Introduction to Uncertainty Analysis and Experimentation
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Module - 08
Reporting and Archiving
Lecture - 29
Course overview

Welcome to the course Introduction to Uncertainty Analysis and Experimentation. We are at the end of module 8 Reporting and Archiving. And in this course we will take an overview of what we have gone through in this entire course.

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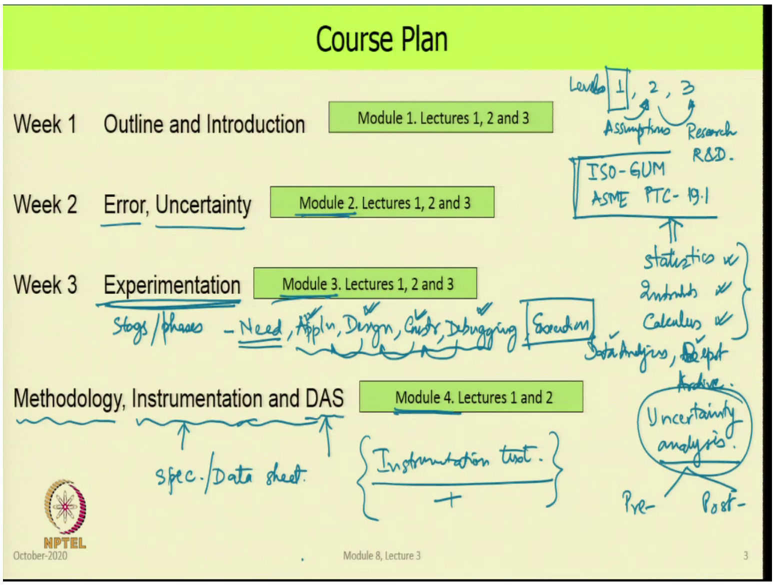

As the title is this is an introductory course to uncertainty analysis. As a first level course and it builds some basic ideas from which we can do first level of uncertainty analysis. So, here is what we have gone through: in week 1 which was module 1, lectures 1, 2 and 3. We looked at the outline of the course and we introduced what are the various terms in measurement and uncertainty science.

We also classified 3 levels of uncertainty analysis levels 1, 2 and 3 and we said first we must learn what is there in level 1 which are the basics and then here we make lot of simplifications and assumptions. So, we are learning about the limited type of experiments and at least that is essential when we begin work.

Once we have learnt that we can learn some more advanced techniques and go to level 2 and I have learned that we can go to even more advanced techniques which is level 3 which brings us to the level of research R and D. We also saw why these are important. One of the biggest reasons being that across the world whether it is academia, whether it is industry, whether it is standardization, whether it is certification everywhere. We now have international standards which is ISO-GUM or ASME PTC 19 dash 1.

So, we have no option, but to learn what is it there that is recommended here and this is based on sound principles of statistics. So, we needed background some basic information about statistics. Since we are making a measurement we need information about instruments and then various techniques for which we have used calculus.

So, those were our prerequisites for taking up this course. After this module we went into a detailed discussion on what is error, what is uncertainty and what are the implications of these and here we defined a series of terms related to the broad category of uncertainty. All this was given in module 2. So, having defined what is uncertainty? what is error, what is uncertainty limits and why it should be there, we then moved on to say that.

Let us look at the big picture of doing experimental work which we called experimentation. And on this we had 3 lectures where we defined various stages of experimentation which is somewhat like a design process starting with the need then and the application, design, then construction, then debugging, then execution, data analysis and finally reporting and archiving.

So, these we said are the different stages of experimentation or phases. And in between these there are some times when we go back and forth to iterate depending on the difficulties that we face.

The important thing here was that what we classically know as go and take data and write a report that is execution with some data analysis and some report writing. This is only a very small part of the larger process by which one does experiments. And often it is these points where you have to put in lot of effort in designing something.

So, that you get the data that you are looking for from which you can draw conclusions that you are looking for which is your need. Then we also saw how at different stages uncertainty analysis comes in. So, it is not that we just do an experiment and after that we said then the result this much was the uncertainty. What we are saying is, we use the techniques of uncertainty analysis in designing the setup in debugging and in some extent construction and even developing concept designs.

