Laboratory Component for Engineering Mechanics Course

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Abstract

The Engineering Mechanics class at Borough of Manhattan Community College has recently integrated a laboratory component. The lab is designed to give students a hands-on experience with the theoretical concepts covered in the lecture. New laboratory exercises covering topics such as Equivalent Force System, Equilibrium of a Particle and Rigid Body, Structural Mechanics, and Friction has been developed. Laboratory equipment required for these exercises have been designed and fabricated. The reformed class was given for the first time in Spring 2004. The changes in the course are part of ongoing integration of various modes of learning in the Engineering Science curriculum at Borough of Manhattan Community College.

Introduction

Undergraduate engineering programs across the U.S. are modifying their curricula to incorporate active learning components. These modifications involve introducing lab components and computerized modeling and simulation into the syllabi. Other approaches incorporate machines and real industrial processes as case studies. These changes are not just focused on upper level courses, but are aimed at courses throughout the engineering curriculum.

The Engineering Mechanics class at Borough of Manhattan Community College (a 3-credit, 5-contact hour sophomore level class) has recently integrated a lab component. The main objective of the laboratory exercises is to supplement the learning and understanding of basic mechanics principles. The laboratory component is designed to give students a hands-on experience with the fundamental engineering concepts covered in the course, see references [1] and [2]. There are six exercises in the laboratory. They are:

1. Concurrent Forces

The first experiment is designed to elaborate *Equilibrium of a Particle in Space.* A given load is suspended from three cables, attached to a horizontal plate. The main objective is to find the magnitude of the tensile forces exerted in the cables. Students will observe the experimental values of a tension in each cable directly by measuring it with spring scales and compare them with analytically obtained solutions. Another significance of this activity is to give the students hands-on experience with fundamental terms like *Line of Action and Point of Application of a Force, Addition of Vectors, Resultant of the Forces, Equilibrium and Equilibrant.* Theoretical solution will reinforce the ideas of *Free Body* and *Free Body Diagram* of a particle and analytical condition for the equilibrium:

$$\mathbf{R} = \sum \mathbf{F_i}$$

Students gain a practical experience determining and distinguishing rectangular components of the 3-D Vectors

2. Equilibrium of Rigid Body

The next laboratory experiment demonstrates *Equilibrium of Rigid Bodies* and *Application of Equilibrium Equations*. Figure 1 presents schematic of the lab exercise. A beam (1) supported by a pin at one end and a roller at the other end is resting obliquely against a vertical wall marked 2 in Fig. 1. It is under action of concentrated force (6) and its own weight. Part one of this experiment focuses on determination of normal reactions in the supports by using digital force scales (3) and (4). A spring-loaded scale (5) is used to find the value of the horizontal component of the reaction in the pin support. In part two, relation between pin support reactions and position and direction of the external force (6) is studied. This exercise emphasizes core concepts such as: *Moment of a Force, Roller, Pin and Bracket supports, Cross and Scalar Product of a Vector*

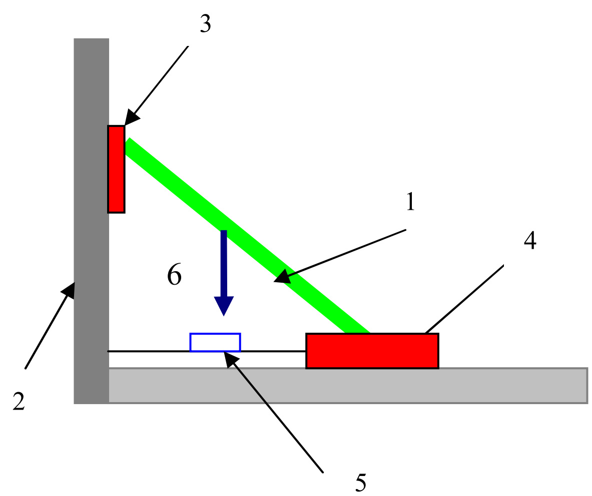

Figure 1. Equilibrium of Rigid Bodies

3. Equilibrium of Structures

The major goal of the subsequent experiment is to understand *Equilibrium of Structures.* Students analyze a truss structure made of several connected links. The exercise involves the determination of not only external reaction forces but also of the forces, which hold together the different components of the structure. Typical experimental layout is shown in Figure 2.

