Session 2793

A Project Based Introduction to Mechanical Engineering

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I. Introduction

The Mechanical Engineering Department at the United States Naval Academy has developed and instituted a new introductory course that all mechanical engineering majors are required to take. The goals of the course are to introduce the midshipmen to the major areas of study in mechanical engineering, to enhance the visualization skills of the midshipmen, and to introduce the midshipmen to the design process. For all three goals hands-on projects are used as the vehicle to introduce the midshipmen to mechanical engineering. The desire is to enhance their understanding and enthusiasm for the major, and to give them a basis for appreciating the sequence of engineering science courses. The course is sixteen weeks long with one lecture period and one laboratory period each week for a total of 2 credits. The design portion of the class takes approximately five weeks, the visualization skills occupy roughly five weeks, and the mechanical engineering topics portion of the class takes five weeks.

This paper describes the format and content of the course, and provides a brief description of the projects used to address each goal. In addition, results from the first two offerings of the course are discussed.

II. Design

In the design segment of the course the students are introduced to the design process, program management, and report writing and presentations. The outline of the design process parallels that given by Norton[1] and contains the following steps:

1. Identify Need
2. Background Research
3. Goal Statement
4. Task Specification
5. Synthesis
6. Analysis
7. Selection
8. Detailed Design
9. Prototype and Testing
10. Production.

The class is lead through the synthesis portion of the process in class using the need to develop a method for anchoring swing sets as an illustration.

The program management material covers Work Breakdown Schedules, PERT Charts and Gantt Charts. The students complete the assignment shown below to help them better understand the concepts of the network diagram and critical path.

Project Management Homework

Construct the PERT Chart for the following table of activities and determine the Critical Path.

Activity	Duration	Predecessors
A	6	None
B	8	None
C	4	A, B
D	5	A, B
E	3	C
F	2	C, D
G	7	F

The culmination of the design portion of the class is a semester long design and build project, which pulls together the design material, the visualization material, and material from statics. A description of the project follows.

EM215 Design Project
Mousetrap Powered Car

Description:
The intent of this project is to pull together the information learned in this course and in Statics. Teams will design and build a mousetrap-powered car to meet given performance criteria subject to design constraints. It is expected that you will implement the design process, project management, sketching, 3D modeling, free-body diagrams, engineering reports and presentations as a pert of completing this project.

Performance:
Your vehicle should be designed for optimal performance in the following areas:

1. Speed - Starting from rest the vehicle will be timed over a 15 ft track.
2. Distance - Maximum linear distance down a hall.
3. Pulling Power - The vehicle will pull a 7 ft chain that has been flaked out 12 in wide.

To test the effectiveness of your final design, your vehicle will complete against all other vehicles in the class. The results of this competition will determine a portion of your grade for the project.

Design Constraints:

1. Power source: One issued mousetrap.
2. Size: The completed vehicle must fit into a 6 in X 6 in X 8 in box.
3. Mass: The completed vehicle must have a mass less than 250 grams.
4. Materials: Material cost must be less than $40.

Final Report:

Your report will include the following:

1. A detailed explanation of the operation of your vehicle and the main issues you addressed in arriving at your final design.
2. An orthographic view of the vehicle.
3. An exploded isometric view of the vehicle.
4. A 3D model of one non-trivial part of the vehicle using IDEAS
5. A calculation of the force applied at the road by the wheel and the torque on the final drive component.

Figures 1 through 3 show some pictures from the end of semester design competition.

