Synopsis and Structure of Lectures for First Year CP1: Mechanics

Michaelmas and Hilary Terms 2016/17

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The purpose of the course is to provide an elementary introduction to classical mechanics and motion. The lectures will fully cover the syllabus. Loosely, I plan to distribute the material as follows:

<u>Michaelmas Term 2016</u>

Lecture 1 : What is classical mechanics? Introduction to vectors. Magnitude and projections of a vector. Simple addition of vectors. Time-dependent vectors and differentiation of vectors.

Lecture 2 : More on vectors. Multiplication of vectors. Differentiation of vectors.Vector velocity and acceleration. Examples.

Lecture 3 : Dimensional Analysis. Newton's laws of motion. Inertial reference frames. The principle of equivalence.

Lecture 4 : More on Newton's laws. Equations of motion. Energy, work and impulse. Conservative forces. Bounded and unbounded motion. Conservation of energy and momentum. Examples.

Lecture 5 : Potential energy and the potential function. The simple harmonic oscillator. Examples of solving equations of motion. Collisions in the laboratory frame. Elastic collisions in 1 dimension.

Lecture 6 : Inelastic collisions and the coefficient of restitution. The centre of mass (momentum) frame. Solving collision problems in centre of mass frame.

Lecture 7 : Elastic and inelastic collisions in 2 dimensions. Geometrical method of transforming between Lab and centre of mass.

Lecture 8 : More on collisions in 2 dimensions. Projectiles moving under gravity. Projectile motion in two dimensions.

Lecture 9: Resisted motion. Forces proportional to velocity and velocity squared (air resistance and turbulent flow).

<u>Hilary term 2016</u>

Lecture 10: Newton's laws with changing mass (rocket motion). One stage and 2-stage rockets.

Lecture 11: More on rocket motion. Non inertial (accelerating) frames.

Lecture 12: The motion of charged particles in uniform E and B fields.

Lecture 13: More on the differentiation of vectors. Angular momentum and torque.

Lecture 14: Angular velocity and angular acceleration. Moments of forces. Central forces.

Lecture 15: Central force equation of motion. Conservation of angular momentum. Keplers' laws. The total energy of an orbit, conservation of energy. Effective potential.

Lecture 16: More on effective potential. Examples.

Lecture 17: Solution to the orbit equation. Derivation of equation for u=1/r (off syllabus for Prelims). Elliptical orbits. Kepler's 3^{rd} law.

Lecture 18: Bound and unbound orbits. Orbits examples.

Lecture 19: Mutual orbits and the centre of mass. Hyperbolic orbit. The distance of closest approach. Angle of deviation.

Lecture 20: Impulse method. Rutherford scattering. Systems of particles – linear and rotational motion.

Lecture 21: The moment of inertia. Rotation in a plane. Moment of inertia of rigid bodies. Angular momentum and energy of rotation.

Lecture 22: Principal axes. Calculations of moments of inertia. Examples.

Lecture 23: The perpendicular and parallel axis theorems. Angular impulse collision, and rolling bodies. Examples.

Lecture 24: Introduction to Lagrangian mechanics. Definition of terms: gereralized coordinates, degrees of freedom, constraints, configuration space. The Lagrangian.

Lecture 25: The calculation of variations. The Euler-Lagrange equation. The principle of stationary action (Hamilton's principle).

Lecture 26: Conjugate momentum and cyclic coordinates. Examples in several coordinate systems.

Lecture 27: The Lagrangian method. More examples. Hamiltonian mechanics.

Lecture 28: The Hamiltonian and energy conservation. Examples. Noether's theorem.

Lecture 29: In reserve.

Syllabus : CP1 Classical Mechanics : 2016/2017

Newton’s law of motion. Mechanics of particles in one dimension. Energy, work and impulse. Conservation of linear momentum including problems where the mass changes, e.g. the motion of a rocket ejecting fuel. Conservation of energy.

Vector formulation of Newton’s law of motion. Time-dependent vectors and differentiation of vectors.

Mechanics of particles in two dimensions. Equations of motion in Cartesian and plane polar coordinates. Simple cases of the motion of charged particles in uniform **E** and **B** fields.

Projectiles moving under gravity, including such motion subject to a damping force proportional to velocity. Dimensional Analysis.

Systems of point particles. Centre of mass (or momentum) frame and its uses. Torque and angular momentum. Conservation of angular momentum. Two-body collisions.

Central forces. Importance of conservation of energy and angular momentum. Classification of orbits as bound or unbound (derivation of equation for $u=1/r$ not required; explicit treatment of hyperbolae and ellipses not required). Inverse square central forces. Examples from planetary and satellite motion and motion of charged particles under the Coulomb force. Distance of closest approach and angle of deviation.

Calculus of variations. Principle of stationary action (Hamilton principle). The Euler-Lagrange equation. Constraints. Application to particle motion in one and two dimensions. Small oscillations, normal coordinates. Compound pendulum. Conservation laws. Noether’s theorem. The Hamiltonian and energy conservation.

Moment of inertia of a system of particles. Use of perpendicular and parallel-axis theorems. Moment of inertia of simple bodies. Simple problems of rigid body dynamics. Angular impulse, collision and rolling. The concept of principal axes. Angular momentum and total energy in rigid body rotation.