So, we said this is important and that is why we went into experimentation that this is applicable in two broad ways which we finally decide pre test uncertainty analysis and post test uncertainty analysis. Then we went into something else and there was a need for it because in an experiment all the data that we get which is the measurement comes from an instrument or a sensor or some electronics associated with it.

So, we said well what is the broad methodology by which we do uncertainty analysis, where does instruments come into that and data acquisition system. So, we went into some aspects of the instruments in particular we said we need to be able to read the specification or the data sheet and then we said that we would be needing this later on in our analysis.

So, one of the ingredient that goes into doing experimental work is to be fully familiar with the instrument and data acquisition system. This we covered in module 4 in the two lectures that we had there. Now, this is not a course on instrumentation and control. So, we gave a very brief overview of this aspect for more details we can look up any test on instrumentation.

And plus of course, there are lot of other data including manufactures data handbooks and standards. So, this we did not go into the detail of it, but we said this is where you would get the data.

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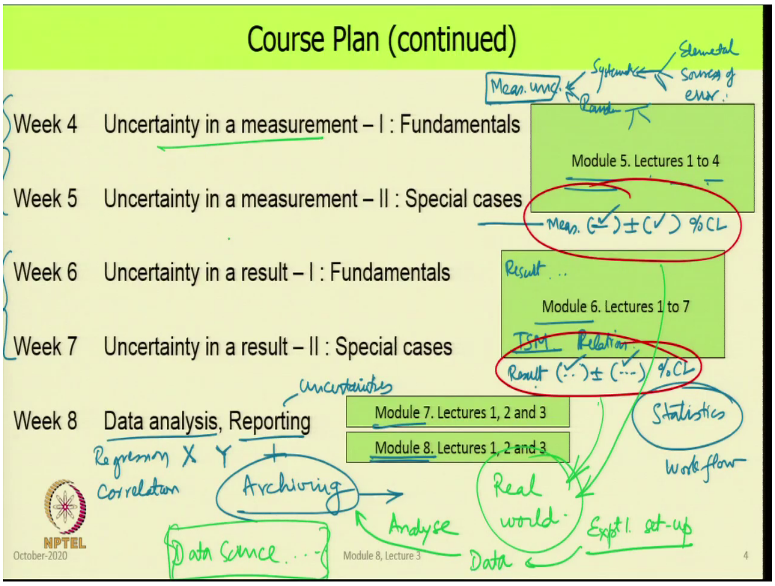

We then moved on to a series of lectures in module 5 on uncertainty in a result, a uncertainty in a measurement. So, in the course this is weeks 4 and 5 and some of these are applicable for the first part lecture the first week 4 and some for week 5.

Here we looked at every aspect of a measurement. This defined various types of uncertainties further broken them down as elemental uncertainties and said how can we evaluate each one of them. So, we said that a measurement uncertainty has systematic and random components.

And each one of these has its own elemental sources of error which in turn contribute to uncertainty. In the each one of them has its own contribution to uncertainty which adds up to this and these two add up to the measurement uncertainty. So, we saw what is the process here, we required now knowledge of statistics.

And using that we develop this process and we also develop the work flow. So, the workflow and the worksheets give us a compact way to do the work for each and every measurement. So, as many measurements are there in an experiment that many of these analysis has to be done.

So, at the end of this, we have measured value what we called a nominal value plus minus certain uncertainty at a certain confidence level. So, these are things we got. So, that was all the data that we wanted from the experiment. The next stage is the calculation part which is uncertainty of the result which is week 6 and 7 and here we had series of 7 lectures in module 6. Where we looked at the Taylor series method for calculating result uncertainty we defined what is the result.

And then we develop using statistics and calculus we develop the full Taylor series method and various relations and formulas. That given the uncertainty in the measurement how can we calculate uncertainty in the result we got that relation. So, at this point what we got is that for every result that we want we have a mean value plus minus some uncertainty at some confidence level.

So, that is what we set out to do is we wanted measurement uncertainty and result uncertainty. This is all the information with which we now move on to do further analysis and draw conclusions. So, that is what we saw in the data analysis part where we learnt about regressions and correlation.

This was in a series of lectures in module 7. And we said that regression is a relation between an independent variable X and a dependent variable Y where either X and Y could be any of these measurements from the experiment or any of the result from the experiment. So, X could be any of them, Y could be any of them except the one that is chosen for X.

