ROUGH COVERAGE
TAM 4735/5735 Intermediate Dynamics and Vibrations

Date of this version: September 28, 2012

Course coverage (non-chronological)

Problem Solving. A subset of the outcomes for this course is total mastery of TAM 2030 and ability to solve most standard 2D ME and TAM Q-exam dynamics and vibrations questions. Relevant examples will be interleaved with the homework and lectures. Throughout the course there will be an emphasis on competence at problem solving: going from pictures to principles to governing equations, solving these equations as appropriate using pencil and paper or numerical methods, presenting the results graphically or with animations, checking special and extreme cases, and using conservation laws to generate or check equations of motion, etc.

This is a **list of topics** and the time spent on those topics. 1 lecture = 1 of 42 lectures each of which is 50 minutes. A topic listed as taking, for example, 1 lecture may be spread over parts of many lectures through the semester. For many topics, the main part of the actual learning, will be in the homework.

3 lect. **Numerical methods.** Computers will be used throughout course to generate numeric solutions and to check theorems, conservation laws and analytic solutions. For example, in almost all parts of the course students will numerically solve ODEs (*e.g.,* , using Matlab), make their own graphics (elementary stick-figure animation) and when needed use the "homogeneous transform" (displacement and rotation in one matrix). This material will be spread over many parts of lectures. Subtopics include:

a. Basic matrix tools (*e.g.,* , solving linear equations, eigenvalues and vectors, etc).
b. Integrating ODES (states, derivatives, types of integrators, issues of time step, precision, et al)
c. Euler's method in a script
d. Euler's method callable as a student-written function (with a ODE's right-hand-side filename being an argument)
e. midpoint method (RK2) as a student-written script
f. ODE23, 45, etc with OPTIONS and parameters
g. Translating EOMs into computational form
h. basic stick figure animation
i. homogeneous transform for 2D displacements and rotations
j. basic use of the symbolic toolbox

3 lect. **Vector Kinematics**

a. Vectors and vector notation ($\vec{\boldsymbol{v}} = v_x\hat{\boldsymbol{\imath}} + v_y\hat{\boldsymbol{\jmath}} = \sum v_i\hat{\boldsymbol{e}}_i, = v\nearrow$)
b. Vector algebra ($\vec{\boldsymbol{a}} + \vec{\boldsymbol{b}}, \vec{\boldsymbol{a}} \cdot \vec{\boldsymbol{b}}, \vec{\boldsymbol{a}} \times \vec{\boldsymbol{b}}$)
c. cylindrical and path coordinates
d. Reference frames and coordinate systems (when is the difference important)

e. Transport theorem ('Qdot formula': $\dot{\vec{Q}} = (\dot{\vec{Q}})_{rel} + \vec{\omega} \times \vec{Q}$)

f. Velocity and acceleration using rotating frames
('3 term velocity' formula and '5-term acceleration formula', *e.g.,* ,
$\vec{a}_P = \vec{a}_{O'/O} + \vec{\omega}_{\mathcal{B}} \times (\vec{\omega}_{\mathcal{B}} \times \vec{r}_{P/O'}) + \vec{\alpha}_{\mathcal{B}} \times \vec{r}_{P/O'} + \vec{a}_{P/\mathcal{B}} + 2\vec{\omega}_{\mathcal{B}} \times \vec{v}_{P/\mathcal{B}}$)

9 lect. **Newton-Euler Vector Dynamics**

a. systems of particles and 2D rigid objects: momentum, angular momentum, work, KE & PE
b. Extracting general 2nd order ODEs for MDOF systems from EOMs (2D)
c. Central-force motion
d. 3D rigid objects: Inertia dyadics, angular momentum, equations of motion.
e. Many example problems with growing complexity.

3 lect. **Lagrange equations**

a. Generalized coordinates
b. DOFs and constraints
c. Equilibria (incl. relative equilibria)
d. Stability of static equilibrium

1.5 lect. **Linearizing equations near an equilibrium**

1.5 lect. **Matrix form of linear vibration equations.** Normal modes and normal coordinates. ($M\ddot{x} + Kx = 0$ and normal modes using $M^{1/2}$ or $M^{-1}K$) Comparison of normal modes with direct integration (homework).

1 lect. Single DOF review (damping, under/over damped, frequency response, resonance. ($m\ddot{x} + c\dot{x} + kx = f(t)$). .

6 lect. More topics in vibrations (chapters 1-6 of Inman)

3 lect. **Continuous systems**

a. Derivation of 1D wave equations for string/rod and beam.
b. Normal modes by separation of variables.

3 lect. **Contact models.** Frictional sliding and collisions.

3 lect. **Optimization.** Using optimization (*e.g.,* FMINCON or SNOPT) to optimize a design.

1.5 lect. **Stability of periodic motions, limit cycles.**

3 lect **More on modeling, simulation and design** Possible topics include the following:

a. Ad-hoc and LINMOD approaches to Linearizing a nonlinear model
b. Monte-carlo analysis
c. Optimization of design parameters through automated iteration (*e.g.,* , FMINCON or SNOPT)
d. Fitting experimental data via models
e. Discrete events and mixed continuous/discrete
f. Stiff equations and multiple time scales