Introduction to Engineering Analysis - ENGR1100
Course Description and Syllabus
Monday / Thursday Sections
Fall 2013

All course materials are available on the RPI Learning Management System (LMS) website. Click the RPI LMS link from the RPI info webpage or go directly to:

https://lms.rpi.edu/

Assigned statics HW will be posted on Connect http://connect.mcgraw-hill.com/. Your instructor will provide you with your section’s address and instructions about how to register during the first week of classes.

Back exams, HW solutions, and other useful links can be found at the following website: http://www.rpi.edu/dept/core-eng/www/IEA

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1. Course Description from the Current Catalog

This course provides an integrated treatment of Vector Mechanics (Statics) and Linear Algebra. It also emphasizes computer-based matrix methods for solving engineering problems. Students will be expected to learn key principles of Statics and Linear Algebra and to demonstrate computer skills with vector and matrix manipulations.

2. Statement of Course Objectives

The objectives of this course are to enable the student to analyze external and internal force systems acting on particles and rigid physical bodies in static equilibrium. The student shall be able to “model” engineering systems by making simplifying assumptions, developing “free-body” diagrams of the physical model, applying the conditions for equilibrium, and utilizing vector and linear algebra methods in their solution. The student shall also be able to utilize computer software in the solution of problems. The student shall learn to present problem solutions in a well-organized, neat, and professional manner.

3. Statement of Course Outcomes

The following outcomes from ABET a – k apply to this course:
(a) an ability to apply knowledge of mathematics, science, and engineering
(e) an ability to identify, formulate, and solve engineering problems
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

4. Outline of Course Content and Learning Objectives

The course consists of four main topic areas; Linear and Vector Algebra, Particle Equilibrium, Rigid Body Equilibrium, and Engineering Applications. The learning objectives for each topic area are presented below.

Objectives for Linear and Vector Algebra

The objectives are to introduce the student to methods for obtaining the solution to a system of linear equations, both manually and by utilizing computer software. Also, the student will be introduced to the algebra of vectors. Upon completion the student shall be able to:

1. Write a system of linear equations in the matrix form $Ax = b$.
2. Determine whether a system of linear equations has a singular solution, no solution, or an infinity of solutions.
3. Evaluate the determinant of a matrix by the methods of cofactor expansion and duplicate columns.
4. Solve up to three linear equations with three unknowns using Cramer’s Rule.
5. Solve up to six linear equations with six unknowns by using the Gauss-Jordan elimination method and elementary row operations.
6. Add, subtract, and multiply matrices and determine the inverse of a matrix by using the adjoint formula and augmented matrices and row reduction.
7. Find a unit vector associated with a line segment, or force vector, and be able to compute the scalar product and cross-product of two vectors and the scalar triple product of two vectors.
8. Obtain the solution to a system of linear equations by the methods stated above utilizing computer software and any additional syntax particular to the program being used.

Objectives for Particle Equilibrium

The objectives are to introduce students to the vector nature of concentrated forces, representing force in Cartesian vector form, and determining the resultant of a system of concurrent forces. The student shall be introduced to Newton’s Law of Gravitation and its application to problems in physics and engineering. The student shall also be able to apply the first condition for static equilibrium (force balance) to systems of concurrent forces acting on particles. The student will be introduced to the concept of modeling a physical system for mathematical analysis by the use of a free-body diagram and formulating the system of linear equations that represent the given system which will lead to the solution of the problem. The use of the computer in solving particle equilibrium problems will be introduced. After completion the student will be able to:

1. Work problems in either the SI or U.S. Customary systems of units.
2. Determine the resultant of a system of concurrent forces and determine the components of a force by using the Parallelogram and Triangle Law.
3. Determine the unit vector associated with a force and express the force in Cartesian unit vector form.
4. By using the scalar product of two vectors, determine vector components in any arbitrary direction and the angle between vectors (dihedral angle).
5. Determine completely the resultant of a two- or three-dimensional system of concurrent forces.
6. Sketch a model of the physical system using a free-body diagram to represent the system, place the forces in a Cartesian coordinate system, and specify the sign conventions to be used.
7. From the first condition for equilibrium (force balance) formulate the governing equations for a two-dimensional or three-dimensional concurrent force system and obtain the solution.
8. Utilize the computer to solve problems in particle equilibrium where more than a singular solution is desired to show the effect of varying system parameters.

