#### PHYS 3053—Physical Mechanics II Autumn 2020

# 1 Equations of Motion [\*Reading Assignment]

#### 1.1 Introduction

- 1.2 Forces of the Form F(t)
- 1.3 Forces of the Form F(v)
- 1.4 Dimensional Analysis
- 1.5 Forces of the Form F(x)

# 2 Harmonic Oscillator

- 2.1 Simple Harmonic Oscillator
- 2.2 Time translation invariance and linearity
- 2.3 Linear homogeneous ordinary differential equation
- 2.4 Forces of the form F = F(v) revisited (HOMEWORK)
- 2.5 Energy in Harmonic Oscillator
- 2.6 Small Oscillations
- 2.7 Coupled Oscillators and Normal Modes
- 2.8 Matrix Formalism for Normal Modes

# 3 Lagrangian Dynamics

- 3.1 Introduction
- 3.2 The Lagrangian, the Action, and Hamilton's Principle
- 3.3 Calculus of Variations
- 3.4 Functional Derivatives
- 3.5 Back to Hamilton's Principle
- 3.6 More Degrees of Freedom

- 3.7 The Euler-Lagrange equation
- 3.8 Generalized Momenta and Generalized Forces
- 3.9 Symmetries and Conservation Laws
- 3.10 Noether's Theorem
- 3.11 Lagrange Multipliers
- 3.12 Constraints and Generalized Forces of Constraints

# 4 The Hamiltonian Dynamics

- 4.1 Hamiltonian and Hamilton Equations of Motion
- 4.2 The Hamiltonian and Energy
- 4.3 Advantages of Hamiltonian Formalism
- 4.4 The Hamiltonian and Quantum Mechanics
- 4.5 Quantum Mechanics and the Sum Over Paths

## 5 Conservation of Angular Momentum

- 5.1 Introduction: Torque and Orbital Angular Momentum
- 5.2 Effective Potential for a Central Force
- 5.3 Small Oscillations
- 5.4 Effective Potential, Lagrangian, and Hamiltonian
- 5.5 Orbit Equation and Eccentricity
- 5.6 Polar Equation of a Conic Section
- 5.7 Kepler's Laws
- 5.8 Rutherford Scattering

## 6 Particle Systems and Rigid Bodies

- 6.1 Many Particle System
- 6.2 Rotational Equation of Motion
- 6.3 Rigid Bodies and Static Equilibrium
- 6.4 Rotations of Rigid Bodies
- 6.5 Gyroscope and Precession
- 6.6 Moment of Inertia Tensor
- 6.7 Principal Moments of Inertia and Principal Axes
- 6.8 Impulses and Billiard Shots
- 6.9 Eigenvalues and Eigenvectors of Inertia
- 6.10 Euler equations
- 6.11 A Free Symmetric Top and Euler Angles
- 6.12 The Tennis Racket Theorem
- 6.13 Transformation to Moving Coordinate Frames
- 6.14 Fictitious Forces
- 6.15 Foucault's Pendulum

#### 7 Classical Collision Theory

- 7.1 Galilean Transformation
- 7.2 Elastic Collisions
- 7.3 Inelastic Collisions

### 8 Special Relativity

- 8.1 The Principles of the Special Relativity
- 8.2 Lorentz Transformation
- 8.3 Length Contraction
- 8.4 Time Dilation

- $8.5\,$  The Twin Paradox
- 8.6 The Addition of Velocity
- 8.7 Relativistic Momentum and Energy
- 8.8 The Space-Time 4-vector
- 8.9 The Momentum-Energy 4-vector
- 8.1 The Metric Tensor in the Minkowski Space
- 8.11 Scalar Product of 4-vectors
- 8.12 Relativistic Dynamics

#### **BONUS:** The Cosmological Principle and Hubble Expansion