INTRODUCTION TO UNCERTAINTY ANALYSIS AND EXPERIMENTATION

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PRE-REQUISITES : This course is aimed at 3rd/4th year undergraduates, masters, and PhD students, and at professionals with at least a bachelors degree in engineering or science.

INTENDED AUDIENCE : UG, PG and PhD level engineering students; Engineering faculty; Professionals in industry and R & D laboratories

INDUSTRIES APPLICABLE TO : Topics in this course are relevant to many industries, especially MSMEs as it will enhance quality and adherence to standards.

COURSE OUTLINE :

I will address fundamental topics on uncertainty analysis and their applications and give an overview of experimentation. Practicing engineers, researchers, and engineering students at UG, PG and PhD, from many disciplines will benefit from this course. The topics include experimentation process, errors in measurement, uncertainty in a measurement and in the result, uncertainty propagations, pre- and post- test uncertainty analysis, uncertainty analysis for design of set-up, and regression and correlation. The methodology will follow ASME Performance Test Code, and ISO Guide to the expression of Uncertainty in Measurement. I will discuss a variety of practical applications and use of national and international standards related to engineering and research and their relevance in education.

ABOUT INSTRUCTOR :

Prof. Sunil R. Kale has been with the Department of Mechanical Engineering since 1989. He has developed and taught UG courses (thermodynamics, energy conversion, heat and mass transfer, power plant technologies, engineering drawing, and mechanical core laboratory), and PG courses (experimental methods for thermal engineering, multiphase flows). His research, academic and industry-related, is in the fields of heat transfer, fluid mechanics, fire dynamics, combustion, and energy conversion.

COURSE PLAN :

Week 1: INTRODUCTION
- Outline of the course; Course objectives; Learning outcomes; Course plan
- Expressing a result as a mean (nominal) value and its uncertainty at a specified confidence level
- Importance of uncertainty analysis in research, industry, legal metrology, education
- Developments in uncertainty analysis, ASME PTC 19.1 and ISO JCGM-100 GUM
- The approach to uncertainty analysis

Week 2: ERROR, UNCERTAINTY
- The result relation, measured parameters
- Error distribution, statistical basis, standard uncertainty, definition of uncertainty and its variants
- Classification of errors as per ASME PTC 19.1 and ISO GUM; Correlated/Uncorrelated errors

Week 3: EXPERIMENTATION
- Processes from need for data (for decision making) to obtaining the data
- Options for conducting an experiment
- Stages / Phases of experimentation, test execution, pre-test and post-test activities
- Relevance of uncertainty analysis in the experimentation processes

Week 4: UNCERTIANTY IN A MEASURMENT – I (FUNDAMENTALS)
- Measured parameters (measurands) and raw data. Calculated parameters (result)
- Sources of errors in a measurement – elemental sources of error; classification as random/ systematic or Type A/Type B
- Calculating/estimating elemental sources of errors in a measurement
- Calculating combined standard uncertainty and expanded uncertainty in a measurement

Week 5: UNCERTIANTY IN A MEASURMENT – II (SPECIAL CASES)
- Systematic uncertainty in a measurement: Instrument specification, Data from handbook,Tolerance limits, Absolute limits, Asymmetric bounds
- Systematic uncertainty in a measurement: Physical basis of phenomenon, e.g. zero error,calibration, time lag, spatial lag, radiation effects in temperature measurement, long-term effects (stresses in strain gauges, etc.)
- Errors in electronics and digitization – Amplification, filtering, analog-to-digital conversion

Week 6: UNCERTIANTY IN A RESULT – I (FUNDAMENTALS)

- The result formula, Taylor Series Method (TSM). Expansion of results formula. 1st order with un-correlated errors. Sum of squares relation
- Sensitivity coefficient. Relative uncertainty coefficient. Uncertainty Multiplication Factors(UMF).
- Uncertainty in the result. Contribution from different measurements, dominant uncertainty. Uncertainty Percentage Contribution (UPC)

Week 7: UNCERTIANTY IN A RESULT – II (SPECIAL CASES)

- Techniques for evaluating sensitivity coefficient, Single variate property, double variate property
- Contribution by measurement uncertainties to result uncertainty, Pareto chart
- Application to pre-test uncertainty analysis

Week 8: DATA ANALYSIS AND REPORTING

- Round-off in reporting mean (nominal) values and uncertainty
- Round-off in reporting mean (nominal) values and uncertainty in measurements and in result
- Data comparison. Introduction to correlations – techniques, goodness
- Depicting uncertainty on plots, e.g. uncertainty bands/bars. Whisker plots
- Course summary. Recommendations for further study