

## MACHINE DYNAMICS – MANE 4170

Spring 2009

Class Hours: Tu, F, 12:00-1:20 PM

Room: Eaton 214

Instructor: Kurt S. Anderson

Office: JEC 4006 Phone: 276-2339 E-Mail: [anderk5@rpi.edu](mailto:anderk5@rpi.edu)

Office Hours: M 3:30-4:30 PM; W 9:00-10:00 AM, Th 3:00-4:00 or by appointment

TA: Simin Chai <[chais2@rpi.edu](mailto:chais2@rpi.edu)>

Office Hours: M 12:30-2:00 PM, Thursday 12:30-2:00 PM, (JEC 2001)

### **Course Objective:**

To develop an understanding of the interrelationships of motion, kinematic constraints, forces, and moments as they apply to the general 3-dimensional dynamic behavior of mechanisms and machine elements.

### **Text:**

Course notes: "Machine Dynamics," prepared by the instructor (available in pdf form on the instructor's webpage at <http://www.rpi.edu/~anderk5/PublicShare/MANE4170-Notes.pdf> )

*Advanced Engineering Dynamics*, by J. H. Ginsberg, Cambridge University Press (in paperback!)

Other texts which may be helpful:

*Fundamentals of Applied Dynamics*, by J.H. Williams, John Wiley & Sons, Inc. 1996

*Principles of Dynamics*, D.T. Greenwood Prentice Hall, 1988

### **Prerequisites:**

ENGR 2090 (Engineering Dynamics) ; MATH 2400 (Intro. to Differential Equations) or equivalent and Linear Algebra  
It is assumed that all students have a good understanding of statics and basic planar (2-D) (Sophomore level) dynamics.  
Furthermore, students must be proficient in all of following basic mathematics:

- a. *Basic vector algebra and calculus*: (e.g. dot product, cross product, chain rule for differentiation).
- b. *Basic Linear Algebra*: Matrix multiplication, matrix inversion, etc.
- c. *Trigonometric Identities and definitions*: (plus the law of Sines and the Law of Cosines)
- d. *Basic Differential Equations*: Formulation and solution of simple homogeneous, non-homogeneous linear differential equations; exposure to simple eigenvalue problems and their solution.

### **Topics:**

1. Introduction to Dynamics
2. Reference Frames and Differentiation of Vectors
3. Kinematics (Constraints, General 3-D Formulas, Cams, etc.)
4. Mass Distribution
5. Kinetics: Newton-Euler Methods
6. Advanced Topics: Lagrangian Methods, Velocity Projection Method a.k.a Kane's Method
7. Solving the equations of motion and simulating dynamic behavior.

### **Homework:**

Homework will account for 10% of the course grade. Problems will be assigned most weeks (except those contain exams) on Tuesday and will be due at the time the next homework is assigned (e.g the usually the following Tuesday, except for weeks with examinations). There will be approximately 10 homework assignments for a total of approximately 40 problems. The problems are best done individually in a professional manner (neatness counts!). Problems will be generally be graded on a 10 point scale and will be returned in class approximately one week after they were due. Collaboration in the solution of the homework problems is permitted and is strongly encouraged if it enhances the learning process, but mere copying of the solution is deleterious at best. In general, **no** late assignments will be accepted. However, extensions may be granted if a situation arises for which it is warranted. In these instances the student must request the extension in writing prior to the assignment due date, stating the reason for the request and the date the assignment is to be submitted. Solutions to all homework assignments will e-mailed to student on instructor's list

**Design Project:**

This course will involve a simple design project associated with the design of *Trebuchet* of sufficient size to ideally hurl a 10 lb projectile (water melon, pumpkin, frozen chicken, gallon container of favorite substance) from the volleyball court (is it still there?) on the hill behind the Russell Sage Dining Hall to the upper floors of the Troy Building. In general, each homework assignment will involve at least one question associated with this design project, but which will be graded separate from the homework. These design project questions are intended to keep you on schedule and on track with regards to this project. You may work in groups of at most three individuals, but each individual is to turn in their own write-ups, with their partners names listed. A final report will be required, but this report need only consist of the will organized collection all problems assigned with regard to this project, plus a short (few pages) additional write-up and final analysis. The overall project will be worth 5% of the course grade.