Finally, we had a couple of lectures on reporting and archiving. That means, what are some of the issues to take care of while reporting in uncertainties. We did not go into the details of report writing that is not the scope of this course. There are many good ways resources available online offline which encourage you to read as to how to put together a good report.

And then we have looked at the issue of archiving which led us to a new thing which is that an experiment generated data like we saw here. Then we also got that this similar data especially measurements in the real world from factories, from equipment, from machinery all types of things. So, we can treat all those things as an experimental setup, they all generate data from of course, measurements and sensors which we can archive and analyse.

And this gives take to course into a completely new domain which is now called data science, data analytics and what not. So, some of the things that we have learnt are relevant to this big picture. We of course, have not gone into the details of this, but now we are aware that when we can get data from measurements we can potentially end up soon in the realm of data science.

So, this completed our course and in this we learnt the very basics of uncertainty in a measurement and uncertainty in the result.

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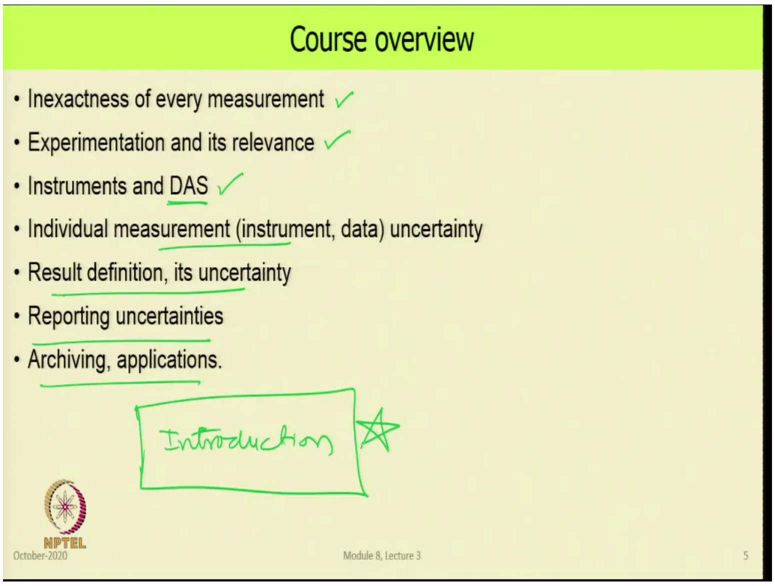

So, what here is what everything that we had. These important things that we saw were that there is in exactness in every measurement which gives rise to uncertainty. We looked at experimentation and its relevance; instruments and data acquisition system and we went a little bit into the electronic aspects of this and saw how it affects our uncertainty calculations.

Then we looked at individual instrument uncertainty, result definition and its uncertainty, reporting of uncertainties, finally archiving. So, this is what we learnt in this course this is what we said is an introduction course. At various stages during the course I said that this is a full form, but this is complex. So we will remove this and we will study only the basics which is the nature of an introductory course.

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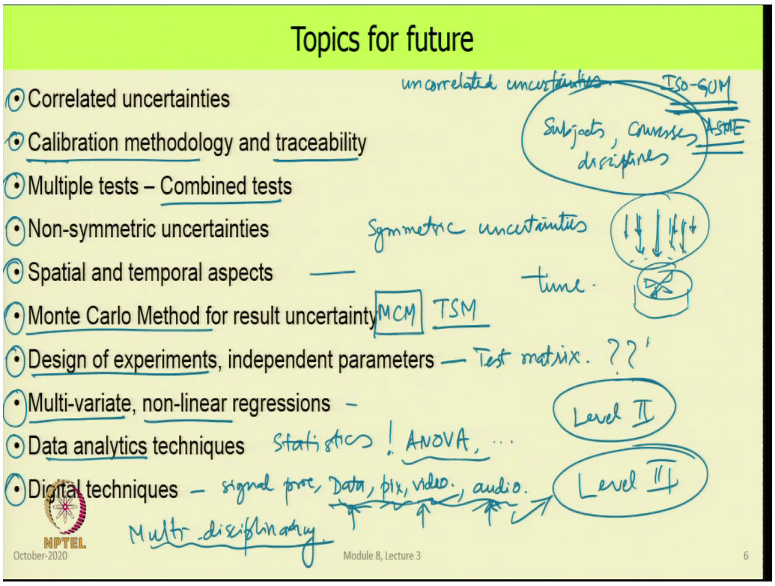

But this becomes the foundation for learning topics in the future. And here are listed some of the topics. What we left out was correlated uncertainties. We said all throughout that we are looking at uncorrelated uncertainties. Correlated uncertainties will arise when one uncertainty source contributes to uncertainty in measurement number 1 and also contributes to uncertainty in measurement number 2 for example, if it coming from the same calibration device.

