UNIVERSITY OF NAIROBI

DEPARTMENT OF ENVIRONMENTAL AND BIOSYSTEMS ENGINEERING

FEB 610: Similitude Theory and Applications

Instructor: Eng. Dr. A .N. Gitau,
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Office Hrs: Immediately before each class.

Students are encouraged to make use of office hours

Course objectives

1. To be able to identify correctly and to list complete, non-redundant set of governing quantities that characterize physical system.
2. To become able to generate valid set of dimensionless parameters that adequately characterizes physical system.
3. To become able to plan and organize experiment to define the response of physical systems to forcing effect through application of dimensional concepts and similitude theory.
4. To become able to use effectively similitude concepts for:

    a. Designing and operating models
    b. Testing physical equations
    c. Developing complete prediction equations.

Course Outline: 2012 / 2013

1. -Introduction to similitude: Theory and applications to engineering experimental research and development.
   - Dimensional Concepts, definitions, units, Newton's 2nd law**.**
2. -Homogeneity and heterogeneity in equations

-Universal governing equations,
-Dimensional similarity and analysis.

3. -Buckingham Pi- theorem. (BPT).
-Huntley's addition (extension) to BPT

4. Identification of pertinent quantities**.**

CAT 1.

5. Experimental design to define a governing equation

6. Project preliminary proposal discussion**.**

7. Model theory and design**.**

8. Applications, Heat transfer, mass transfer, fluid mechanics, soil mechanics, structures and solid mechanics etc.

9. Homework on experimental project.

CAT 2.

10. Project reports.

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GRADING

Problem sets (Assign.)	5%
2- 1 hr. 30 min. CATs	15%
Report	10%
Final Examination	70%
Total	**100%**

PROBLEM SETS (Assign.)

1. Problem sets are due first class meeting following the week when the problem set was handed out.
2. All problem sets will be recorded if handed in on time and completed.
3. Selected problem sets will be graded based on: correct approach, correct results, organization, and presentation.

CATs and EXAMS

Test and exam questions will be graded on: correct approach, correct results, and organization. Test and exam may be either closed or open book, depending on circumstances.

REPORT

A term report based on an experimental project will be required. The subject will be chosen in consultation with the instructor. The purpose of the project will be to develop and conduct experimental research on some problem relevant to engineering and using similitude principles. Usually, the final objective is to obtain an equation that predicts performance of the system.

The content of the report will include:

1. Title

2. Introduction-Explain why the subject is significant and how it is related to engineering research, design, or development.
3. Objective – state clearly and succinctly what is the objective of the research.
4. Description of the physical system –Characterize and describe the physical system. Cite recent literature. Include appropriate sketches to describe the system. Identify clearly the pertinent quantities on the sketch (es).
5. List of pertinent quantities, to include: Serial number, symbol, brief descriptive name, units, dimensions.
6. List of pi-terms, to include: serial number, symbol, definition and brief descriptive statement of nature or meaning of pi-term.
7. Governing equation for the system. This may be general or defined as specifically as possible. Include any known theory or previous experimental work that could help to define the nature of the governing equation.
8. Experiment design.
9. Description of experimental apparatus and procedures.
10. Data analysis and results.
11. Discussions.
12. Conclusion, e.g., prediction equation, other conclusions.

Reference:

1: Murphy, G. Similitude in Engineering.
2: Godon, D. Similitude: Theory and Application
3: Any text on dimensional analysis
4: Any text on similitude theory and www.internet

DEFINITIONS:

Physical system: An interacting set of physical quantities, finite in number that responds in a consistent, measurable and predictable manner to forcing or disturbing effect.

Examples are:

- ✓ Liquid in an open channel. Gravity, as the forcing function, causes the liquid to flow toward a lower elevation, such as the end (s) of the channel.
- ✓ A fluid in stationary contact with an object at a different temperature. The temperature difference as the forcing function between the object and the fluid causes heat to be transferred.
- ✓ A structural member in a machine or building. An applied load as the forcing function causes deformation and internal stresses and strains in the member.

Physical quantity: The physical attributes or pertinent quantities which must be measured in identifiable units in order to uniquely describe a physical system.

Dimension: The qualitative characteristic of a physical quantity which specifies or characterizes the kind of process used to measure a physical quantity.

Basic dimension: An independent dimension which, based on human Experience and human sensory perceptions, appeals to our sense of how to describe the quantities in a physical system. Commonly used dimensions include: Force (F), Mass (M), length (L), Time (T).

Unit: A standard of comparison for establishing the magnitude of physical quantity. Examples are: kilograms, meters, seconds of time, Newton of force.

Dimensional Homogeneity in Equations

1 Meaning of dimensional homogeneity:

Both sides of equality sign reducible to some dimensions

2 Validity of equations from standpoint to homogeneity:

a) Dimensional homogeneity required by Axiom 1
b) Dimensional homogeneity necessary but not sufficient.
c) Dimensional homogeneity fulfilled simply by introduction of dimensional constant.

3 Examples of valid, non-homogenous equations:

a) Newton's second law: f = m x a
b) Newton's law of universal Gravitation: $f = m_1 m_{2/} r^2$
c) Fick's law of diffusion: p = A dc/dx
d) Peltier or thermoelectric effect:
   H = Iθ(dE/dT) where H = rate of heating or cooling,
   I = current,θ = absolute temperature, dE/dt = rate of change of thermo. emf with temperature, t.
e) Foregoing equations can be made homogeneous by introduction of a dimensional constant.
f) Foregoing equations are empirically derived from observations of the physical world.

4 Key points:

a) All our basic equations in physics are dimensionally non-homogeneous.
b) We make them homogeneous by supplying dimensional coefficient, usually called a "coefficient," which may be named after some person.
c) More trivial correlations, e.g. a regression of mosquito population on rainfall, give rise to dimensional coefficients which can be hardly regarded as basic.
d) In engineering research and development, we should strive to preserve dimensional homogeneity without resorting to trivial dimensional coefficients in our prediction equations.