

**San José State University**  
**Aerospace Engineering**  
**AE 138 Vector-Based Dynamics for Aerospace Applications, Fall 2016**

<b>Instructor:</b>	Prof. J.M. Hunter
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<b>Office Hours:</b>	MW 10:30 am – 1:15 pm M 4:30 pm – 6:00 pm
<b>Class Days/Time:</b>	MW 1:30 – 2:45pm
<b>Classroom:</b>	E164
<b>Prerequisites:</b>	Grade of “C” or better in MATH 32
<b>Co-requisite:</b>	AE112
<b>Class Website</b>	<a href="https://sjsu.instructure.com">https://sjsu.instructure.com</a> Under the courses tab, select this course

#### **Online Courses**

Usually this class will meet in person in Engineering 164. Sometimes, however, the class will meet online, using a WebEx link. In these cases, I will announce the online schedule ahead of time and post the link on Canvas.

#### **Course Description**

Vector mechanics of three degree-of-freedom particle motion. Particle kinematics, reference frames and rotational relative motion. Two degree-of-freedom rigid body motion, moments/products of inertia. Particle & rigid body equations of motion and numerical time histories.

#### **Course Goals**

1. To provide a fundamental knowledge of vector dynamics.
2. To establish the basics of reference frame mechanics and relative motion.
3. To provide the fundamentals of particle kinematics of using Newtonian methods.
4. To write three-dimensional equations of motion using vector mechanics.
5. To understand the influence of moments/products of inertia on rigid body rotational motion.
6. To develop physical intuition about dynamic systems by examining the connection between the differential equations (equations of motion) and their time history solution.

#### **Course Learning Outcomes**

1. *Combine and solve for vectors using the operations of vector algebra.*
2. *Find area using vector algebra.*
3. *Set up basis vectors and use them to express and solve for particle position.*
4. *Set up a direction cosine matrix relating the planar orientation of two reference frames.*

5. *Express and resolve vectors into reference frames related by direction cosine matrices.*
6. *Differentiate scalars; differentiate vectors in arbitrary reference frames.*
7. *Express angular velocity/acceleration and relate these concepts to the direction cosine matrix.*
8. *Solve kinematic (position/velocity/acceleration) problems when multiple reference frames are involved.*
9. *Express particle and rigid body constraints for rolling and sliding (slipping) situations.*
10. *Calculate mass center of a system of particles and of a rigid body.*
11. *Calculate rigid body mass moments/products of inertia (mass properties). Intuitively understand the relationship between mass properties and rigid body motion.*
12. *Write the linear/angular momentum vectors of a dynamic system.*
13. *Inertially differentiate linear/angular momentum vectors, set them equal to applied forces/moments and thereby write the equations of motion of the system.*
14. *Write the total kinetic energy and use it to solve for the motion/reaction forces, etc. of a dynamic system.*
15. *Use MotionGenesis to model the equations of motion of a dynamic system.*

## Required Texts/Readings

### Textbook

Mitiguy: Dynamics of mechanical, Aerospace and Biomechanical Systems, MotionGenesis, Inc.

### Other Readings

Hibbeler: Engineering Mechanics and Dynamics

Greenwood: Principles of Dynamics

Kane: Dynamics

Thomson: Introduction to Space Dynamics

Anderson: Introduction to Flight

## Course Requirements and Assignments

Homework	15%
Project	25%
Two Hour Exams	40%
Final Exam	20%

Reading assignments will be posted for most classes and should be completed before coming to class. Homework problems will be assigned every week or two. These homework sets are essential to your understanding. Allow 8 – 10 hours per week for homework. Often we will work problems in groups during the class period, sometimes for credit, sometimes not. As homework is graded and returned to you, I will post the solutions on Canvas and work selected problems on the board. If there is a particular problem that you would like to see worked out, please let me know and I will be sure to make time to do this.

### Final Examination or Evaluation

A comprehensive written final exam will be given on Thursday, December 15, 12:15 – 2:30pm, in Engineering 164.

### Grading Information

Problem grades are based on:

- i* conceptual understanding (i.e., identifying the correct physical principle or law of motion),
- ii* setting up the problem equations, and

iii solving the problem for a numerical or symbolic expression.

Two old exam problems are shown below, with partial credit indicated.

(25 pt) An aircraft, particle Q, travels overhead at constant altitude,  $h$ , and constant horizontal velocity,  $v$ . A radar tracks the aircraft so that  $\mathbf{b}_x$  is always pointed toward the aircraft.

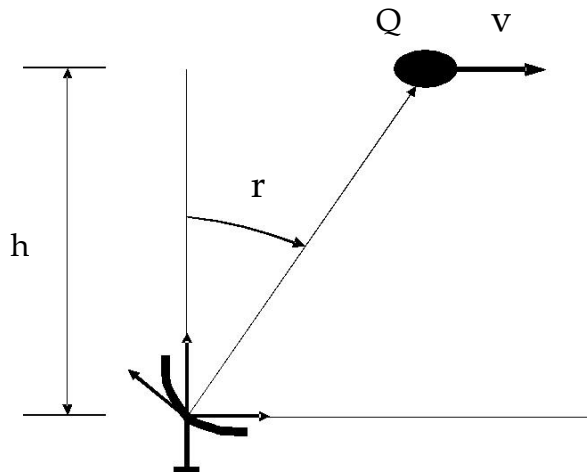
Newtonian reference frame N is fixed in the ground. Reference frame B is fixed in the radar and rotates with it.

This problem happens entirely in the vertical plane.

