PHYSICAL REVIEW

AND

PHYSICAL REVIEW LETTERS

INDEX

VOLUMES 21 AND 22 *Third Series*

JANUARY-DECEMBER 1980

PHYSICAL REVIEW
AND
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INDEX

Including

PHYSICAL REVIEW A, B, C, and D

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JANUARY - DECEMBER 1980

INTRODUCTION

As with last year's Index, this combined volume once again covers a full year of journal publications. The compilation of entries was prepared by the American Physical Society editorial staff from the computerized data base system developed in the journals' Editorial Office using the UNIX* system.

Entries under each author or subject heading are listed in the following order: Physical Review Letters, Physical Review A, B, C, D. Entries for each journal are listed in ascending order of volume and page number. For articles in Physical Review B and D, a small (1) or (15) at the end of the entry indicates that the article appeared in an issue dated the 1st or 15th of the month, respectively. The abbreviation (CA) appearing in an entry represents a Comment, Communication, or Addendum; the abbreviation (E) represents an Erratum.

In the Author Index a full listing occurs under the name of the first author only. Other author entries list the volume and page of the publication and direct the reader to the first-author entry. Authors who have used more than one version of their names are listed under the most complete version, in those cases where we could unambiguously determine that the names identified the same author. Every author is again strongly urged to select one form of his name and to use this consistently.

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PHYSICAL REVIEW LETTERS
INDEX

THIRD SERIES, VOLUMES 21 AND 22 JANUARY–DECEMBER 1980

Subject Index

Papers are indexed under the following headings, which are a subset of the 1977 version of PACS. Only those headings which are relevant to papers published in *The Physical Review* and *Physical Review Letters* are listed.

00. GENERAL

02. Mathematical methods in physics

02.10.+w Algebra, set theory, and graph theory

02.20.+b Group theory *(for algebraic methods in quantum mechanics, see 03.65.F; for symmetries in elementary particle physics, see 11.30)*

02.30.+g Function theory, analysis

02.40.+m Geometry, differential geometry, and topology *(see also 04 Relativity and gravitation)*

02.50.+s Probability theory, stochastic processes, and statistics *(see also 05 Statistical physics)*

02.60.+y Numerical approximation and analysis

02.70.+d Computational techniques *(for data handling and computation, see 06.50)*

02.90.+p Other topics in mathematical methods in physics

03. Classical and quantum physics: mechanics and fields

03.20.+i Classical mechanics of discrete systems: general mathematical aspects *(for applied classical mechanics of discrete systems, see 46.10; for celestial mechanics, see 95.10.C)*

03.30.+p Special relativity

03.40.−t Classical mechanics of continuous media: general mathematical aspects

03.40.Dz Mathematical theory of elasticity *(see also 46.20 Continuum mechanics, and 46.30 Mechanics of solids)*

03.40.Gc Fluid dynamics: general mathematical aspects *(see also 47 Fluid dynamics)*

03.40.Kf Waves and wave propagation: general mathematical aspects *(see also 46.30.M Mechanical and elastic waves, 43.20 General linear acoustics)*

03.50.−z Classical field theory

03.50.De Maxwell theory: general mathematical aspects *(for applied classical electrodynamics, see 41)*

03.50.Kk Other special classical field theories

03.65.−w Quantum theory; quantum mechanics *(see also 05.30 Quantum statistical mechanics)*

03.65 Bz Foundations, theory of measurement, miscellaneous theories

03.65.Ca Formalism

03.65.Db Functional analytical methods

03.65.Fd Algebraic methods *(see also 02.20 Group theory, 33.10.C Calculational methods in molecular spectroscopy)*

03.65.Ge Solutions of wave equations: bound states

03.65.Nk Nonrelativistic scattering theory

03.65.Sq Semiclassical theories and applications

. . . . . *Relativistic wave equations, see 11.10.Q*

03.70.+k Theory of quantized fields *(see also 11.10 Field theory)*

03.80.+r General theory of scattering *(see also 11.20 S-matrix theory and 11.80 Relativistic scattering)*

04. Relativity and gravitation

. . . . . ***Special relativity, see 03.30***

04.20.−q General relativity *(see also 02.40 Geometry and topology)*

04.20.Cv Fundamental problems and general formalism

04.20.Fy Canonical formalism, Lagrangians, and variational principles

04.20.Jb Solutions to equations

04.20.Me Conservation laws and equations of motion

04.30.+x Gravitational waves and radiation: theory

04.40.+c Continuous media; electromagnetic and other mixed gravitational systems

04.50.+h Unified field theories and other theories of gravitation

04.60.+n Quantum theory of gravitation

. . . . . ***Relativistic astrophysics, see 95.30.S***

. . . . . ***Relativistic cosmology, see 98.80.D***

04.80.+z Experimental tests of general relativity and observations of gravitational radiation

04.90.+e Other topics in relativity and gravitation

05. Statistical physics and thermodynamics *(see also 02.50 Probability theory, stochastic processes, and statistics)*

05.20.−y Statistical mechanics

05.20.Dd Kinetic theory

05.20.Gg Classical ensemble theory

05.30.−d Quantum statistical mechanics *(see also 67 Quantum fluids and 71 Electron states in condensed matter)*