Universal testing equipment is used for this lab exercise. It enables students to test various type of engineering structures such as Pratt Bridge Truss, Fink Truss, Howe Roof, Bridge Trusses and more. Each of the truss members has a strain gauges bonded to the surface of the member. The Digital Force Display unit measures and displays this force during the experiment. The truss in the experiment is subjected to coplanar forces (up to 500N) by employing electronic load cell.

Students assemble various configurations and experimentally determine the tension or compression in each member. Then using *Method of Section*, they will analytically compute the forces and make comparison of the results. Students are expected to gain a practical understanding of core concepts such as *Strain Gauges, Joints, Two and Three Force Members, Internal Forces, Roof & Bridge Trusses, Compression and Tension*

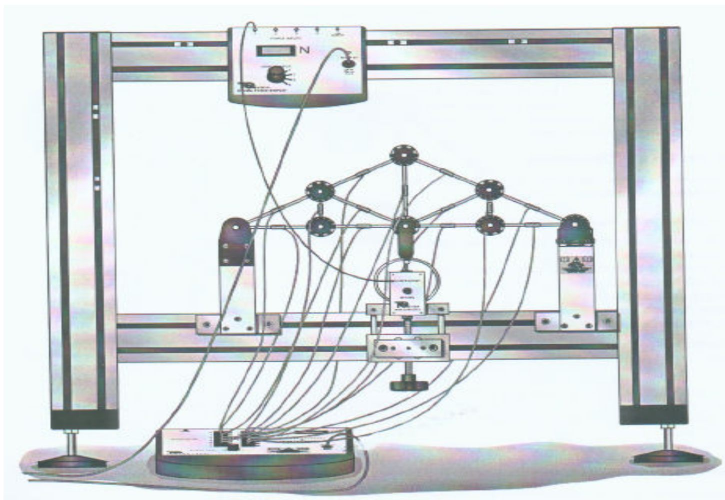

Figure 2 Roof Truss

4. Centroid of Composite Area

In this lab exercise centroid of a composite plate is investigated. The testing body consists of a 4' x 4' x ¾" equilateral triangular plates made of finished plywood and supported by vertical pins at its vertices. Different plates with various sized triangular shapes (marked 3 in fig.3) removed from the plate are used in the experiment. Three digital scales (marked 1 in fig.3) are used for measuring the reaction force at the supports. The vertical pins supporting the plate are resting on the horizontal platforms of the scale. The main objects of this exercise are:

- to determine the *Centroid* of the plate
- to investigate the relation between the position of *Centroid* and the distribution of the reactions exerted on three pinned supports

The reactions exerted in the supports depend on the size and shape of the cut (3). Students are required to investigate the relation between the reactions and the geometry of cuts.