Objectives for Rigid Body Equilibrium

The objectives are to introduce the concept of moment of force, Varignon’s theorem, force couples, the vector cross product, the triple scalar product, and equivalent force systems. After completion the student will be able to:
1. Use Varignon’s Theorem (the theorem of moments) to calculate the moment effect of a force.

2. Calculate the vector cross product term by term and also by evaluating the corresponding determinant and interpreting the resulting moment vector (i.e., understand the right-hand rule).

3. Calculate the scalar triple product and interpret the resulting scalar quantity.

4. Calculate the value of a couple and state its magnitude and direction and be able to state the properties of couples. Couples will be calculated by both scalar and vector methods.

5. Replace a force by a force and couple for a single eccentrically applied force and also for a system of forces.

Objectives for Engineering Applications

The objectives of this unit are to enable the students to calculate the external and internal reactions to external forces and couples acting on beams, structures, frames, or machines. Additional objectives are to introduce the student to the effects of friction on physical systems and to enable the student to calculate centroids for planar bodies. After completion, the student shall be able to:

1. Sketch, within reasonable scale and proportion, the model of the physical system using a “free-body” diagram for applying all forces and couples and determining the force and moment reactions for pins, bearings, cables, struts, and built-in reaction points.

2. Determine the external reactions to the external loads placed upon rigid bodies, such as beams, truss structures, and frames.

3. Analyze a truss structure to determine the internal reactions in the truss members due to the external loading and verify that the design is stable. The truss analysis will use the “method of joints” and the “method of sections.” The student shall also be able to use computer methods for analyzing the truss structure by solution of a system of linear equations derived from the equilibrium equations written at the truss joints.

4. Analyze frame structures to determine external reactions to external loads and the resulting internal forces.

5. Analyze non-rigid devices classified as machines to determine mechanical advantage and pin forces due to the input loading and the corresponding output forces.

6. Determine the forces required for motion to impend or whether motion will take place given the friction coefficients for the contact surfaces using the Coulomb Friction Law.

7. Apply the Coulomb Friction Law to determine slip or tip conditions and how to position the applied forces to prevent tipping.

8. Determine centroids of regular areas by the method of composite areas

5. Instructional Methods, Course Requirements, Evaluation Techniques

The pre-requisite knowledge for students entering this course of study consists of satisfactory completion of traditional secondary-school courses in physics, algebra, trigonometry, and geometry. This is a problem-solving engineering course. Theory, illustrative problems, and the use of computer methods in problem solving will be presented. The course will be delivered in a “studio” format which will allow students to interact with the instructor, teaching assistant, and
each other in the problem-solving time allotted to each class. Problems will be assigned as homework related to the topics discussed in class. Hence, attendance is expected for each meeting of the class. As an introductory course in engineering that emphasizes problem solving methodology, it is necessary for the student to understand the underlying theory, simplifying assumptions, and the limitations and degree of accuracy of the resulting computations. A student’s progress, learning, and productivity will be assessed by class attendance and participation, homework, in-class assignments, periodic exams, and a comprehensive final exam. To minimize distraction during the studio sessions, and thus enhance the learning process, the usage of laptop and desktop computers is prohibited. The lowest 2 HW assignments and 4 CA will be dropped.