05.30.Ch Quantum ensemble theory

05.30.Fk Fermion systems and electron gas

05.30.Jp Boson systems

05.40.+j Fluctuation phenomena, random processes, and Brownian motion

05.50.+q Lattice theory and statistics; Ising problems *(see also 64.60.C Order-disorder and statistical mechanics of model systems; 75.10.H Ising models)*

05.60.+w Transport processes: theory

05.70.−a Thermodynamics *(see also 64 Equations of state, phase equilibria, and phase transitions, and 65 Thermal properties of condensed matter; for chemical thermodynamics, see 82.60)*

05.70.Ce Thermodynamic functions and equations of state

05.70.Fh Phase transitions: general aspects

05.70.Jk Critical point phenomena

05.70.Ln Nonequilibrium thermodynamics, irreversible processes *(see also 31.70.F Potential energy surfaces, 82 Physical chemistry)*

05.90.+m Other topics in statistical physics and thermodynamics

06. Measurement science, general laboratory techniques, and instrumentation systems

06.20.−f Metrology

06.20.Hq Measurement standards

06.20.Jr Determination of fundamental constants

06.30.−k Measurement of basic quantities

06.30.Bp Measurement of spatial dimensions

06.50.−x Data handling and computation

06.50.Dc Data gathering, processing, and recording; data displays (including digital techniques)

06.70.−h General instrumentation

06.70.Td Servo and control devices

06.90.+v Other topics in measurement science, general laboratory techniques, and instrumentation systems

07. Specific instrumentation and techniques of general use in physics *(see also within each subdiscipline for specialized instrumentation and techniques)*

07.20.−n Thermal instrumeats and techniques

07.20.Mc Cryogenics

07.58.+g Magnetic resonance spectrometers, auxiliary instruments, and techniques *(see also 61.16.H EPR and NMR determinations)*

07.60.−j Optical instruments and techniques *(for radiation detection, see 07.62; for spectroscopy and spectrometers, see 07.65; for optical lens and mirror systems, see 42.78; for optical devices, techniques, and applications, see 42.80)*

07.60.Fs Polarimetry and ellipsometry

07.60.Ly Interferometers and Interferometry

07.62.+s Detection of radiation (bolometers, photoelectric cells, infrared and submillimeter wave detection)

07.65.−b Optical spectroscopy and spectrometers *(see also 07.85 X-ray spectroscopy)*

07.65.Eh Visible and ultraviolet spectroscopy and spectrometers

07.75.+h Mass spectrometers and mass spectrometry techniques

..... ***Radiation spectrometers and spectroscopic techniques, see 29.30***

..... ***Radiation measurement, detection, and counting, see 29.70***

07.85.+n X- and γ-ray instruments and techniques

10. THE PHYSICS OF ELEMENTARY PARTICLES AND FIELDS

(FOR COSMIC RAYS, SEE 94.40; FOR EXPERIM. METHODS AND INSTRUMENTATION, SEE 29)

11. General theory of fields and particles *(see also 03.65 Quantum theory, 03.70 Theory of quantized fields, 03.80 General theory of scattering)*

11.10.−z Field theory

11.10.Ef Lagrangian and Hamiltonian approach

11.10.Gh Renormalization

11.10.Jj Asymptotic problems and properties

11.10.Lm Nonlinear or nonlocal theories and models

11.10.Mn Schwinger source theory

11.10.Np Gauge field theories

11.10.Qr Relativistic wave equations

11.10.St Bound and unstable states; Bethe–Salpeter equations

11.20.−e *S*-matrix theory

11.20.Dj Scattering matrix and perturbation theory

11.20.Fm Dispersion relations and analytic properties of the *S* matrix

11.30.−j Symmetry and conservation laws *(see also 02.20 Group theory)*

11.30.Cp Lorentz and Poincaré invariance

11.30.Er Charge conjugation, parity, time reversal, and other discrete symmetries

11.30.Jw SU(2) and SU(3) symmetries

11.30.Kx SU(4) symmetry

11.30.Ly Other internal and higher symmetries

11.30.Na Nonlinear and dynamical symmetries (spectrum-generating symmetries)

11.30.Pb Supersymmetry

11.30.Qc Spontaneous symmetry breaking

11.30.Rd Chiral symmetries

11.40.−q Currents and their properties

11.40.Dw General theory of currents

11.40.Fy Lagrangian approach to current algebras

11.40.Ha Partially conserved axial-vector currents

11.50.−w Dispersion relations and sum rules

11.50.Ec *N* / *D* method

11.50.Jg Crossing symmetries

11.50.Li Sum rules

11.50.Nk Multivariable dispersion relations (including Mandelstam representation)

11.60.+c Complex angular momentum; Regge formalism *(see also 03.80 General theory of scattering, 12.40.M —in strong interactions)*

11.80.−m Relativistic scattering theory *(see also 03.80 General theory of scattering)*

11.80.Cr Kinematical properties (helicity and invariant amplitudes, kinematic singularities, etc.)