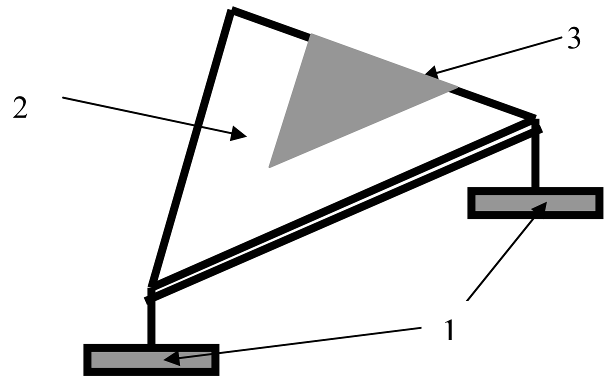

Figure 3. Composite Plate

5. Sliding on rough surface

This experiment consists of two parts and is designed to examine role of friction in maintaining equilibrium. In part one of this laboratory experiments, the coefficient of static friction is determined by conducting a standard experiment. In the second part, two slender rods AC and CB (shown in fig. 4.) are pin-connected at one end. Rod BC's end is attached to block B, which is resting on a rough surface. Rod AC's other end is attached to a fixed support. Starting with AC making an angle of 30° with the horizontal surface, a downward vertical force F is applied at C. Students determine the maximum vertical force F for which equilibrium is maintained. They repeat the exercise at angles of *45,* 60° and 75° and observe the impact of angle on magnitude of the vertical force. The laboratory experiment is designed to reinforce topics such as *Theory of Friction* and *Impending Motion* and give students experience working on problems involving *Dry Friction.*

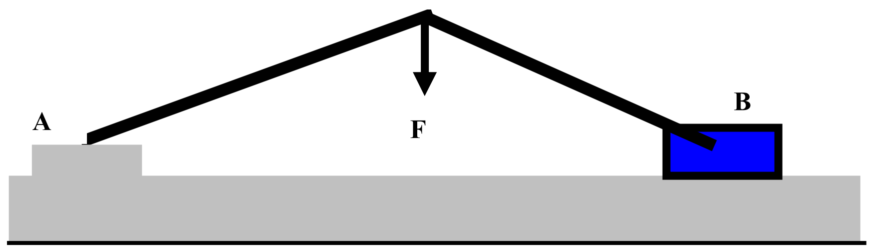

Figure 4. A Box sliding on rough surface

6. Torque and Belt Transmission

Application of equilibrium equations for three-dimensional rigid bodies, involving bearings, and shafts are illustrated in this exercise. The main objective is to explore torque and mechanical power transmission. Two transmission belts pass over sheaves fixed to an axle supported by bearings C and D, Fig. 5. Belt A is driven by a motor, while belt B drives sheave E attached to another axel equipped with drum brake. The apparatus is designed to allow the students to measure reaction forces in the bearings A & B, and the braking force. The major objective is to provide students hands-on experience with the methods of solution of problems related to the *Equilibrium of Rigid Body* in three dimensions, involving *Bearings, Shafts, Sheaves and Transmission Belts.*

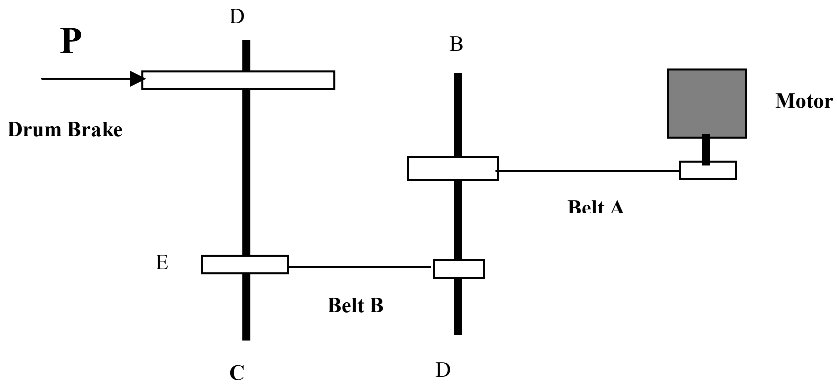

Figure 5. Belt and Torque exercise

Photographs of some of the exercises used in the laboratory are presented in appendix.

Conclusion

Laboratory assignments have become a significant part of the syllabus for the mechanics courses. First two projects- *Equilibrium of a Particle* and *Equilibrium of Rigid Bodies* were offered and tested earlier-in 2003. However most of the above described laboratory experiments, are introduced for the first time in the Spring 2004.

Main objective of using laboratory experiments in mechanics courses is to further advance the learning and understanding of basic mechanics principles and enable engineering students to get hands-on experience with them to promote experiential learning. In the future we will study, analyze and evaluate the impact of this innovation to the overall student performance.

Acknowledgment
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References

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2. David R. Sokoloff, *Mechanics, Module 1.Active learning laboratories*. Central Book Company, New York, 1998.

Appendix

Biographies

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