

# An Integrated Course on the Experimental Method in Engineering

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## Abstract

In 1996, the Mechanical Engineering Department of l'Université de Sherbrooke introduced a new and progressive curriculum. A course entitled "Experimental Method in Engineering" was developed to teach to the students how to solve technical problems using an experimental approach. The course was offered for the first time in the fall of 1997 to a class of 120 sophomores. The purpose of the course is threefold. First, it covers the basic knowledge associated to experimentation. Second, several laboratories are used to enhance the understanding of the courses content and to develop the students skills. Finally, the course is closely linked to a major semester experimental project. This paper presents a short description of the course content and how the course was designed. It also demonstrates that the course is an excellent "integrator" that allows the students to link the knowledge covered in various courses.

## I. Introduction

A new mechanical engineering curriculum was introduced in 1996. This innovative curriculum is based on the development of the students skills. The students are guided not only to acquire knowledge but also competences and skills. One key word that inspired the development of the new program is integration : vertical integration to link the knowledge from one semester to another ; horizontal integration to link the courses within a semester.

In order to favor the integration especially in regards of the mathematics concepts, the freshmen year is merged ("integrated") into the new curriculum. All the students must follow the same courses in the same class. A progression "a la carte" is no longer possible. The mathematical and computer science knowledge are deployed in the program only if they are pertinent and used by the other basic engineering courses taught during the same semester. This is considered as a "just in time approach". The objective is to maximize the integration of mathematics and computer science knowledge since the students can sense that these topics are relevant and useful.

In the new curriculum, computer science, mathematics and experimentation are considered as three equivalent tools that the student must learn to use and master. After World War II, the development of experimentation skills has been considerably neglected in favor of a more theoretical background. This was one of the reasons why the best engineers became the best analysts, but not the best designers. In the new program, the experimentation is rehabilitated and is considered as a practical tool that can be used to solve problems.

## II. The “Semester Integration Project”

One very efficient way to favor the integration of knowledge is to use a so called “Semester Integration Project”. All the students are grouped in teams of four (30 teams). This major project lasts all semester. The project is designed and animated by all the professors teaching in the semester. Consequently, all courses must, to a certain degree, have an input in the project. An interesting side effect of this activity is that the Faculty is led to work together as a team. Indeed, the project is evaluated by the professors, and a global mark is obtained. This mark will count for 20 to 30 % in each course.

## III. The third semester courses content (sophomore)

Here are the courses that the students have to follow in the third semester. Remember that the 120 students are in the same class and that they attend the same course at the same time. Note as well that the Experimental Method is taught in this third semester.

- Experimental Method in Engineering (3 credits)
- Fluid Mechanics (3 credits)
- Mechanics of Materials (strength of material) (3 credits)
- Materials Properties (1 credit)
- Initiation to Research (1 credit)
- Mathematics for Engineer I (3 credits).

The content of the last course of the list, Mathematics for Engineer I, is divided in the three following parts :

- 0.5 credit in fluid mechanics
- 1 credit in the Experimental Method
- 1.5 credits in a math course (statistics)

This allows to adopt a just in time approach for teaching mathematics. Again, the general principle in the new curriculum is that new mathematics concepts are not taught if they are not used during the semester. The students can thus feel and appreciate the relevancy of the material covered, which is essential for a long term retention.

## IV. The Experimental Method in Engineering course

The major objective of this course is to teach the students how to use an experimental approach to solve engineering problems. The course provides basic knowledge and develops necessary skills to make the students competent in using the Experimental Method. Note that the objective of the course is not to demonstrate various experimental techniques.

The major topic covered in this course are :

- Metrology (description of Experimental Method, definitions, etc.)
- System analysis (input and output variables, sub-systems, linearity)
- Frequency analysis (time-frequency relations, transfer function, dynamic response of transducer)

- Electric circuits (Kirchhoff laws, AC circuits impedance, Norton-Thevenin sources, impedance matching, floating and grounded circuits, domestic electricity)
- Experimental data analysis (uncertainty analysis, curve fitting and graphic representation)

The mathematics concepts taught in conjunction with the Experimental Method courses are :

- Complex numbers
- Laplace transform

These topics are taught by the same professors who teach the Experimental Method courses.

