Introduction to Engineering—Analysis and Design

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Engineering applies mathematics and science to develop innovative solutions to meet the needs of the world. The motivation for this new course is to provide students with the challenges of experiencing engineering, as it is actually practiced, before completing their college selection process.

The course is presented on two teaching fronts. The heart of the course are projects that build on their scientific knowledge from earlier physics and chemistry courses and apply it to physical projects which they design, construct, test. and document. Concurrently, engineering concepts, which are used in these projects are taught.

- **Project Example**: A 2 L soda bottle can be filled with water and pressurized with air. The rocket launches into flight when the pressure is released. In a multi-step project, the students begin with (i) Newton's Laws, (ii) apply them to a rocket's flight characteristics, (iii) use a NASA rocket simulator to optimize a design, (iv) construct the bottle rocket to these specifications, noting required compromises, (v) launch the it, (vi) analyze the results and (vii) document the project. There is some rigor in this engineering design cycle, but the students are always excited to see their design go higher than the school building and compare their results with the other groups. There are similar projects involving calorimetry and bridge design.
- **Concurrent topics** include concept mapping, problem solving methods (including heuristics, Fermi problems, engineering design cycle, brainstorming), group interactions, risk management, converting data into information, strategy of experimentation, Bayes probability, ethics, and an overview of engineering disciplines.

Features and Future Directions

Engineering Projects and Problem Solving Resources

A 150 page resource book was assembled for this year. There was no fully appropriate text book for this course that justified the expense.

Direction: This document is being revised with the following objectives:

- Free Resources: The book will be posted on the web so that it is **available without charge** for use by any interested teacher or school. There will be no copyright encumbered information to prevent this.
- Flexibility: It can be used in a stand-alone course or unit. However, a physics or chemistry teacher could select the appropriate project and supporting material for incorporation as a unit in a traditional course.
- Affordable: The projects themselves are straightforward and inexpensive. Supplies and the start-up requirements can be minimal. The value is in taking relatively straightforward experiments and applying a rigorous methodology and analysis.
- Organization Support for Physical Science teachers. These resources provide guidance to any physical science educator to present the engineering principles. These units can be effectively taught by physical scientists without and engineering background

Outreach

- The content has been offered to other schools on a collaborative basis. Topics can be modified by each individual, according to needs and interests. However, a training session can be planned to really bring non-engineers into the philosophy. It was the experience this year of going over the one page sheet (attached) with a training teacher gave him the confidence to "know how to proceed" with such a course

Philosophy and Outcomes

Both the structure of the projects and the selection of the concurrent topics are a reflection of over 30 years of industrial and college teaching experience. Consequently, there are some topics that are not normally included (i.e. risk management, Bayesian probability). Such topics have value both for engineers as well as application to other areas of the students' activities.

The approach here is "doing as thinking", which allows the student to actually experience the excitement of their own work on an engineering project. A traditional approach is to continue to teach fundamentals with the carrot that rewarding activities will follow in the future.

Beyond the ability to experience, master, and use each of the principles above, the emphasis is to develop the ability to analyze complex problems in a logical manner, formulate quantitative solutions, demonstrate, and communicate them effectively. A very successful outcome is for the students to be able to apply these principles to more effectively resolve future problems and situations, in whatever context they appear.

Experiencing Engineering
Introduction to Design and Analysis (Rev 0; P. Schubert 2/13/2013)

The objective of this one semester course is to give students personal experience of engineering theory and practice. More generally, the goal is to generalize the principles and experience so that the problem solving approaches learned here can be applied to a range of living situations.

The core of the course is three projects that require use of the engineering design cycle. This cycle includes systematic analysis of the problem, application of previously learned scientific principles, design using simulators, construction, testing, analysis, and documentation. Concurrently, a number of supporting topics are introduced, including risk management, strategy of experimentation, and Bayesian probability, which are not normally covered at this level.

The course is designed so it maximizes readily available materials. A shop is not required and the cost of supplies and equipment is minimal. The student source-book will be available without charge.

Problem Solving

- Quantitative Problem Solving Methods
- Problem Solving Framework
- Problem Solving Cycle-Polya
- Heuristics
- Effective Group Dynamics
- Resourcefulness Skills
- Brainstorming
- Engineering Design Cycle
- Strategy for Difficult Exams

Data into Information

- Basis of Cognitive Learning
- Concept Maps
- Gantt Charts
- Principles of Graphical Analysis
- Data Analysis
- Strategy of Experimentation
- Engineering Models/Simulations
- Risk Assessment
- Bayes Probability

Projects:

Heating Project:

Demonstrate a system that raises the temperature of 100 mL of water by 10ºC in 10 minutes.

Water Rocket:

Demonstrate a water rocket constructed from a 2L soda bottle meets performance based on design determined using NASA simulator.

Truss Bridges:

Build the most efficient bridge (strength to weight ratio) from 100 craft sticks, with guidance from the JHU truss simulator.

- General Problem Statement/Analysis
- Scientific Theory Review and Application
- Initial Design (Simulators for Rocket and Bridges)
- Construction/Compromises
- Reconciliation with Design
- Initial Test
- Analysis, Revisions, Modifications
- Final Test
- Project Report

Articles and Writing Assignments

- Thinking as Doing
- Strategy of Experimentation
- Engineering
- Engineering Challenges
- Risk Management
- Ethics/Citicorp Case Stu