Physics 136 Caltech
Kip Thorne Oct 16, 2002

Important Concepts

Chapters 1 through 3

I Frameworks for physical laws and their relationships to each other
- A General Relativity, Special Relativity and Newtonian Physics: Sec. 1.1
- B Phase space for a collection of particles: Chap 2
- C Phase space for an ensemble of systems: Chap 3
- D Relationship of Classical Theory to Quantum Theory
  - 1 Mean occupation number as classical distribution function: Sec. 2.3
  - 2 Mean occupation number determines whether particles behave like a classical wave, like classical particles, or quantum mechanically: Secs. 2.3 & 2.4; Ex. 2.1; Fig. 2.5

II Physics as Geometry
- A Newtonian: coordinate invariance of physical laws
  - 1 Idea Introduced: Sec. 1.2
  - 2 Newtonian particle kinetics as an example: Sec. 1.4
- B Special relativistic: frame-invariance of physical laws
  - 1 Idea introduced: Sec. 1.2
  - 2 Relativistic particle kinetics: Sec. 1.4
  - 3 4-momentum conservation: Secs. 1.4 & 1.12
    - a Stress-energy tensor: Sec. 1.12
  - 4 Electromagnetic theory: Sec. 1.10
    - a Lorentz force law: Sec. 1.4
  - 5 Kinetic theory: Chap. 2
    - a Derivation of equations for macroscopic quantities as integrals over momentum space [Sec. 2.5]
    - b Distribution function is frame-invariant and constant along fiducial trajectories [Secs. 2.2 & 2.7]
- C Statistical mechanics: invariance of the laws under canonical transformations (change of generalized coordinates and momenta in phase space): Sec. 3.2, Ex. 3.1

III 3+1 Splits of spacetime into space plus time, and resulting relationship between frame-invariant and frame-dependent laws of physics
- A Particle kinetics: Sec. 1.6
- B Electromagnetic theory: Sec. 1.10
- C Continuum mechanics; stress-energy tensor: Sec. 1.12
- D Kinetic theory: Secs. 2.2, 2.5 & 2.7
  - 1 Cosmic microwave radiation viewed in moving frame: Ex. 2.3

IV Spacetime diagrams
- A Introduced: Sec. 1.7
- B Simultaneity breakdown, Lorentz contraction, time dilation: Exercise 1.11
- C The nature of time; twins paradox, time travel: Sec. 1.8
- D Global conservation of 4-momentum: Secs. 1.6 & 1.12
- E Kinetic theory -- Momentum space: Sec. 2.2

- V Statistical physics concepts
  - A Systems and ensembles: Sec. 3.2
  - B Distribution function
    - 1 For particles: Sec. 2.2
    - 2 For photons, and its relationship to specific intensity: Sec. 2.2
    - 3 For systems in statistical mechanics: Sec. 3.2
    - 4 Evolution via Vlasov or Boltzmann transport equation: Sec. 2.7
      - a Kinetic Theory: Sec 2.7
      - b Statistical mechanics: Sec. 3.3
  - C Thermal equilibrium
    - 1 Distribution functions: Sec. 2.4
    - 2 In statistical mechanics; general form of distribution function in terms of quantities exchanged with environment: Sec. 3.4
    - 3 Evolution into statistical equilbrium--phase mixing and coarse graining: Secs. 3.6 and 3.9
  - D Specific statistical-equilibrium ensembles and their uses
    - 1 Canonical, Gibbs, grand canonical and microcanonical defined: Sec. 3.4
    - 2 Microcanonical: Sec. 3.5 and Ex. 3.8
    - 3 grand canonical: Sec. 3.8 and Ex. 3.6
  - E Fluctuations in statistical equilibrium
    - 1 Particle number in a box: Ex. 3.7
  - F Entropy
    - 1 Defined: Sec. 3.6
    - 2 Second law (entropy increase): Secs. 3.6, 3.9
    - 3 Entropy per particle: Secs. 3.8, 3.9, Fig. 3.4, Exs. 3.5, 3.9
  - G Macroscopic properties as integrals over momentum space:
    - 1 In kinetic theory
      - a Number-flux vector, stress-energy tensor: Sec. 2.5
      - b Equations of state: Sec. 2.6
      - c Transport coefficients: Sec. 2.8
    - 2 In statistical mechanics: Extensive thermodynamic variables
      - a Grand partition function: Ex. 3.6
- VI Computational techniques
  - A Tensor analysis
    - 1 Without a coordinate system, abstract notation: Secs. 1.3 and 1.9
    - 2 Index manipulations in Euclidean 3-space and in spacetime
      - a Tools introduced; slot-naming index notation: Sec's 1.5, 1.7 &1.9
      - b Used to derive standard 3-vector identities: Exercise 1.15
  - B Two-lengthscale expansions: Box 2.2
    - 1 Solution of Boltzmann transport equation in diffusion approximation: Sec. 2.8
    - 2 Semiclosed systems in statistical mechanics: Sec. 3.2
    - 3 Statistical independence of subsystems: Sec. 3.4