There are four major labs in the Experimental Method in Engineering course. A pre-lab homework helps (“forces”) the students to prepare themselves for the lab. Experience has shown that this is quite important. For three out of the four labs, the students are teamed up (2 students per station) by the professor. The teams change for each laboratory. This approach has interesting benefits. For example, at the third semester, the students only know a limited number of classmates. This gives them an opportunity to know new classmates. Moreover, the students do not want to look silly in front of their colleagues ; they thus work harder to prepare the labs.

#### Lab # 1 : TIME–FREQUENCY RELATIONSHIP

Equipment : The computer science class is used. Two classrooms are available and are equipped with a total of 70 PC. This is the only lab which the students do individually. The three hour laboratory must be repeated twice.

Description : This lab uses a Matlab program to teach the link between time and frequency representation of a time varying signal. Both the time signal and its frequency representation are always displayed simultaneously. Fourier Series of typical periodic signals are available and can be displayed. The students can also construct their own signal by setting its frequency content. The students are asked to filter a signal by removing few frequency components. The useful information which was buried in a noisy signal is then recovered.

#### Lab # 2 : BASIC INSTRUMENTATION

Equipment : in a single classroom, 14 experimental stations are equipped with :

- a digital oscilloscope
- a multimeter
- a signal generator
- a strain gauge Wheatstone bridge power supply
- a desktop computer (PC). Each oscilloscope is connected to the PC. The scope can be used as an a/d data acquisition system.

The three hour laboratory must be repeated 5 times.

Description : The objective is to teach the students how to use basic instruments. The following topics are also covered : rms, peak to peak, clipping, DC and AC coupling, triggering of a signal.

### Lab # 3 : ELECTRIC CIRCUITS

Equipment : same as lab #2 plus :

- bread board with basic electric elements (resistor, coil, capacitor).

The three hour laboratory must be repeated 5 times.

Description : One of the objectives is to help the m.e. students to get rid of their complex about electricity and electric circuits. The following topics are covered : floating vs grounded instrument, impedance matching, filtering, phase measurement, frequency response function measurement, zero, first and second order transducer.

### Lab # 4 : STRAIN GAUGE MEASUREMENT AND DATA ANALYSIS

Equipment : same as lab # 2 plus :

- Cantilever beam equipped with 2 strain gauges (half bridge).
- Accelerometer and power supply
- Accelerometer calibrator

The three hour laboratory must be repeated 5 times.

Description : The strain gauge is the selected basic transducer. It is a relatively inexpensive transducer and it can be used in various applications. The following topics are covered : balancing a Wheatstone bridge, using the strain gauges data for the estimation of Young modulus, uncertainty analysis on the Young modulus, curve fitting, transient measurement, calibration procedure (accelerometer), measurement of impulse response, natural frequencies of a mechanical system, FRF measurement via the Fourier transform (FFT) of the impulse response.

## V. The Semester Integration Project

As described previously, the new curriculum has introduced the concept of a Semester Integration Project in order to favor the students integration of knowledge and competence. A brief description of the 1997 project is presented in this section.

The context : This context is explained to the students at the first course of the semester. The Faculty participates to the presentation.

A modified airplane propeller driven by an electric motor has to be adapted to be used in a large scale wood incinerator. The propeller will be installed in a tube with its tips machined down. The propeller mechanical characteristics must be determined in order to select the motor. To study this problem, an engineering firm decides to fabricate a scaled down test setup.

The project experimental environment : For the Semester Integration Project, three identical setups are available (see figure 1).