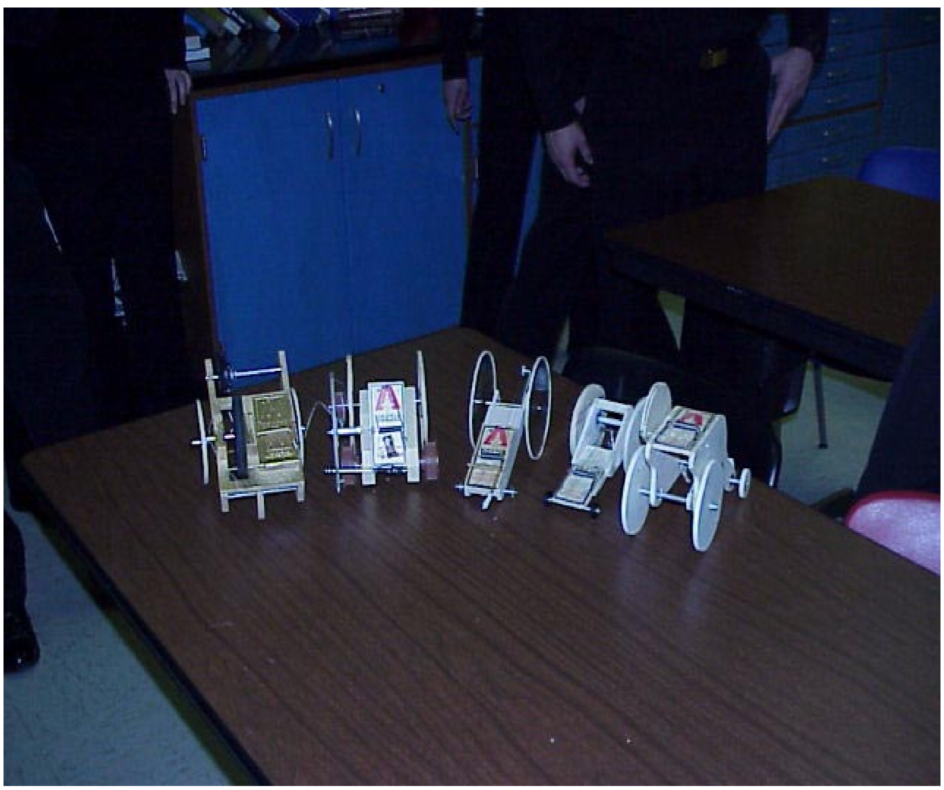
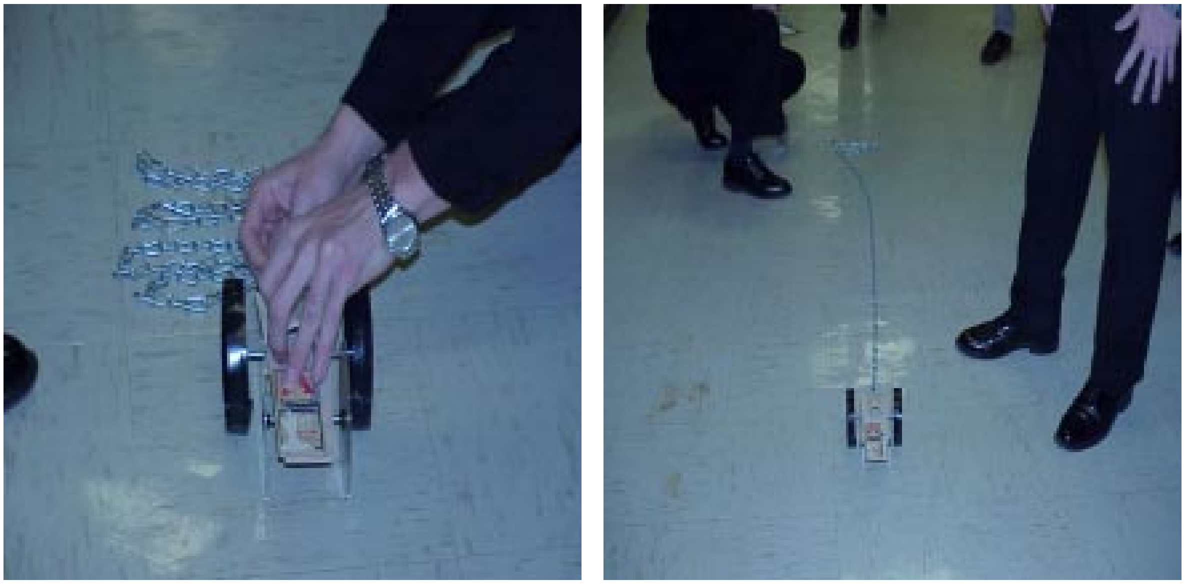