**Exams:**

There will be three full period, in-class exams during the course. Each exam will be closed book, closed note, however, one 8.5"X11" sheet of notes (both sides) written in the students own handwriting (no photo copies) will be allowed. This sheet must contain the name and ID # of the student and be submitted with the completed exam. This crib sheet will be returned to the student with the graded exam. No make-up exams will be granted except for illness, emergency, or unusual situations. The approximate exam schedule is:

Exam 1: Topics 1, 2, 3	Feb. 13, 2009
Exam 2: Topics 3, 4	Mar. 24, 2009
Exam 3: Topic 4, 5,6	Apr. 24, 2009

**Final Exam:**

There will be a 3-hour in-class final exam given during the Finals Week interval set aside for examss. This final exam will be comprehensive. This exam is closed-book, closed-note, with the exception of three handwritten 8.5"X11" sheets of notes (as described for exams, above) being allowed. These crib sheets must be turned in with the completed final exam.

**Grade Appeal:**

Students are encouraged to discuss there grades with the instructor as frequently as is necessary. Appeals of grades should be made within one week of the return of the homework/exam in question to the student.

**Grading:**

Homework 15%:                      Project 5%                                      Exams 50%:                                      Final Exam 30%

**Statement of Academic Integrity:**

Student-teacher relationships are built on trust. The students must trust that the instructor has made appropriate decisions about the structure, content, etc., of the courses they teach, and the instructors must trust that assignments which students turn in are their own. Acts which violate this trust undermine the education process.

The *Rensselaer Handbook* defines various forms of Academic Dishonesty and procedures for dealing with them. All forms are violations of the trust between the students and instructors. All students should familiarize themselves with this portion of *the Rensselaer Handbook* and should note that the penalties for the various forms of dishonesty can be quite harsh.

# Proposed Schedule

MACHINE DYNAMICS – MANE 4170

Winter semester, 2009

Class Hours: TuF 12:00-1:20 PM

Room: Eaton 214

Kurt S. Anderson, Professor

#	Date	Topic [Sections in Williams] {Pages in Required Course Notes}
1.	Tu 1/13	Introduction, review, definitions, position, velocity, acceleration [1.1-2.3]{1-7}
2.	F 1/16	No Class (Instructor out of country)
3.	Tu 1/20	Reference frames, basis vectors, Coordinate (basis) transformations direction cosine matrices [3.1-3.2]{8-14, 26-33}
4.	F 1/23	Derivative Notation, differentiation of vectors, closer look at orientation/rotation (not a vector!), {22-26}, Simple rotations [3.3.4]{38-43}
5.	Tu 1/27	Angular Velocity, Addition Thm. of angular velocity [3.3.4]{44,45,48,49}, Analytic derivative, kinematic derivative [3.4]{45-50}
6.	F 1/30	Auxiliary reference frames [3.5]{49-50} Angular acceleration {51-52k}
7.	Tu 2/3	General velocity [3.5-3.6]{53-58}, Review for Quiz.
8.	F 2/6	No Lecture (at NSF)
9.	Tu 2/10	General acceleration [3.5-3.6]{53-58}, No unique way to look at or solve problem! {57-58}
10.	F 2/13	<b>Quiz #1</b>
11.	Tu 2/17	<b>No Class!!! This is a “Monday”!</b>
12.	F 2/20	# Degrees-of- freedom, geometric and motion constraints, 4-bar linkage {35-38, 59}
13.	Tu 2/24	Spatial Rolling constraints with slipping without slipping (gears) {65-67}
14.	F 2/27	Need external forces only, center of mass for curves, surfaces, volumes {68-72d}, Center of mass for composite systems
15.	Tu 3/3	Rotational inertias, [6.3.1]{73-77}; Inertia Tensor, dyadic, matrix, basis transformations {76-80,84-86}
16.	F 3/6	3-D Parallel axis Thm.[6.3.2] {81-83, 85,86}, Inertia matrix for composite bodies {87-95}
17.	Tu 3/10	Spring Break, NO CLASSES!!!
18.	F 3/13	Spring Break, NO CLASSES!!!
19.	Tu 3/17	Inertial ellipse, principal inertias [6.3.3]{96-102}, Principal directions and why they are important {96-102}
20.	F 3/20	3-D kinetics of a rigid body (Newton-Euler/direct approach)[6.4]{103-116}
21.	Tu 3/24	<b>Quiz #2</b>
22.	F 3/27	Newton-Euler Equations for multibody system (DAE's +/- 's)
23.	Tu 3/31	Newton-Euler Equations, Angular Momentum
24.	F 4/3	Potential and Kinetic energy energy associated with a particle, rigid body, system [6.5.2]{116-123}
25.	Tu 4/7	Lagrange's equations/indirect method [5.5-5.7]{136-150}
26.	F 4/10	Lagrange's equations/indirect method [5.5-5.7]{136-150}
27.	Tu 4/14	Solving system equations of motion, Simulation of dynamic behavior; Matlab
28.	F 4/17	Free vibration, effective mass and stiffness [8.1-8.3.1]{151-159}
29.	Tu 4/21	Forced vibrations, resonance, dynamic application [8.1-8.3.1]{151-159}
30.	F 4/24	<b>Quiz #3</b>
31.	Tu 4/28	Advanced Topics, Review for Final.