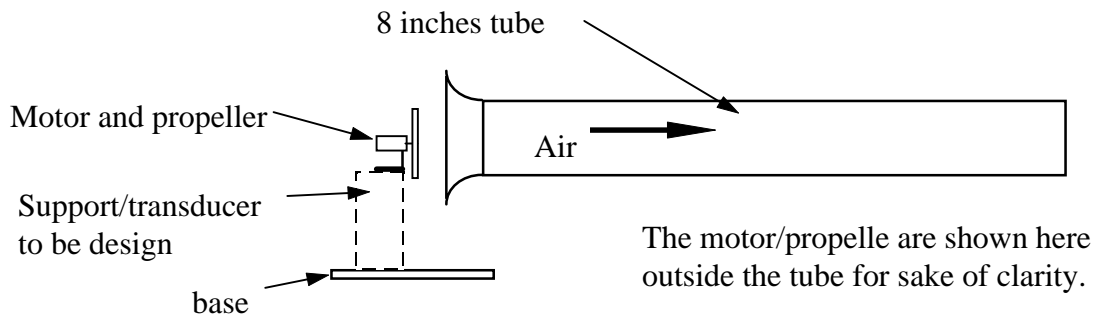


Figure 1 : Experimental test setup

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The main objective is: The students must design, fabricate and test a structure that will support the motor/propeller. The structure must be attached to the base and must be equipped with strain gauges to measure the torque and the thrust developed by the propeller.

The specific objectives for each team (of four students) are :

- Identify a concept that uses strain gauges to measure the thrust and the torque created by the propeller.
- Design (calculate and optimize) the support/transducer.
- Fabricate the support/transducer.
- Instrument it (install the strain gauges).
- Calibrate (static calibration) the support/transducer.
- Use the transducer to determine the thrust and the torque.
- Calculate the propeller full scale mechanical characteristics and determine the motor characteristics.

Figure 2 and 3 show pictures of typical finish product for the 1997 Semester Integration Project.

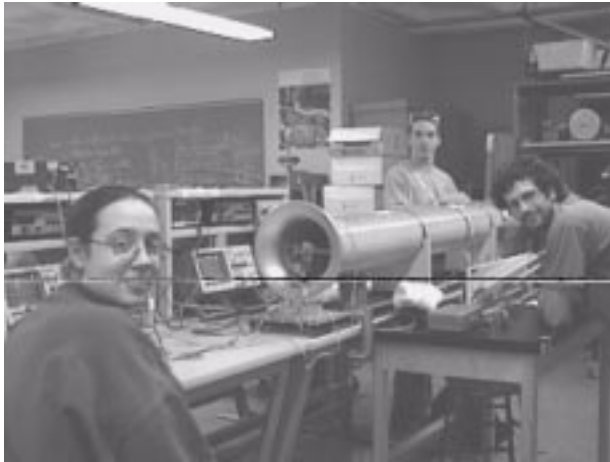


Figure 2 - Test setup



Figure 3 - Typical support/transducer prototype

## VI. The integration role of the experimentation

The Semester Integration Project is designed by all the professors involved in teaching during the semester. Consequently, one can see that the project can easily link and integrate the content of each course described previously.

In each course, specific laboratories prepare the students to the project. The skills developed in the laboratories are used in the project. The entire content of the Experimental Method course is used in the project. Interestingly, all the laboratories would have had existed independently of the project because they cover fundamental aspects of an experimental investigation.

Experimentation provides a very good way to integrate the knowledge. It also provides, with the Semester Integration Project, an excellent opportunity to improve the students design skills.

## VII. Conclusion

A course on the Experimental Method in Engineering has been introduced in a new M.E. curriculum. The course rehabilitates the role of experimentation to solve engineering problems. In order to integrate horizontally and vertically the knowledge and the skills covered in different courses, a Semester Integration Project is proposed to the students. Experimentation plays a leading part in the semester and in the project. The students response is very positive because they work hard and they gain confidence in their capability to do engineering work.