Figure 1 Some Typical Cars



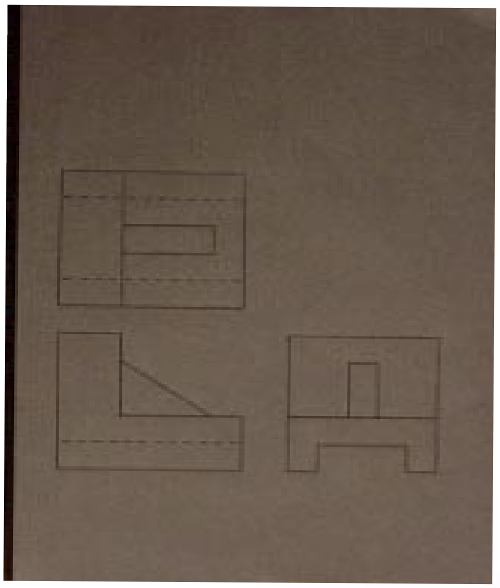
Start Finish

Figure 2 The Pull Event

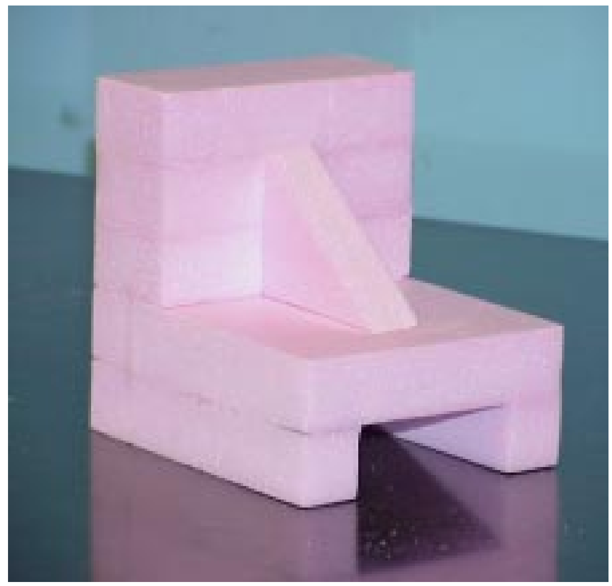
Figure 3 The Speed Event

III. Visualization

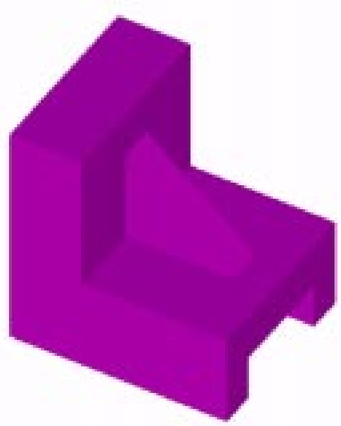
The topics covered in the visualization portion of the course include orthographic sketching, isometric sketching, sectioning and dimensioning, and 3D solid modeling. The text used for this portion of the course is by Duff and Ross[2]. For each lecture topic the students are given a sketching assignment that they complete in the lab. In addition to the sketching assignments, the students are given two small projects. The first requires them to take an orthographic sketch and construct the object shown out of foam. Then they create a solid model of the object using IDEAS. Figure 4 shows an example of this project. The other project reverses the process, having the students generate an orthographic sketch for an object they can hold and measure. Figure 5 illustrates this project.