### **Recommendations for format of problem solutions:**

The following should be included in the solution of all homework problems.

1. Problem description: Brief description/statement of problem to be solved.
2. Diagram of problem clearly showing all relevant quantities and coordinate frames.
3. Free-Body-Diagram and Mass-Acceleration Diagram if formulation warrants them.
4. Basic Laws/Formulas: clearly give relevant formulas necessary to solve problem.
5. Assumptions: Clearly state and briefly justify all assumptions used in analysis
6. Analysis: Carry through analysis symbolically to the point where numerical substitution is appropriate.
7. Number and underline important intermediate equations.
8. Numbers: When numbers are substituted into expressions, use consistent units and limit the number of significant figures to that appropriate with the given data.
9. Label (BOX) your final answer.
10. Odds and Ends:
  - a) Always start a problem on a new page
  - b) Use lined (ideally Engineering) paper
  - c) Organized flow to work
  - d) Always use a straight edge
  - e) Only write on the front side of each sheet of paper
  - f) Don't annoy the grader with sloppy, hard to follow work!!!!

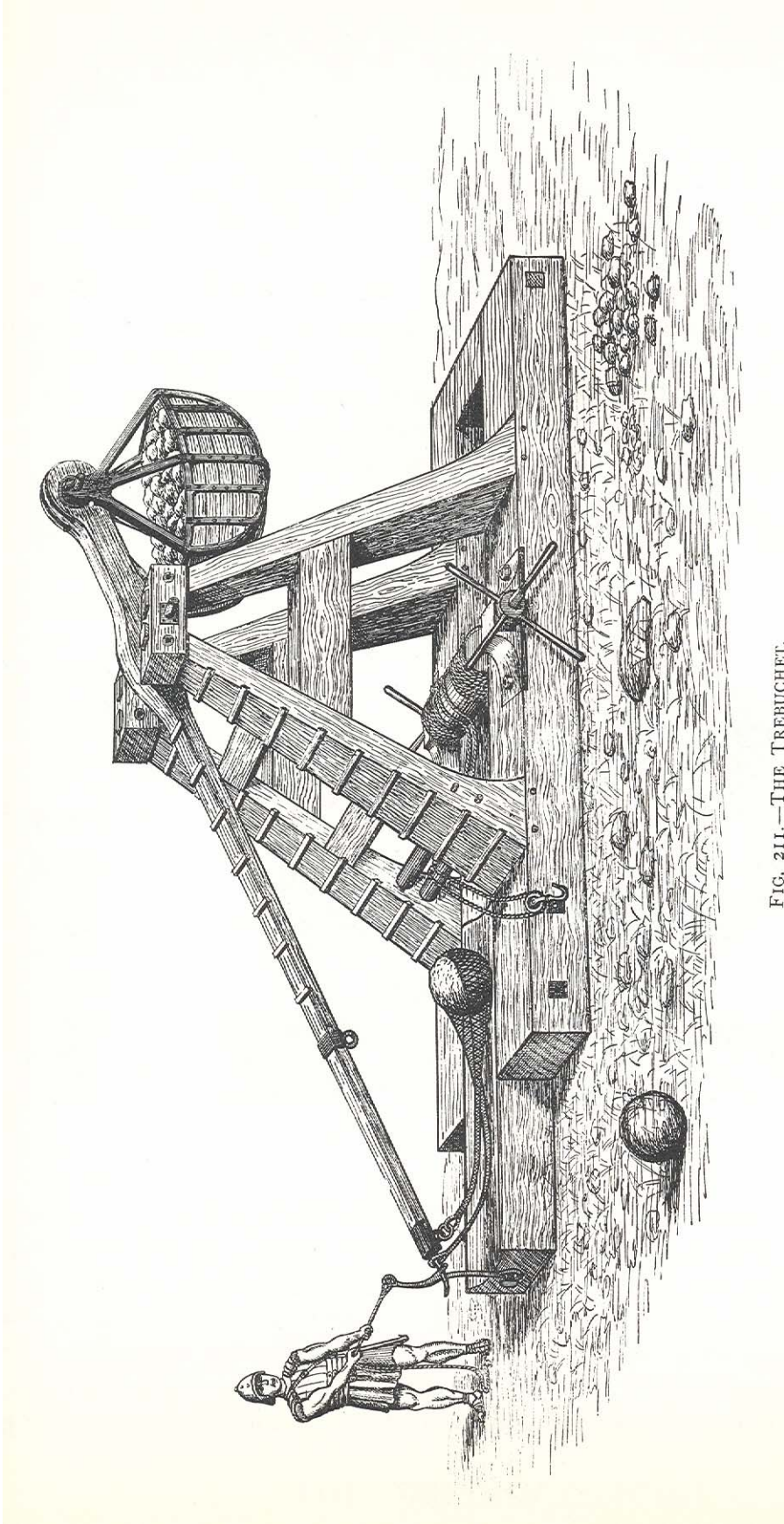


FIG. 211.—THE TREBUCHET.