6. Determination of Final Grades

The grading system shall consist of the following components:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exams 1 - 3</td>
<td>50%*</td>
</tr>
<tr>
<td>Homework</td>
<td>15%</td>
</tr>
<tr>
<td>In-Class problems</td>
<td>5%</td>
</tr>
<tr>
<td>Final examination</td>
<td>25%</td>
</tr>
</tbody>
</table>

**TOTAL** 100%

* The highest test grade will have a weight of 20%

The final numeric grade for the course work will be computed from the components on the basis of 100 as a perfect score, and will use the grade modifier system outlined in the “Grading System” section of the Rensselaer Catalog. Generally:

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>[94 -</td>
</tr>
<tr>
<td>A-</td>
<td>90 - 94)</td>
</tr>
<tr>
<td>B+</td>
<td>87 - 90)</td>
</tr>
<tr>
<td>B</td>
<td>84 - 87)</td>
</tr>
<tr>
<td>B-</td>
<td>80 - 84)</td>
</tr>
<tr>
<td>C+</td>
<td>77 - 80)</td>
</tr>
<tr>
<td>C</td>
<td>74 - 77)</td>
</tr>
<tr>
<td>C-</td>
<td>70 - 74)</td>
</tr>
<tr>
<td>D+</td>
<td>67 - 70)</td>
</tr>
<tr>
<td>D</td>
<td>60 - 67)</td>
</tr>
<tr>
<td>F</td>
<td>- 60</td>
</tr>
</tbody>
</table>

A schedule for all three exams and make-ups is found at the end of this syllabus. The date and time for the final exam will be announced later in the semester when it is scheduled by the Registrar.

Two grade-challenging sessions will be held after each exam, except for the final exam.
If there is a legitimate reason for missing an original examination, the student will be allowed to take the make-up (the student must present to the professor in charge of the section a note from the Dean of Students office). There will be no “making up” for missed make ups for whatever reason.

Class attendance is expected and there will be no make-up for problems assigned during a class session. A grade of zero will be given for each missing homework or in-class problem assignment.

7. Academic Dishonesty Policy

Student-teacher relationships are built on trust. For example, students must trust that teachers have made appropriate decisions about the structure and content of the courses they teach, and teachers must trust that the assignments that students turn in are their own. Acts which violate this trust undermine the educational process. The Rensselaer Handbook of Student Rights and Responsibilities defines various forms of Academic Dishonesty and you should make yourself familiar with these. In this class, all assignments that are turned in for a grade must represent the student’s own work. In cases where help was received, or teamwork was allowed, a notation on the assignment should indicate whom you collaborated with. Submission of any assignment that is in violation of this policy will result in a grade of zero for that particular assignment. If you have any questions concerning this policy before submitting an assignment, please ask for clarification. Also, cheating on an exam will result in a grade of zero for that exam. In addition, students are expected to conduct themselves in a professional manner at all times.

8. Required Texts


9. Supplementary Readings and Other Materials

Available in the bookstore:
- The Essentials of Linear Algebra – Research and Education Associates
- Super Review – Linear Algebra – Research and Education Associates

10. Course Format

This course will be offered in a “studio” format. Material will be presented in lecture format and students will have the opportunity to work problems in that same class to reinforce the lecture material and illustrative problems presented. Generally there will be two such meetings each week.
Homework (problems to be solved outside of the class period) is assigned for each class period (see Section 12 of this syllabus) and should be turned in at the beginning of the next class period. Late homework will not be accepted. Homework should be completed in accordance with the required problem-solving format (see Section 10 of this syllabus). The homework will be collected periodically and graded for completeness, clarity, adherence to the required format, and correctness. The homework grading policy may vary among the different sections of the course. Your instructor will inform you of the homework grading policy for your section. Solutions to homework will be posted on the course website after the homework is turned in.

11. General Problem-Solving Format

Required Procedure for the Solution of Engineering Problems

1. GIVEN - State briefly and concisely (in your own words) the information given.

2. FIND - State the information that you have to find.

3. DIAGRAM - A drawing showing all quantities involved should be included. Free-body diagrams are drawn separately. Label appropriate coordinate directions.

4. BASIC LAWS - Give appropriate mathematical formulation of the basic laws that you consider necessary to solve the problem.

5. ASSUMPTIONS - List the simplifying assumptions that you believe applicable to the problem.

6. ANALYSIS - Carry through the analysis to the point where it is appropriate to substitute numerical values.

7. NUMBERS - Substitute numerical values (using a consistent set of units) to obtain a numerical answer. The significant figures in the answer should be consistent with the given data.