Sketch



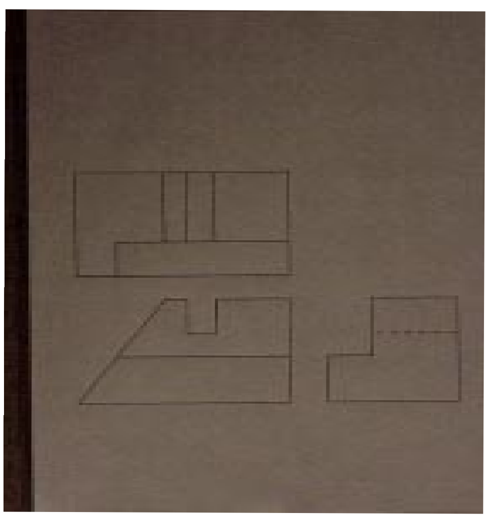
Foam Object



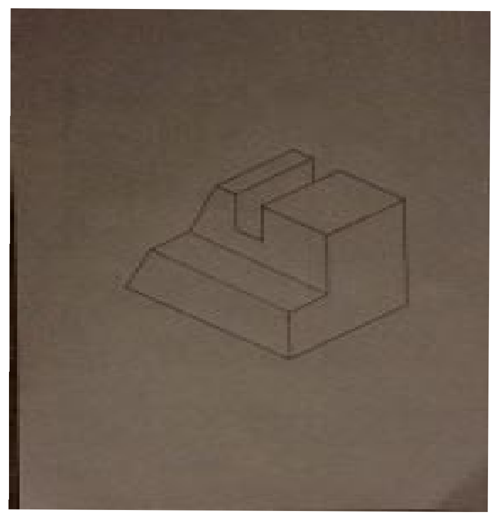
Solid Model

Figure 4 Sketch to Object Project

Object



Orthographic Sketch



Isometric Sketch

Figure 5 Object to Sketch Project

As a means of assessing the benefit of this portion of the course the students are given a Preliminary Visualization Test which is based on the Purdue Spatial Visualization Test[3]. Only the rotations and views from the Purdue test are used. Examples of the rotation and view test questions are shown in figures 6 and 7. The students are given twelve of each type of question with an average of thirty seconds to answer each. After the visualization portion of the course is completed the test is repeated with six of each type of question, with an average of thirty seconds for each. Over the past two years we have seen an average improvement of 11% on the rotations and 13% on the views.

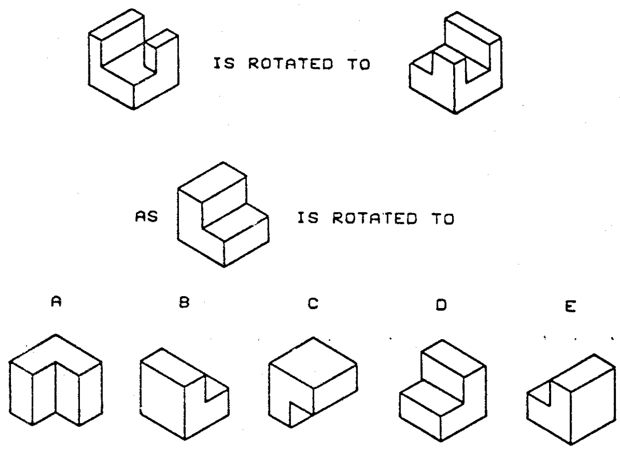


Figure 6 Visualization Test Rotation Question

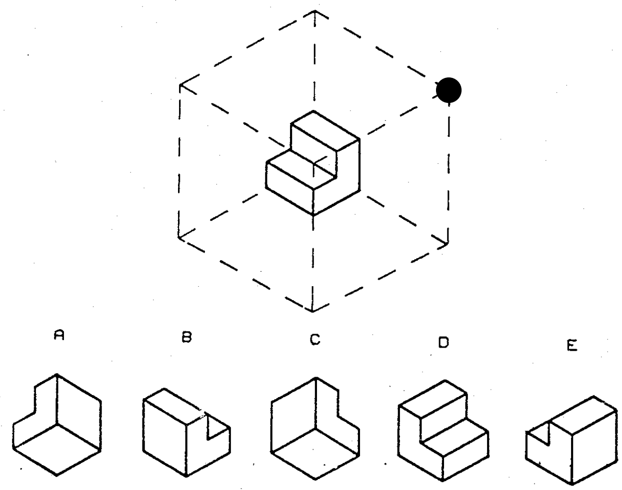
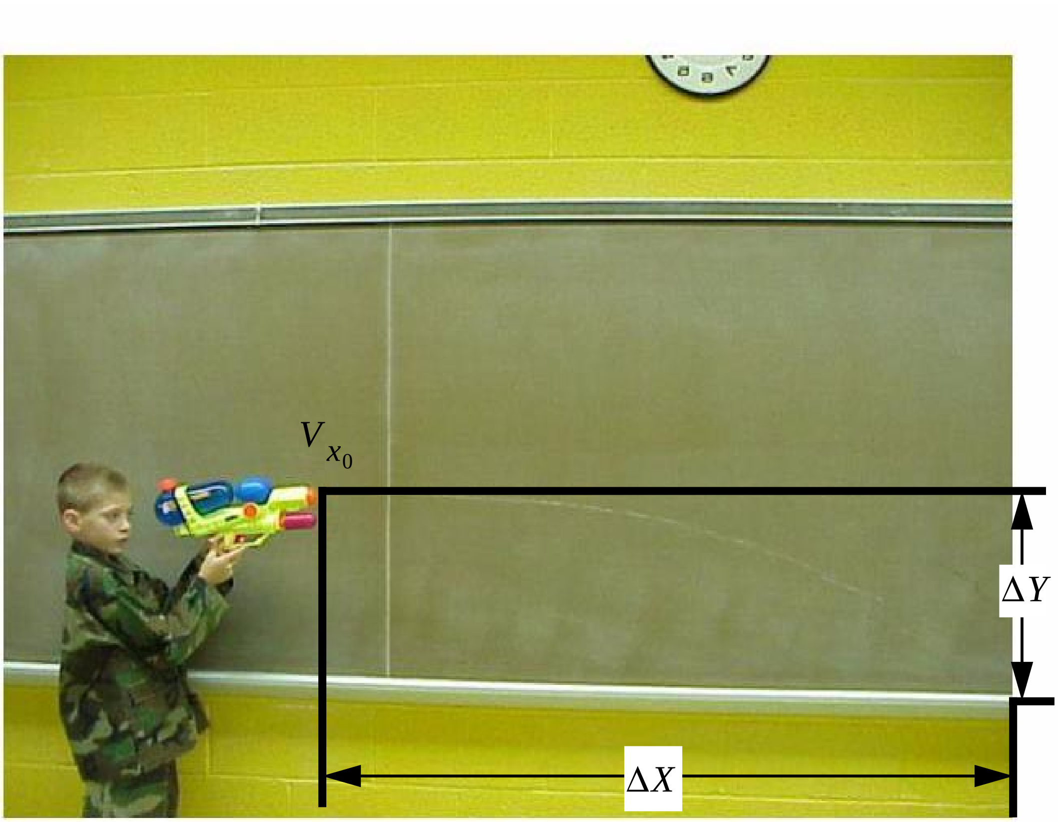


