Outline of Study Groups : EM & CM

1. Electromagnetism

   a. Maxwell Equations:

      i Differential and Integral form

      ii Derive scalar potential V and vector potential $\vec{A}$ and discuss their dynamics.

      iii Gauge transformation, Coulomb and Lorentz Gauge

      Ref: ***Jackson - Classical Electrodynamics*** *Ch6.1, Ch6.6(Macroscopic Maxwell Equations), Ch6.2(Vector and Scalar Potentials), Ch6.3(Gauge Transformation)*
      Griffith - Introduction to Electrodynamics *Ch7.3.3(conclusion), Ch2.2∼Ch2.3(Guass's Law and Electrostatic potential), Ch5.3∼5.4(Ampere's Law and no-name Law and vector potential for magnetostatics case), Ch7 (for the remaining), Ch10.1(gauge, gauge transformation)*

   b. Solving Maxwell Equations (static case):

      i Some Examples for Maxwell Eqs + B.C.

      ii Solving Laplacian and Poisson Equation and their properties (uniqueness)

      iii Green's Function & Mirror charges methods

      Ref: ***Jackson - Classical Electrodynamics*** *Ch1.5(Boundary Condition at Interface Between Different Media), Ch1.9(Uniqueness of the Solution with Boundary Conditions), Ch2.9, Ch3.1, Ch3.7(Laplace equation in Rectangular,Spherical and Cylindrical Coordinates), Ch2.6(Green Function for the Sphere)*
      Griffith - Introduction to Electrodynamics *Ch2.3.5(Electrostatic B.C), Ch3.1 ∼ Ch3.3 (Laplace Equation and mirror charge), Ch5.4(solving magnetic vector potential)*

   c. EM waves with or without source

      i Poyting Vector & the energy conservation

      ii Electric & Magnetic Dielectric & B.C.

      iii Multiple Expansion (optional)

      iv EM Wave in Dielectric & Snell Eq. & Fresnel Eq.

      Ref: ***Jackson - Classical Electrodynamics*** *Ch6.7(Poynting's Theorem and Conservation of Energy and Momentum), Ch4.1(Multipoles Expansion), Ch4.4(Boundary-Value Problems with Dielectrics)*
      Griffith - Introduction to Electrodynamics *Ch2.4(energy density for electric field), Ch7.2.4(energy density for magnetic field), Ch8.1(poynting theorem), Ch9 (em wave), Ch3.4(multiple expansion), Ch4(Dielectric), Ch6(Magnetic Field in Matter)*

2. Classical Mechanics

   a. Lagrangian Formalism

      i Generalized coordinates, degree of freedom and constraints (holonomic, nonholonomic, nonintegrable, rheonomous, scleronomous)

      ii Using virtual displacement to derive d'Alembert's principle (no constraint = Newton 2nd law) and Euler Eq. (E.O.M.)

      iii The principle of least action, using variation method to derive Euler Eq.

      iv Some examples : pendulum, free fall, a ball on a bowl,... (optional)

      v What is field? Lagrangian formalism for fields (optional)

      Ref: ***Goldstein - Classical Mechanics*** *Ch1.4, Ch1.6(d"Alembert's principle, a first taste of Lagrangian), Ch2.1 ∼ 2.5 (Least Action Principle, variation)*
      Marion - Classical Dynamics of Partices and Systems *Ch6.2, Ch6.3 (the easier version for variation method)*
      David Tong, "Lectures on Quantum Field Theory" *Ch1.1 (Classical Field (advanced))*
      Jorge V. Jose Classical Dynamics - A Contemporary approach *Ch2,3*

   b. Noether Theorem

      i. Infinitesimal and finite transformation (this is why ω is a vector while θ is not)

      ii. The def of symmetry and the statement of the Noether Theorem

      iii. Noether current and the conserved charge

      iv. Some examples : translation, rotation, internal,... (optional)

      Ref: ***Goldstein - Classical Mechanics*** *Ch2.6, Ch2.7(Noether Theorem)*
      David Tong, "Lectures on Quantum Field Theory" *Ch1.3.1 ∼ Ch1.3.3 (Noether Theorem for Classical Field (advanced))*
      A short review on Noether's theorem, gauge symmetries and boundary terms 1601.0361 *p5∼p26*

   c. Hamiltonian Formalism

      i. Legendre transformation, canonical relation, physical meaning (H=T+V holds iff system have some restrictions), Liouville Theorem

      ii. Canonical transf, generating function and Hamilton-Jacobi Eq.

      iii. Action-angle coordinates and adiabatic invariance (optional)

      iv. Poisson bracket (Lie bracket structure) and canonical invariant

      v. Some examples : charged particle in an EM field (optional)

      vi. Primary, Secondary constraints & First, Second class constraints & Dirac bracket : Gauge Invariance

      vii. Hamiltonian in field language, canonical conjugate field (optional)

      Ref: ***Goldstein - Classical Mechanics*** *Ch8 (Hamilton E.O.M)*
      Shankar - Principles of Qunatum Mechanics *Ch2.5∼2.8*
      Jorge V. Jose - Classical Dynamics - A Contemporary approach *Ch5*

   d. Gauge Theory (optional)

      i. Gauge transformation, gauge symmetry and gauge inavriance of the action

   ii. Noether Identity
   iii. generating sets and Lie algebras
   iv. Counting degree of freedom, gauge fixation

   Ref: ***Marc Henneaux and Claudio Teitelboim - Quantization of Gauge Systems*** *Ch1*
   R.Jackiw - (Constrained) Quantization Without Tears
   L.D.Faddeev - Gauge Fields Introduction to Quantum Theory
   David Bleecker - Gauge Theory and Variational Principles
   A short review on Noether's theorem, gauge symmetries and boundary terms 1601.0361 - *section 3*

e. Rotation
   i. Velocity and acceleration in rotation frame
   ii. Coriolis force
   iii. Euler Rotation and Euler angles
   iv. Quaternion and rotation, SU(2), SO(3) and Sp(1) (optional)

   Ref: ***Goldstein - Classical Mechanics*** *Ch4*

f. Central Force field
   i. Differential and integration Eqs, effective potential
   ii. Kepler laws, Relations between some physical quantities : Energy, Eccentricity, Angular Momentum, ...
   iii. Laplace-Runge-Lenz (LRL) Vector, SO(4) (optional)
   iv. Scattering, Differential Cross-Section

   Ref: ***Goldstein - Classical Mechanics*** *Ch3*
   L. D. Landau and E. M. Lifshitz *Ch18∼Ch20*

- Recommended books for E& M :
  a. David J. Griffiths, ”Introduction to electrodynamics” 4th ed.
  b. John David Jackson, ”Classical Electrodynamics” 3rd ed.
  c. Roald K. Wangsness, ”Electromagnetic Fields” 2nd ed.
- Recommended books for Classical Mechanics:
  a. Vladimir I. Arnold, ”Mathematical Methods of Classical Mechanics”
  b. ”Classical Mechanics” by H. Goldstein, C.P. Poole, JR. J.L. Safko, 3rd edition
  c. L.D. Landau and E.M.Lifshitz , ”Mechanics”
  d. L.D. Landau and E.M.Lifshitz, ”The Classical Theory of Fields”
  e. David Tong, ”Lectures on Quantum Field Theory”, section 1
  f. Marc Henneaux and Claudio Teitelboim, ”Quantization of Gauge Systems”