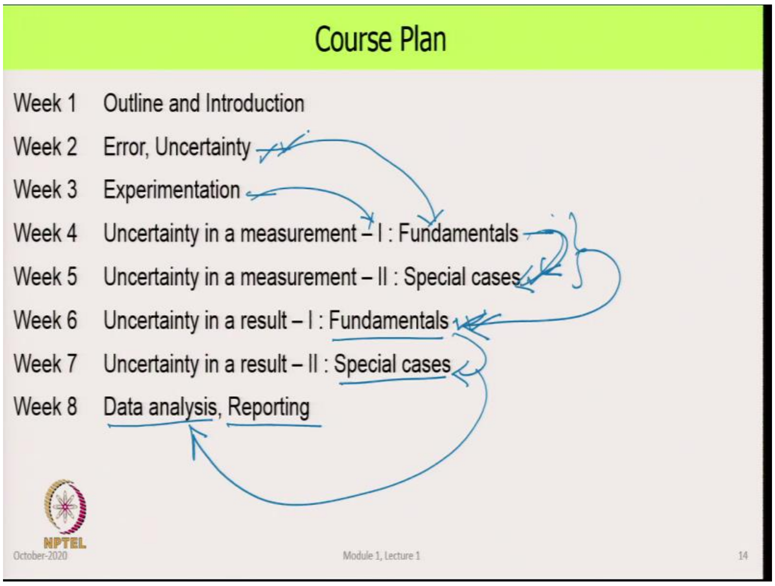

Now, how have I planned this course? We have 8 weeks and I have divided different topics for the different weeks, starting with this week which is outline and introduction. Then, we will move on in the second week to error uncertainty what they mean and how we treat them.

We will use that knowledge we then we will move towards slightly different topic which is (a) experimentation; so, we will see what are the phases of experimentation, what is this whole thing all about. Then, we will use knowledge of both of these and start looking at in week 4 uncertainty in a measurement, we will look at the fundamentals. The next week we will look at special cases of uncertainty in a measurement.

After getting knowledge of these and experimentation, we move to the next stage which builds up on these items to look at uncertainty in a result and we will first look at the basics. Week 7, we will look at special cases. And in the last week, we look at some aspects of data analysis particularly regression and correlations; and how we can report results and data keeping in mind what the uncertainty is.

So, that is the 8 week plan and this builds up on this uncertainty analysis builds up on this also requires this. From fundamentals we go to special cases from both of these we come to here, then from here we come to here and some of this comes to data analysis.

So, there is a hierarchical approach in this course and so, what it means for you is that you need to get your understanding in good shape at the end of every week. If there is any doubt or any clarification that you want do come back. Now, few minutes I will explain how I have organized this course and how we will manage this course.

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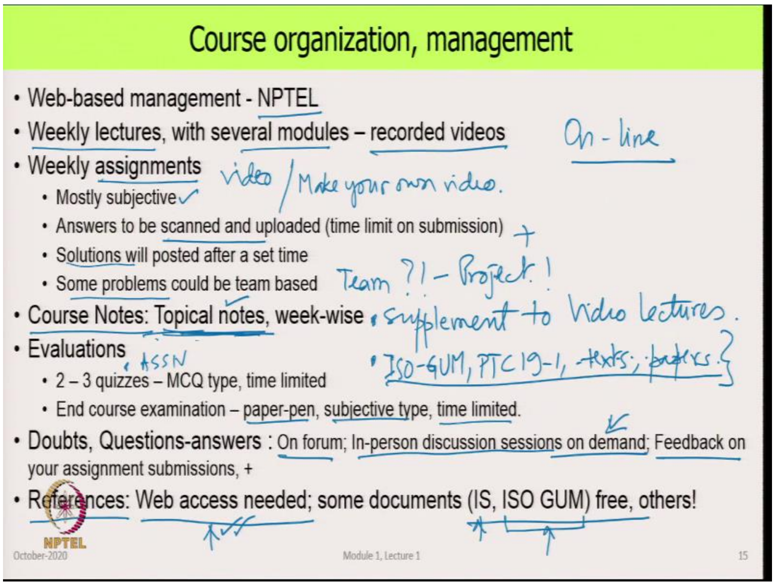

This is completely an online course. So, we will not physically meet. It is managed the website is managed by NPTEL and we will make use of that for all our work. You will have pre-recorded lectures for that particular week as a set of modules. So, this will be made available to you at the beginning of the week.