Figure 7 Visualization Test View Question

IV. Mechanical Engineering Topics

The mechanical engineering program at the U. S. Naval Academy addresses three major areas, thermo-fluid sciences, mechanics, and materials. The purpose of this portion of the course is to introduce the students to each of these areas. Each topic is covered in two lectures and a laboratory period. The first lecture is used to introduce the topic. This introduction includes an overview of the courses related to the topic and some basic principles related to the area. The lab period is used to complete a small hands on project that uses the basic principles previously introduced. The final lecture is used to discuss the results of the project and to outline the write-up that the teams turn in on the project.

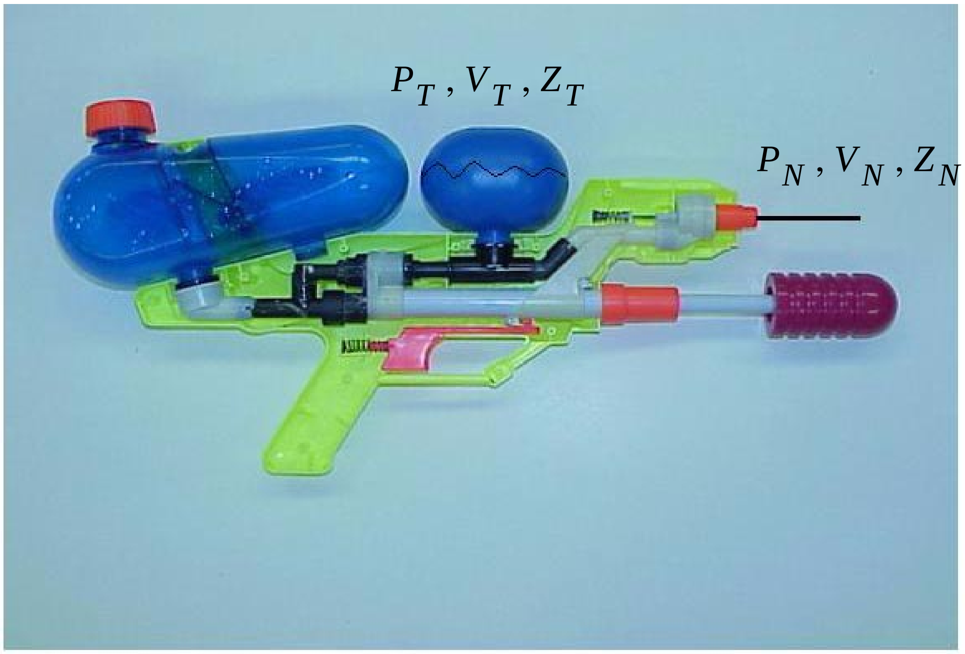
In the thermo-fluids area the conservation laws for mass, momentum, and energy are introduced. These principles are illustrated in a project to determine the number of pumps required to shoot a Super Soaker 70™ a specified distance. Student teams solve the ballistics equations to determine the muzzle velocity, figure 8. Then use conservation of energy in the form of Bernoulli's equation to determine the required tank pressure, figure 9. Having determined the tank pressure, the teams use conservation of mass and the ideal gas law to determine the number of pumps required to develop the necessary tank pressure. Each team implements its firing solution and discovers that the shot falls short. In the discussion following the test shot the concept of losses is introduced and a loss term is added to the energy equation. The calculations are repeated and another shot is taken. In the write-up each team outlines their calculations, discusses their results, provides a plot of tank pressure vs. target distance neglecting losses and including losses and provides a plot of pumps vs. target distance.