8. CHECK - Check the answer and the assumptions made in the solution to make sure they are reasonable.

9. LABEL - Label the answer (e.g., underline it or enclose it in a box).

IMPORTANT:
- Include name, student number, and section number on each page.
- Staple pages together.
- Always start a problem solution on a new page.
- Always use pencil (and an eraser to remove errors).
• Always use a straight edge.
• Never write on the back of a page.
• Handwriting and diagrams must be legible and work should not be crowded.
• Keep all assigned work in a binder for reference when studying for exams.
Suggested Problem Solving Format

**PROBLEM NO. 6-2**

**Data**

- **Course & number**
- **Date due**
- **Number of this sheet**
- **Number of sheets in this assignment**

**Data**

- **μ = 0.20 for all surfaces**

**Req'd**

Determine magnitude of force \( P \) to prevent block \( A \) from sliding down the plane.

**Sol'n**

**Free bodies on left**

- **A**
  - 1000 lb
  - 30°
  - \( N_A \)
  - \( F_A \)

**Calculations on right**

- \( \Sigma F_y = 0 \)
- \( N_A - 1000 \cos 30° = 0 \)
- \( N_A = 866 \text{ lb} \)
- \( F_A = \mu N_A = 0.20 \times 866 = 173.2 \text{ lb} \)
- \( \Sigma F_x = 0 \)
- \( T - 1000 \sin 30° + 173.2 = 0 \)
- \( T = 500 + 173.2 = 326.8 \text{ lb} \)

- \( \Sigma F_y = 0 \)
- \( N_B - 600 = 0 \)
- \( N_B = 600 \text{ lb} \)
- \( F_B = \mu N_B = 0.20 \times 600 = 120 \text{ lb} \)
- \( \Sigma F_x = 0 \)
- \( P + F_B - T = 0 \)
- \( P + 120 - 326.8 = 0 \)
- \( P = 206.8 \text{ lb} \)

**Double underline answers, and state units**

**Show direction of vector quantities**

**Index answer**

(If two or more problems can be placed on one sheet, draw a double line between adjacent problems. Do not begin a new problem when it is obvious that it cannot be completed on the same sheet.)
12. Minimum Requirements for a Complete Exam Problem Solution

For all exams given during the semester, the minimum requirements for a complete exam problem solution are provided below. Students should adhere to these requirements to ensure that they receive the maximum credit possible.

For any problem related to statics, the solution should contain:

- Appropriate sketches of the problem as needed. Specifically, in many static problems one or several free body diagram(s) (FBD) are necessary, with the number and characteristics of these FBDs depending on the problem. Each FBD should include: (a) coordinate system (labeled); b) all forces and moments (with unique identification); and c) full definition of geometry (i.e., location of points and/or distances between points, angles, etc.)
- The governing equations (i.e., equilibrium of forces and moments)
- Correct use of vector notation throughout (clearly distinguishing scalar quantities from vector quantities)

For any problem involving linear algebra, the solution should contain:

- All intermediate work (e.g., elementary row operations should be shown)

For all problems, the solution should always contain:

