

Field Guide to

# **Solid State Physics**

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## Field Guide to Solid State Physics

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Solid state physics is a branch of physics that deals primarily with the physical properties of periodic condensed matters, especially the electromagnetic, thermodynamic, and structural properties of various systems, such as semiconductors, quantum structures, and superconductors; these properties are the consequences of solids interacting with light and under external fields, etc.

The *Field Guide to Solid State Physics* provides a compact introduction of select topics within the field of condensed-matter physics. For students and engineers alike, the book facilitates an in-depth understanding of physical concepts, as well as their applications, to help them develop new ideas for innovative devices. The topics chosen were influenced by our own areas of interest: single-particle and many-body interactions in the form of quasi-particle and collective excitations. Whenever possible, simple line art illustrates the essential concepts.

Over the last few decades, we have witnessed the significant (and increasing) effect of solid state physics on everyday life. The field is essential for the development of state-of-the-art concepts because it provides effective guidance for designing circuits and new materials for electronic and spintronic devices (it contributed to both the transistor and the semiconductor chip). Over the last ten years, more than half of the Nobel Prizes in physics were awarded to topics relevant to solid state physics.

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## Glossary of Symbols

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0D	Zero-dimensional
1D	One-dimensional
2D	Two dimensional
3D	Three-dimensional
<b>A</b>	Vector potential
<b>a<sub>1</sub>, a<sub>2</sub>, a<sub>3</sub></b>	Vectors defining unit cell
<b>B</b>	Magnetic field
<b>b<sub>1</sub>, b<sub>2</sub>, b<sub>3</sub></b>	Vectors defining reciprocal lattice
bcc	Body-centered cubic
BCS	Bardeen–Cooper–Schrieffer
BJT	Bipolar junction transistor
BL	Bravais lattice
BZ	Brillouin zone
CB	Conduction band
CB	Coulomb blockade
CBM	Conduction band minimum
<i>c<sub>V</sub></i>	Specific heat at constant volume
<i>D<sub>n</sub></i>	Diffusion coefficient
DFT	Density functional theory
dHvA	de Haas–van Alphen
DOS	Density of states
<b>E</b>	Electric field
<i>E<sub>c</sub></i>	Charging energy
<i>E<sub>F</sub></i>	Fermi energy
<i>E<sub>g</sub></i>	Bandgap energy
<i>F</i>	Free energy
<i>f<sub>FD</sub>(e)</i>	Fermi-Dirac distribution function
fcc	Face-centered cubic
FD	Fermi–Dirac
FQHE	Fractional quantum Hall effect
FS	Fermi surface
GaAs	Galium arsenide
Ge	Germanium
GL	Ginzburg–Landau
<i>H</i>	Hamiltonian
hcp	Hexagonal close-packed
HRs	Hund’s rules
<i>I[f]</i>	Collision integral
<b>J</b>	Total angular momentum

## Glossary of Symbols

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<b>k</b>	Wavevector
<b>K</b>	Reciprocal lattice vector
KS	Kohn–Sham
<b>L</b>	Total orbital momentum
LDA	Local density approximation
LED	Light-emitting diode
<b>M</b>	Magnetization
$m^*$	Effective mass
MBE	Molecular beam epitaxy
MOS	Metal–oxide–semiconductor
MOSFET	Metal–oxide–semiconductor field effect transistor
MRI	Magnetic resonance imaging
$n$	Density of electrons
$N_A$	Concentrations of acceptors
$N_D$	Concentrations of donors
$n_i$	Intrinsic concentration
$n_{\mathbf{q}}(\mathbf{r}, t)$	Local density of phonons
NMR	Nuclear magnetic resonance
NN	Nearest neighbor
$p_F$	Fermi momentum
$R_H$	Hall coefficient
rf-SQUID	Radio-frequency superconducting quantum interference device
RKKY	Ruderman–Kittel–Kasuya–Yosida
RL	Reciprocal lattice
<b>S</b>	Spin angular momentum operator
SET	Single-electron transistor
Si	Silicon
SOI	Silicon-on-isolator
$T$	Absolute temperature
$T_1$	Longitudinal relaxation time
$T_2$	Transverse relaxation time
$T_C$	Critical temperature
TB	Tight binding
$u_{\mathbf{k},n}(\mathbf{r})$	Periodic part of the Bloch function
$V(\mathbf{r})$	Periodic potential
(h,k,l)	Miller indices
$\hbar$	Dirac constant

## Glossary of Symbols

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$\Delta$	Order parameter
$\varepsilon(\omega)$	Electrical permittivity
$\lambda$	Wavelength
$\boldsymbol{\mu}$	Magnetic moment
$\mu_B$	Bohr magneton
$\mu_n$	Mobility
$\rho(E)$	Density of states
$\sigma$	Electrical conductivity
$\tau$	Average time between collisions
$\Phi_0$	Flux quantum
$\Phi$	Magnetic flux
$\chi$	Magnetic susceptibility
$\psi$	Wave function
$\psi_{\mathbf{k},n}(\mathbf{r})$	Bloch function
$\omega$	Frequency
$\omega_c$	Cyclotron frequency
$\omega_p$	Plasma frequency
$\Omega$	Volume of unit cell in real space
$\Omega_{\mathbf{K}}$	Volume of the primitive cell in the reciprocal lattice
QD	Quantum dot
QPC	Quantum point contact
VB	Valence band
VBM	Valence band maximum
VLSI	Very-large-scale integration
WS	Wigner–Seitz