Every week we will have assignments, most of these are subjective type, it requires you to do lot of calculations. Some of the assignments will require you to go to the web, look up some data and use that data in your calculations. You have to scan your answers and upload them within the prescribed time limit and we will do our best to correct it as quickly as possible so that you get feedback on what you have done.

A certain percentage of these marks will count towards the final course marks. After the time limit for submission is over we will post the solutions, for every assignment problem. The nature of this course is such that sometimes there is a lot of work involved of different types and so, we could have some problems which are team based.

So, how do we make an online team, let us see if you can share your ideas and in that way we can pick up some problems and go more deeper into it rather than just one person trying to do a lot of it. So, that is about assignments. This could even be (that) a small project type of an assignment, (involving) a lot of experimentation, (is on) some sort of a project. For every week I have prepared course notes which are very topic specific and those will be made available on the website.

So, these notes will supplement the pre recorded lectures. Now, the notes are not a transcript of the lectures; although the transcript of the lecture will also be available to you. The notes are like a sort of a book, which look at the same material in a slightly different way this some elaboration done there. And lot of the step by step mathematics which I will skip in the video lectures is given in the notes, you can read that up. So, they are a supplement to the videos.

The other reason why I have made notes is that because that material that we are learning is very widely scattered. So, you have as I have said there is a two standards ISO GUM, ASME PTC 19.1 and some text books and papers. So, none of these are actually like a text book where you can quickly read and get an overview of it. It will be nice if you can read any of them they are available, but understanding them in the context of a larger course that is not done in these documents.

So, the notes are like what a student would like to look at it from their perspective. So, the material from all these things is what I have recast added my own understanding and made these notes. So, that is how these notes are different the evaluations will be based on assignments.

We will have 2 or 3 quizzes which will be online MCQ type with a limited time, the end course examination will be paper pen subjective type of a exam so limited time. Then, how do we interact? First let me make it clear I am absolutely open and free and would love to answer any doubts or questions that anybody may have. You can post your doubts on the forum; I will try to give reply to that within 24 hours.

If you believe that there are or if I believe that there are certain issues in which there is a lot of difficulty or clarification is needed, we could have a live session, or I could take those topics make a video lecture upload it or I could make elaborating notes on it and I could upload it all of that is possible; and this is based on what your demand is.

We will make our best attempts to give you feedback on the assignment submission that you have done. So, if there is a better way of doing something or you have made a mistake, you can learn from it that is the most important thing of education. Finally, reference materials what is the reading material, where there is first there are some standards.

All Indian Standards are available for free and many of these Indian Standards (we) will be referring to in this course. The ISO standards on uncertainty analysis are free and you can download it from the web, my notes contain the websites. So, at least two things we have in plenty. Some of the others are priced items, we may be able to give some of those or you may be able to access it partly on the web or otherwise.

We will learn a lot from the web, particularly about instruments about data acquisition systems various softwares; and there is also lot of material related to that in ideas of measurement and instrumentation on the web. So, you will need lot of web access and you have to keep going and say well let us look at this instrument, let us look at that data acquisition card, let us look at that particular calibration system, or look at what this manufacturer has or what that researcher did.

So, this is an important part of this course and so, you will have to do a lot of web based work there. I can also mention here, that some of the assignments and some of the explanations, they themselves will be videos. So, I will have the you will see a video and then there are many questions, where you have to look at the video and answer those questions.

The other thing also is that besides the video, you will have to look up your own experiment that you have done, and make your own video and share it. So, we will bring these aspects also into the course.

