Course name: ESO209A
Instructor: Anindya Chatterjee, Professor, ME
Semester: July-Dec, 2014

Lecture wise coverage of topics (based on notes taken by 2 TAs; lecture count is approximately correct but not verified exactly, since no other records were kept):

1. Free body diagrams. Importance. How they are drawn. Examples. *(Moment about an axis should be done here. I forgot, and did it during a break in a later lecture.)*
2. Coordinate systems. Right handed coordinate systems. Matrix of components of a vector. Vectors (magnitude, direction; scalar multiplication, addition; addition is commutative). Transformations of vectors. Linear transformations of vectors are tensors. Underline/boldface notation. Example: projection tensor. Matrix of components of tensors.
3. Rotations. Euler's theorem (the most general displacement of a rigid body with one point fixed is a rotation about some axis passing through that point). Proof. Leads to demonstration that rotation is a linear transformation. Definition of rotation tensor **R**. Interpretation of eigenvalues of **R**. Axis-angle formula for **R**.
4. Successive rotations. Products of successive **R** matrices. Rotations do not commute. Euler angles (3-1-3). Definitions and drawing of rotated axes. Intuitive definition of angular velocity using Euler's theorem (infinitesimal rotation about some axis in infinitesimal time interval).
5. Recall angular velocity. Also as the "axial vector" of the skew symmetric matrix $\dot{R}R^T$. Derivatives of vectors with respect to rotating frames. Leading up to the 5-term acceleration formula.
6. Recall 5-term acceleration formula. Example problems (planar and 3D).
7. Kinetics. Systems of particles. Center of mass, c.m. velocity and acceleration, angular momentum of a system of particles and of a rigid body about its center of mass. The moment of inertia tensor. Kinetic energy of a rotating body in 3D.
8. Example problems. Moment of inertia tensor again. Parallel axis theorem.
9. Moment of inertia tensor again. Simple rotation, non-parallel angular velocity and angular momentum (in 3D). Linear and angular momentum balance in 3D (for a single rigid body). Example problem (wheel on axle, axle ends in a ball and socket joint).
10. Previous problem continued. Discussion of indeterminacy in ground forces, and reasonable approximations for the same.
11. Rigid body supported at a ball and socket joint in 3D. Linear and angular momentum balance. More example problems.
12. More example problems.
13. Specialization to planar problems. $\boldsymbol{\omega} \times \boldsymbol{I}_{cm} . \boldsymbol{\omega}$ is zero for such cases. Several FBDs and example problems.
14. Rolling without slip in 2D, up an inclined plane. Disk with cutout (non-axisymmetric mass distribution allowed). Problem of rod with a frictionless hinge (support forces, planar kinetics simplification). Unidirectional sliding of a block with different friction at contact points (role of acceleration in determining friction, and vice versa).
15. Solution of differential equations using Matlab. Demo for double pendulum.
16. Rigid body with one point fixed frictionlessly, in 3D, using Euler angles. Simplification to axisymmetric case. Steady precession under gravity.
17. More example problems.
18. Conserved quantities: energy, momentum, angular momentum components. Problems where some conserved quantity allows direct solution (energy and momentum methods).

19. Euler's equations for a torque free rigid body (in body-fixed axes); stability of pure spin about principal axes (largest and smallest); final long-term stability only about axis of largest moment of inertia (argued using conserved quantities – ellipsoids for energy and momentum – as well as linearized stability analysis).
20. More examples with conserved quantities. Example of an unfeasible problem (energy is conserved, but there may not be a path from state A to state B). Example of a problem where energy is not conserved though some might expect it to be (chain suddenly moved up from one end).
21. Control volume approach. Net force/moment on control volume equals net rate of change of linear/angular momentum inside control volume plus net rate of outflow of linear/angular momentum from control volume. Examples: bent pipe carrying water; rocket; conveyor belt with material dropping on it; falling chain problem overview, pointer to youtube http://www.youtube.com/watch?v=i9gLi4pBgpk
22. Solution of falling chain problem, assumptions that are usual. Other examples: including snow-blower truck from Meriam and Kraige. Review discussion.
23. Small vibrations. Pendulums with multiple strings. Energy methods and momentum balance methods (small deviations from equilibrium).
24. Discussion of several review problems (solutions not discussed).
25. Class on introduction to nonlinear oscillations. Matlab solution. Nonlinear ODEs. Harmonic balance for periodic forcing. Numerical solution and comparison. Jump phenomena.
26. In addition, one lecture was used by Saurabh Biswas (student tutor) to give a more detailed introduction to Matlab; and there were 2 in-class quizzes.