

# ICTP DIPLOMA PROGRAMME IN CONDENSED MATTER PHYSICS 2017-18

## SYLLABUS

**Electrons and Phonons in Solids - {24 Lectures = 36 hours}**

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### 1. CRYSTAL STRUCTURES

Bravais Lattices  
Wigner-Seitz Unit Cell  
Lattices with a Basis  
Close Packed Lattices

### 2. RECIPROCAL LATTICE

Plane Waves with Lattice Periodicity  
Definition of Reciprocal Lattice  
Brillouin Zone

### 3. ELECTRONIC STATES IN A CRYSTAL

Bloch Theorem  
K-dependent Hamiltonian  
Band Structure  
Fermi Level and Fermi Surface  
Density of States  
Fermi-Dirac Distribution  
Heat Capacity of Free Electrons

### 4. QUASI-FREE-ELECTRON MODEL

Free-Electron Bands in a Ghost Lattice  
Splitting Degeneracies  
Estimate of Splitting with Bare Ionic Potential  
Thomas-Fermi screening

### 5. TIGHT-BINDING APPROXIMATION

Derivation of Secular Equation  
Matrix Elements between s and p States  
Examples including Graphene, fcc and bcc Lattices with s, p Orbitals

### 6. APPLICATION OF BAND THEORY

Optical Properties of Crystals

Vertical Transitions

Direct and Indirect Gap  
Velocity of a Bloch State  
Semiclassical Transport  
Bloch Oscillations

### 7. BORN-OPPENHEIMER APPROXIMATION

Full Hamiltonian (Electrons + Ions)  
Electronic Hamiltonian  
Newton's Equation as Classical Limit & Ion Dynamics

## 8. PHONONS

Expansion of Total Energy

Force Constants and Dynamical Matrix

Normal Modes

Linear Monoatomic Chain

Linear Chain with Two Springs

Acoustic and Optical Modes