EME 109

Course Description

This course involves experiments to illustrate principles of thermal-fluid systems. Lectures will cover certain aspects of the experiments as well as statistical and uncertainty analysis of data, statistical design of experiments, and measurement devices. Experiments may involve thermodynamic cycles, combustion, compressible flows, and incompressible flows. There will be five guided experiments as well as a project.

Experiment Schedule

Reading

Required textbook: R. S. Figliola and D. E. Beasley, *Theory and Design for Mechanical Measurements*, 7th ed., Wiley, 2019.

Background information for the experiments can generally be found in typical undergraduate thermodynamics and fluid mechanics textbooks (e.g., see your ENG 103, ENG 105, and EME 106 textbooks).

Software

We will use the (free) software package R, which is widely used for statistics and data analysis. R is compatible with Windows, Macs, and Linux machines.

Course Learning Outcomes

(1) Students will be able to formulate and solve problems related to:
  (a) principles of measurement theory, data analysis, and bases for statistical comparisons.
  (b) principles of data collection with regard to fluid dynamics and thermodynamics through a series of laboratory experiments.

(2) Students will understand:
  (a) technical report writing.
  (b) the documentation required in data collection and analysis.

Topics

- Laboratory practices, safety, and documentation.
- The R software package.
- How to report data.
  - Middle value and uncertainty.
  - Number of digits.
- Experimental error classification.

        - Random.
        - Systematic.
        - Blunder.
    - Statistical analysis of data.
        - Common statistics.
            - Mean.
            - Median.
            - Standard deviation.
            - Variance.
            - Covariance and correlation.
        - Visualization of data.
            - Boxplots.
            - Histograms.
            - Density plots.
            - Scatter and line plots.
        - Parametric models for experimental data.
            - Probability density functions.
                - Normal.
                - Student's t.
                - Chi-square.
                - Uniform.
                - Triangular.
        - Statistical evaluation.
            - Goodness-of-fit test.
            - t Test.
            - Outlier detection.
                - Chauvenet's criterion.
                - Modified Thompson ι– test.
        - Statistical techniques for extracting trends.
            - Curve fits.
                - p Values.
    - Design of experiments (DOE).
        - Factorial experiments.
- Artificial neural networks.
- Uncertainty analysis of data.
    - Definition of uncertainty.
    - Uncertainty interval.
        - Coverage factor.
        - Bayesian approach.
        - Monte Carlo approach.
    - Comparison of data.
- Propagation of uncertainty.
    - Correlated and uncorrelated errors.
    - Taylor series approach.
        - Coverage factor.
    - Monte Carlo approach.
    - Curve fit uncertainty bands.

        - Comparison of curve fits and data
- Measurement of physical quantities.
    - Fluid flow.
    - Pressure.
    - Temperature.
- Measurement systems.
    - Types of transducers.
        - Mechanical.
        - Electrical.
        - Optical.
    - Application to thermal-fluid systems.
    - Discussion of aerospace sensors and instrumentation.
- Laboratory preparation:
    - Experimental methods and analysis documentation
- Laboratory experiments:
    - Guided experiments.
    - Project.