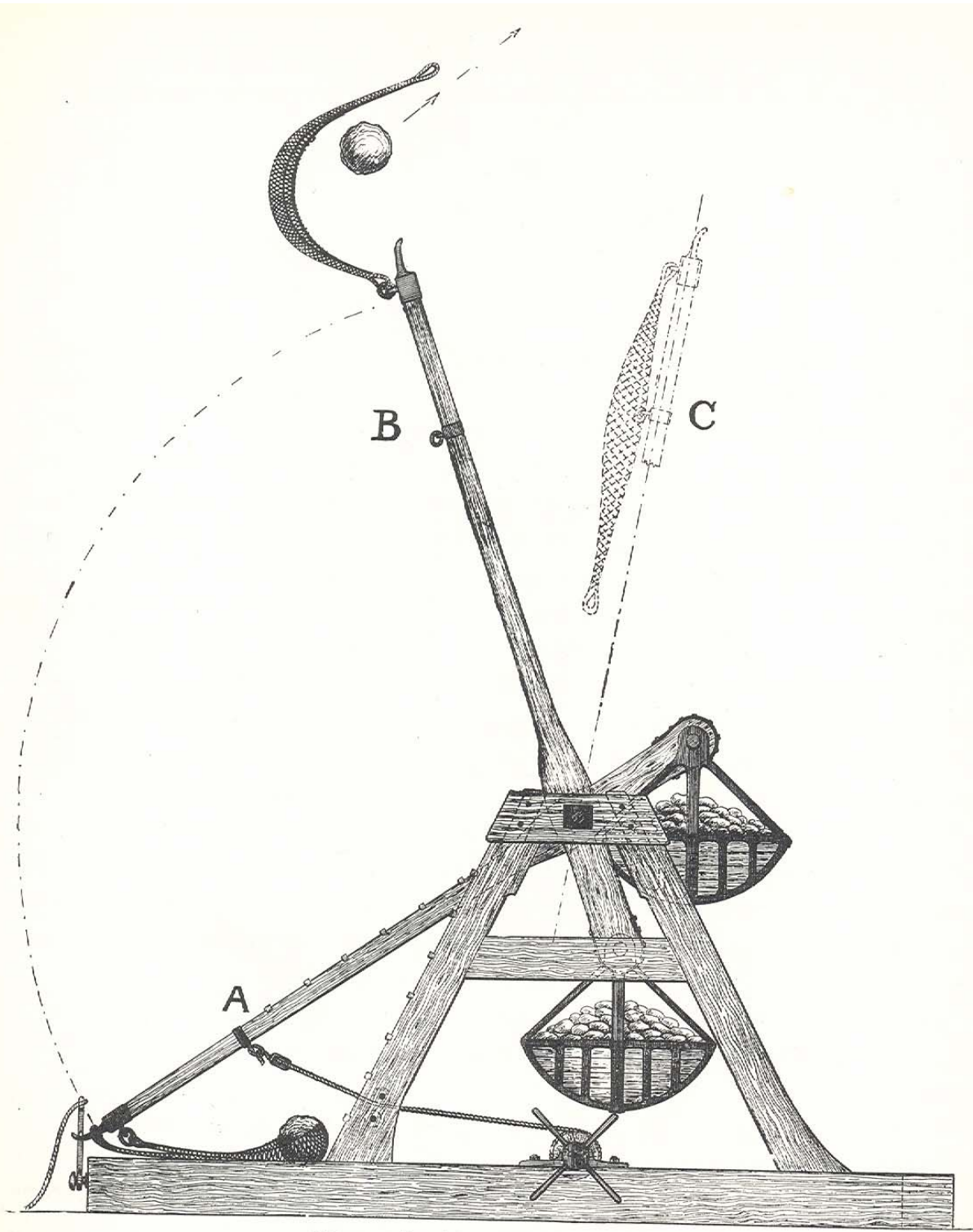


FIG. 212.—THE ACTION OF THE TREBUCHET.

A. The arm pulled down and secured by the slip-hook previous to unhooking the rope of the windlass. B. The arm released from the slip-hook and casting the stone out of its sling. C. The arm at the end of its upward sweep.