$$\Delta Y = V_{Y_0} t + \frac{a_y t^2}{2}$$

$$\Delta X = V_{X_0} t + \frac{a_x t^2}{2}$$

Figure 8 Ballistics Calculation



$$\frac{P_T}{\rho} + \frac{V_T^2}{2} + gZ_T = \frac{P_N}{\rho} + \frac{V_N^2}{2} + gZ_N + Loss$$

Figure 9 Energy Equation Calculation

For the mechanics of materials topic the basic principles discussed are the deflection and strength of beams. In particular the effect of material properties (Young's Modulus) and cross section geometry (I) on beam deflection and stress are examined. Student teams construct beams with different cross sections from foam board. They calculate I for both the vertical and horizontal orientation of their cross section and then they measure the load vs. deflection curve for the beam in both orientations. After measuring load vs. deflection, the beam is loaded in the orientation with the largest I until it fails. Teams compare their deflection results for the two orientations of their own beam. In addition, the failure loads for the different cross sections within a class are compared. In a report the teams are asked to explain the results of the project. This particular project comes at a time during the semester when the students are discussing the calculation of moment of inertia in statics, which gives them a greater appreciation for the importance of determining cross section properties. Figure 10 shows some typical cross sections and the set up used to determine the load deflection curve.

In the materials segment of the course the effect of atomic structure and processing on material properties are examined. The properties emphasized are strength and toughness. Along with these the concepts of brittleness and ductility are introduced. The project for this portion of the class has student teams measure the load vs. deflection curves for copper bar stock. Four separate pieces are compared, as received, heat treated at 600F, heat treated at 900F, and heat treated at 1200F. In addition, hardness measurements are made for the as received and 1200F treated material. Also, Charpy Impact tests are performed on the as received and 1200F treated material. After the testing is complete the teams prepare reports that discuss the relative strength and toughness of the specimens tested. They are asked to consider the hardness and Charpy test results in comparison to the areas under the load vs. deflection curves. Figure 11 shows the apparatus used for the load vs. deflection testing.