(A) Determine the angular velocity,  $\dot{\theta}$ , and the angular acceleration,  $\ddot{\theta}$ , of the radar in terms of  $v$ ,  $r(t)$  and  $\theta(t)$ .

(B) Evaluate  $\dot{\theta}$  and  $\ddot{\theta}$  at the point of closest approach of the airplane to the radar. At this point,  $\dot{\theta} = 0$  and  $r = h$ .

(C) Hint: Write two expressions for  ${}^N \mathbf{v}^Q$  and equate them.



Partial Credit

- (10 pt) Correctly writing the expression for  ${}^N \mathbf{p}^Q$  and differentiating to find  ${}^N \mathbf{v}^Q$
- (5 pt) Writing a second expression for  ${}^N \mathbf{v}^Q$  from the problem statement
- (5 pt) Equating the scalar components of  ${}^N \mathbf{v}^Q$  and solving for  $\dot{\theta}$  and  $\ddot{\theta}$
- (5 pt) Evaluating  $\dot{\theta}$  and  $\ddot{\theta}$  at PCA

(25 pt) A satellite (particle Q of mass  $m$ ) is in an elliptical orbit around the Earth.

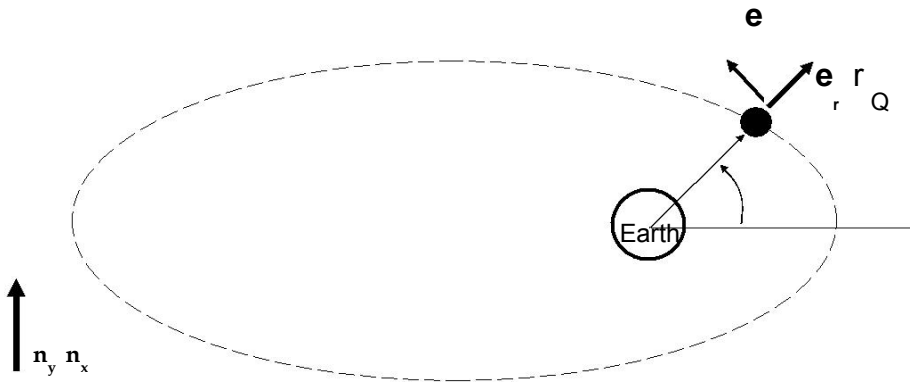
The position of Q in N is a function of  $r$  and  $\theta$  as shown, where  $r = r(t)$  and  $\theta = \theta(t)$ .

The only force applied to the particle is the gravitational force:  $\mathbf{F}^Q = -\frac{G m m_E}{r^2} \mathbf{e}_r$

where  $m_E$  = mass of the Earth and  $G$  = universal gravitational constant.

Satellite reference frame,  $S$ , consists of  $\mathbf{e}_r$ , along radial line  $r$ ;  $\mathbf{e}_\theta$  which is perpendicular to  $\mathbf{e}_r$  in the orbital plane; and  $\mathbf{e}_z = \mathbf{e}_r \times \mathbf{e}_\theta$ .

Write the equations of motion of the particle,  $Q$ .



Partial Credit

(10 pt) Recognizing that the Golden Rule version of Newton's Second Law of Motion is the correct principle (5 pt) Writing the expression for  ${}^N \mathbf{p}_Q$

(5 pt) Differentiating  ${}^N \mathbf{p}_Q$  to obtain  ${}^N \mathbf{v}_Q$

(5 pt) Using the applied force to write the equations of motion; taking the dot product with the unit vectors to obtain scalar equations

### Determination of Grades

Grading Scale: 100 – 97% A+; 96.9 – 93% A; 92.9 – 90% A-; 89.9 – 87% B+; 86.9 – 83% B; 82.9 – 80% B-; 79.9 – 77% C+; 76.9 – 73% C; 72.9 – 70% C-; 69.9 – 67% D+; 66.9 – 63% D; 62.9 – 60% D-; < 59.9% F. All exams must be taken to receive a passing grade.

### University Policies

*Per University Policy S16-9, university-wide policy information relevant to all courses, such as academic integrity, accommodations, etc. will be available on Office of Graduate and Undergraduate Programs' [Syllabus Information web page](http://www.sjsu.edu/gup/syllabusinfo/) at <http://www.sjsu.edu/gup/syllabusinfo/>.*

*AE Department and SJSU policies are also posted at <http://ae.sjsu.edu/program-policies>.*

# AE 138 Vector-based Dynamics for Aerospace Engineering Fall 2016 Course Schedule

## Course Schedule

Week	Date	Topics, Readings, Assignments, Deadlines
1	8/31	Class Overview
2	9/5 & 9/7	Vector dynamics review
3	9/12 & 9/14	Position vectors and vector geometry
4	9/19 & 9/21	Vector basis
5	9/26 & 9/28	Direction cosine matrices
6	10/3 & 10/5	Vector differentiation and integration
7	10/10 & 10/12	Angular velocity & angular acceleration
8	10/17 & 10/19	Points: Velocity and acceleration
9	10/24 & 10/26	Constraints
10	10/31 & 11/2	Particles
11	11/7 & 11/9	Mass, center of mass, centroid
12	11/14 & 11/16	Moments/Products of inertia
13	11/21	Inertia properties
14	11/28 & 11/30	Rigid Bodies, force and momentum
15	12/5 & 12/7	Force, impulse, and resultant Moments and torque Equations of motion
Final Exam	Thursday, December 15	ENGR 164 at 12:15 pm – 2:30 pm