- A final result which is enclosed within a box. When applicable, this final result should include appropriate units.
<table>
<thead>
<tr>
<th>Meeting Date</th>
<th>Topic(s)</th>
<th>Reading Before Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 8/26 (1)</td>
<td>Newton’s Laws, Introduction to Vectors</td>
<td>Ch. 1, 2.1 – 2.3</td>
</tr>
<tr>
<td>R 8/29 (2)</td>
<td>Vectors, unit vector, dot product</td>
<td>2.7-2.8, 3.9</td>
</tr>
<tr>
<td>R 9/05 (3)</td>
<td>Force Resultants, Force Components, Rectangular Components of Force Resultant</td>
<td>2.4 – 2.6</td>
</tr>
<tr>
<td>M 9/09 (4)</td>
<td>Particle Equilibrium, Free Body Diagrams</td>
<td>2.9 – 2.11</td>
</tr>
<tr>
<td>R 9/12 (5)</td>
<td>Intro. to Linear Equations, Gauss-Jordan Elimination</td>
<td>LA 1.1, 1.2</td>
</tr>
<tr>
<td>M 9/16 (6)</td>
<td>Review</td>
<td></td>
</tr>
<tr>
<td>W 9/18</td>
<td><strong>EXAM No. 1</strong></td>
<td></td>
</tr>
<tr>
<td>R 9/19 (7)</td>
<td>Matrix Operations, Determinants (up to 3 by 3), Vector Cross Product</td>
<td>LA 1.3</td>
</tr>
<tr>
<td>M 9/23 (8)</td>
<td>Cross Product, Three Dimensional Problems</td>
<td>2.12 – 2.15, 3.4 – 3.5</td>
</tr>
<tr>
<td>R 9/26 (9)</td>
<td>Moment of a Force, Principle of Moments</td>
<td>3.6 – 3.8</td>
</tr>
<tr>
<td>M 9/30 (10)</td>
<td>Moments in Three Dimensions, Moments About a Line</td>
<td>3.11 – 3.13</td>
</tr>
<tr>
<td>R 10/03 (11)</td>
<td>Couples, Resolution of Force into a Force and/or Couple</td>
<td>3.14 – 3.20</td>
</tr>
<tr>
<td>M 10/07 (12)</td>
<td>Rigid Body Equilibrium, Free Body Diagrams</td>
<td>4.1 – 4.4, 4.8</td>
</tr>
<tr>
<td>R 10/10 (13)</td>
<td>Two Dimensional Equilibrium</td>
<td>4.5 - 4.7</td>
</tr>
<tr>
<td>T 10/15 (14)</td>
<td>Review</td>
<td></td>
</tr>
<tr>
<td>W 10/16</td>
<td><strong>EXAM No. 2</strong></td>
<td></td>
</tr>
<tr>
<td>R 10/17 (15)</td>
<td>Three Dimensional Equilibrium</td>
<td>4.9</td>
</tr>
<tr>
<td>M 10/21 (16)</td>
<td>Three Dimensional Equilibrium</td>
<td>4.9</td>
</tr>
<tr>
<td>R 10/24 (17)</td>
<td>Composite Areas</td>
<td>5.1 – 5.4</td>
</tr>
<tr>
<td>M 10/28 (18)</td>
<td>Distributed Loads</td>
<td>5.5, 5.8</td>
</tr>
<tr>
<td>R 10/31 (19)</td>
<td>Analysis of Truss Structures, Method of Joints</td>
<td>6.1 – 6.4</td>
</tr>
<tr>
<td>M 11/04 (20)</td>
<td>Method of Sections</td>
<td>6.7</td>
</tr>
</tbody>
</table>
Exam Schedule

There will be “common” exams for all students. Exams are scheduled on Wednesday mornings as detailed in the table below. Examination rooms will be assigned for each section. These exams will be closed book and closed notes. For maximum credit, you must show all set-ups and all details necessary for solving the exam problems (see Section 11 of this syllabus for minimum requirements for exam problems solutions).

All exams are closed book / closed notes.

You may use a hand-held calculator for calculations only. Cell phones, audio devices, headphones and laptops must be off and stored away during the exam. Any person found deviating from this policy will be asked to leave the exam room, given a grade of zero, and no retest will be allowed.

<table>
<thead>
<tr>
<th>Exam No.</th>
<th>Date</th>
<th>Time</th>
<th>Makeup</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9/18</td>
<td>8:00-9:50am</td>
<td>9/25</td>
<td>5:00–6:50pm</td>
</tr>
<tr>
<td>2</td>
<td>10/16</td>
<td>8:00-9:50am</td>
<td>10/23</td>
<td>5:00–6:50pm</td>
</tr>
<tr>
<td>3</td>
<td>11/13</td>
<td>8:00-9:50am</td>
<td>11/20</td>
<td>5:00–6:50pm</td>
</tr>
</tbody>
</table>