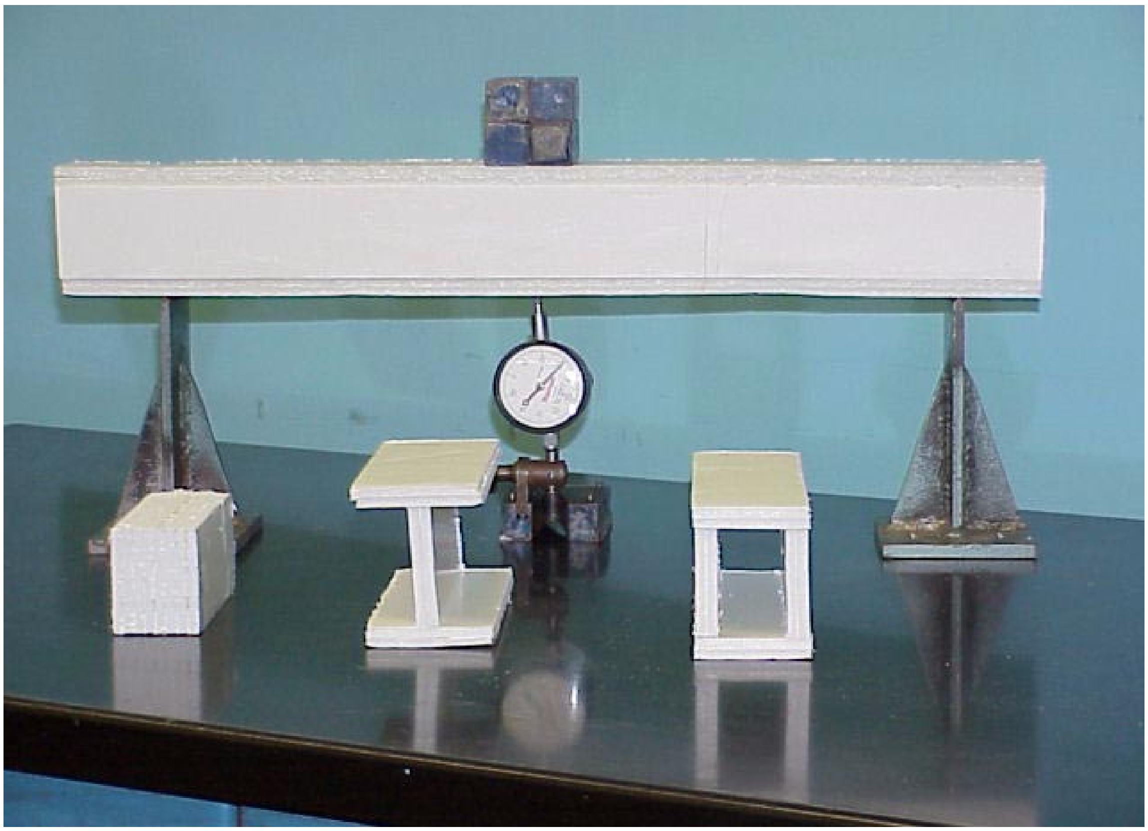


Figure 10 Mechanics of Materials Project

V. Conclusion

Student response to the class has been very positive. They especially enjoy the opportunity to gain some hands on experience with the design project. They also enjoy the projects relating to the mechanical engineering topics. Again, the hands on aspect is appealing, but also the ability to understand and apply some basic concepts related to their major is appreciated. Students that have taken some of the follow on engineering science courses in the thermo-fluids, mechanics, and materials areas have commented on remembering the projects and the basic concepts form the introduction course when they see those topics again. The visualization portion of the course has improved their ability to visualize objects.

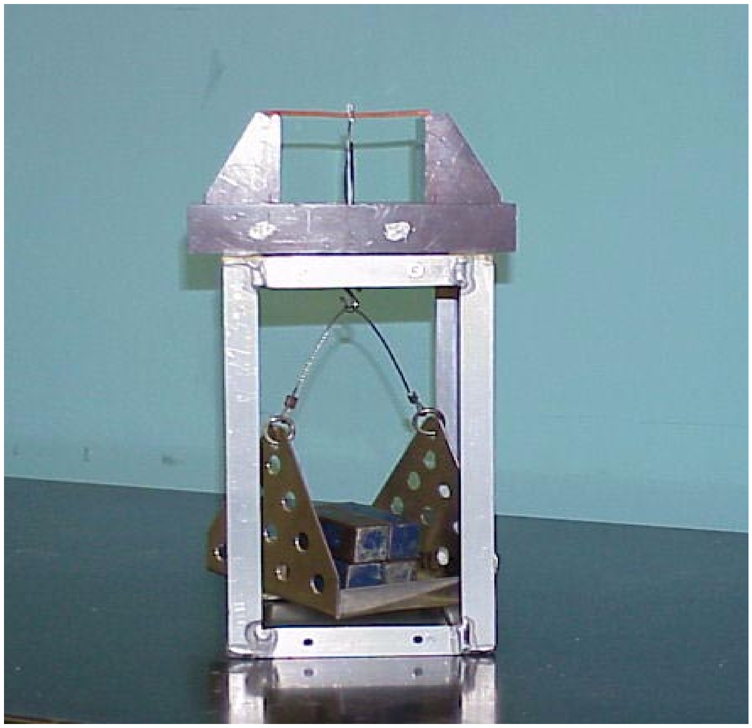


Figure 11 Materials Project Apparatus

Bibliography

1. Norton, R. L., Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines, McGraw-Hill, Inc., 1992.
2. Duff, J. M., and Ross, W. A., Freehand Sketching for Engineering Design, PWS Publishing Co., 1995.
3. Guay, R., Purdue Spatial Visualization Test, Purdue Research Foundation, 1976.

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