So, we did not look at that there are many more additional mathematical terms that come into the equation and there are various techniques by which we handle correlated uncertainties. We did not look at the details of calibration methodology and we did not see what is traceability and how do we account for that. But we said that there is we have realized there is something calibration and calibration produces certain uncertainty which we factor into our analysis.

So, there are things we did not learn. We looked at multiple tests repeated tests, but we did not look at the multiple tests combined tests. So, this is a situation where there are changes to the setup or at different setups may be using the same instruments then we get data and then we want to compare it. The technique for that we have not studied. We studied the same case where you have a setup everything is the same and the test is done again and again that is repeated tests.

Then we looked at we have not looked at non symmetric uncertainties everywhere we kept on saying that we look at only symmetric uncertainties. In many measurements there are special and temporal aspects and maybe even aspects of the engineering.

This we have not gone into detail and an example of this is that if you are using a vein anemometer, which has got blades sort of a fan when air goes through this it rotates and you count and correlate that with the mean flow through this.

So, this works fine if the velocity coming all over the anemometer everywhere is the same. So, if it is uniform over the face we are this is a good instrument, but what if this velocity were larger, then this is smaller, this is even smaller, this is much smaller. Then what does the reading of the instrument mean? This is a issue of special uncertainty.

Temporal uncertainty means that issues with time. And this would happen in say temperature measurement when something is heating or cooling, but your instrument or your sensor is not able to track it that fast, then what happens? We looked at it very quickly, but there is lot more to learn about these aspects. We learnt about Taylor series method of uncertainty propagation and that too for a very simple case for uncorrelated uncertainties.

The other technique which is equal is powerful is the Monte Carlo method MCM. We have not studied this at all that is another topic for an advanced course. Then there are many issues led to design of experiments we came across this during the design and the development of the test plan, test matrix at that stage. We only made a mention that there are mathematical techniques by which instead of making running the experiment at say a series of 10 parameters values of the parameter, we could do it at 5 and learn the same thing.

So, what is the science behind it? Some of that came out in our later discussions, but that is only very cursory and not design of experiments as the field by itself gives you lot more insights into how you can do just the right number of experiments not too less not too much and yet learn everything that you wanted to learn.

Then we looked at regression where we looked at just 1 independent variable in a linear regression, but many applications we need more there are multiple variables 2, 3, 4 and some of the functions could be non-linear.

So, this is something we have not looked at. Then we looked at various data analytics techniques. We seen some data analytics techniques, but not many of the new analytical techniques that are there for data analysis and many techniques where you need various levels of knowledge of statistics. So, for example, ANOVA analysis of variance and all we have not looked at that.

And then there are various sophisticated techniques like digital techniques, where you may look at signal processing and this could be related to data or data sequence or pictures or video. There are many engineering applications where we now learn about the phenomena by looking at this and in some cases audio also.

So, there is much to learn about all of these. So, we have left all of this for higher level courses. Some of this can be taken up what we will call as a level II course which is an intermediate course.

And then more advanced topics which in go to level III and here you have to start getting more and more interdisciplinary in your approach because all of this will require understanding of digital signal processing and various techniques used in computer science and electrical engineering.

Here you will have to learn lot more about statistics and as we see as we go on further, we are becoming more and more multidisciplinary. And not just that what we have learnt in this course is not related to this particular subject or that particular discipline. The techniques that you have we have learnt as we have seen here are applicable to everything.

So, this is a course that is encompassing a whole bunch of subjects, courses, disciplines and further our approach is strengthened by the fact that the ISO-GUM which is the guiding standard for everything in science and engineering is and was produced by all these professionals, organizations getting together along with ASME and various other professional bodies.

So, we are looking at a technique the methods that have been broadly covered by all these disciplines and. So, they are universally applicable. This makes this knowledge essential for any experimental work. So, on that note we conclude this course.

Thank you.