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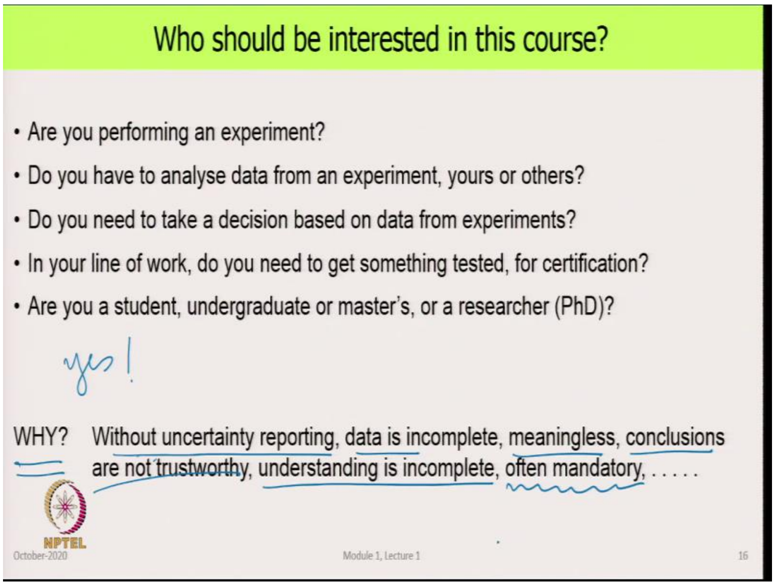

Now, who should be interested in this course? So, here are some questions that you can ask yourself, are you performing an experiment? Do you have to analyze data from an experiment which you have done yourself or somebody else has done?

Do you need to take a decision based on data from experiments or if you are a practicing engineer, or a scientist, or a researcher in your line of work, do you need to get something tested maybe for certification? Or are you a student UG, PG, PhD whatever? If the answer to any of these questions is yes then, you must take this course without that your work will never be complete.

If you are already familiar with this work about uncertainty analysis, this could be a refresher course, you can add to it or maybe give input so, we can pick up and then help you take a level II course. So, you got to take your advice to take this course the question is when why should I take this course? It is not part of a curriculum it is generally not part of any subject.

But, as I have said already without uncertainty reporting anything that you do with measurements, data interpretation, drawing conclusions from experimental data; all of it is meaningless the conclusions are not trustworthy, understanding of the subject is incomplete.

And you will be missing a very important thing that in life in practical situations in many instances reporting uncertainty is mandatory. So, you will be missing out on a very important aspect of life particularly that deals with measurements and experiments.

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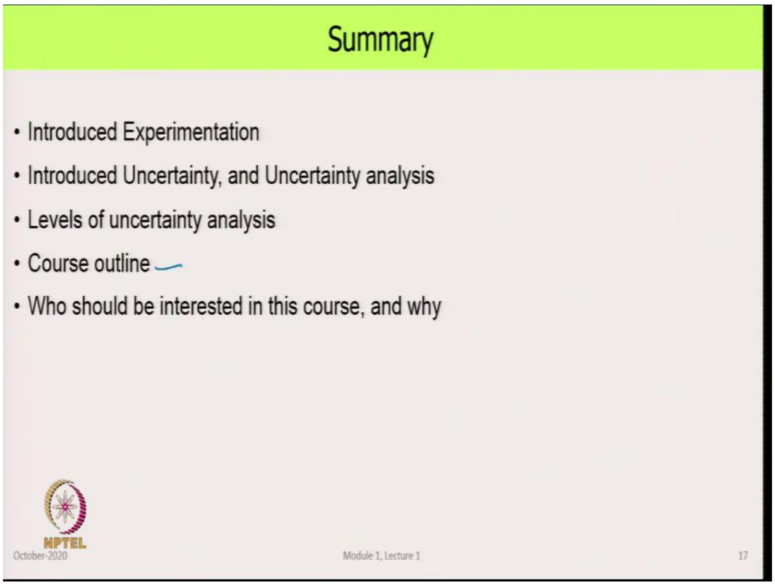

So, that brings us to the end of this module, where I have introduced a very briefly introduced experimentation; what is uncertainty, what is the uncertainty analysis, what are the levels of uncertainty analysis as I have organized them. Then I have given you a brief outline of the course and finally, we said why or how you should take a course and what benefits it will give you. So, with that we conclude module 1, lecture 1.

Thank you.