11.80.Et Partial-wave analysis

11.80.Fv Approximations (eikonal approximation, variational principles, etc.)

11.80.Gw Multichannel scattering

11.80.Jy Many-body scattering and Faddeev equation

11.80.La Multiple scattering

11.90.+t Other topics in general field and particle theory

12. Specific theories and interaction models; particle systematics

12.20.−m Electromagnetic and unified gauge fields

12.20.Ds Specific calculations and limits of quantum electrodynamics

12.20.Fv Experimental tests of quantum electrodynamics

12.20.Hx Unified field theories and models

12.25.+e Models for gravitational interactions *(see also 04.60 Quantum theory of gravitation)*

12.30.−s Models of weak interactions

12.30.Cx Neutral currents

12.30.Ez Intermediate bosons

12.40.−y Models of strong interactions

12.40.Bb Composite models of the structure of hadrons (general models, dynamics, schemes for confinement)

20. NUCLEAR PHYSICS

21. Nuclear structure

21.10.−k General and average properties of nuclei; properties of nuclear energy levels *(for properties of specific nuclei listed by mass ranges, see 27)*
21.10.Dr Binding energy and masses
21.10.Ft Shape, charge, and radius
21.10.Hw Spin, parity, and isobaric spin
21.10.Jx Spectroscopic factors
21.10.Ky Electromagnetic moments
21.10.Ma Level density and structure
21.10.Pc Single-particle structure in levels
21.10.Re Collective structure in levels (including rotational bands)
21.10.Sf Coulomb effects

21.30.+y Nuclear forces *(see also 13.75.C Nucleon-nucleon interactions)*

21.40.+d Few-nucleon systems

21.60.−n Nuclear-structure models and methods
21.60.Cs Shell model
21.60.Ev Collective models
21.60.Fw Models based on group theory
21.60.Gx Cluster models
21.60.Jz Hartree–Fock and random-phase approximations

21.65.+f Nuclear matter

..... ***Exotic atoms and molecules, see 36.10***

21.80.+a Hypernuclei

21.90.+f Other topics in nuclear structure

23. Nuclear decay and radioactivity
(see also 82.55 Radiochemistry)

23.20.−g Electromagnetic transitions
23.20.Ck Lifetimes and transition probabilities
23.20.En Angular distribution and correlation measurements
23.20.Gq Multipole mixing ratios
23.20.Js Multipole matrix elements
23.20.Lv Gamma transitions and level energies
23.20.Nx Internal conversion and extranuclear effects

23.40.−s β decay; electron and muon capture
23.40.Bw Weak interaction and lepton aspects of β decay
23.40.Hc Nuclear matrix elements and nuclear structure inferred from β decay

23.60.+e α decay

23.90.+w Other topics in nuclear decay and radioactivity

30. ATOMIC AND MOLECULAR PHYSICS *(FOR PHYSICAL CHEMISTRY, SEE 82)*

32. Atomic spectra and interactions with photons

32.30.—r **Atomic spectra, grouped by wavelength ranges**

32.30.Bv Radiofrequency, microwave, and infrared spectra (including magnetic resonance spectra)

32.30.Jc Visible and ultraviolet spectra *(for fluorescence and phosphorescence spectra, see 32.50)*

32.30.Rj X-ray spectra

32.50.+d **Fluorescence, phosphorescence (including quenching)** *(for quenching processes, see also 34.)*

32.60.+i **Zeeman and Stark effects**

32.70.—n **Intensities and shapes of atomic spectral lines**

32.70.Cs Oscillator strengths, transition moments

32.70.Fw Lifetimes, absolute and relative intensities

32.70.Jz Line shapes, widths, and shifts

32.80.—t **Photon interactions with atoms**

32.80.Bx Level crossing and optical pumping

32.80.Dz Autoionization

32.80.Fb Photoionization and photodetachment

32.80.Hd Auger effect and inner-shell ionization

32.80.Kf Multiphoton processes

32.90.+a **Other topics in atomic spectra and interactions of atoms with photons**

33. Molecular spectra and interactions of molecules with photons

33.10.—n **Calculation of molecular spectra**

33.10.Cs Calculational methods (including new theoretical techniques and applications of group theory) *(see also 03.65.F Algebraic methods in quantum mechanics)*

33.10.Ev Rotational analysis

33.10.Gx Vibrational analysis

33.10.Jz Vibration-rotational analysis

33.10.Lb Vibronic, rovibronic, and rotation–electron-spin interactions

33.20.—t **Molecular spectra, grouped by wavelength ranges** *(for photoelectron spectra, see 33.60)*

33.20.Bx Radio-frequency and microwave spectra *(for NMR spectra, see 33.25; for EPR spectra, see 33.35)*

33.20.Ea Infrared spectra

33.20.Fb Raman and Rayleigh spectra (including optical scattering)

33.20.Kf Visible spectra

33.20.Lg Ultraviolet spectra

33.20.Rm X-ray spectra

33.25.—j **Nuclear magnetic resonance (NMR) and relaxation**

33.25.Bn Relaxation phenomena

33.25.Dq Chemical shifts

33.25.Fs Nuclear spin interactions and quadrupole effects

33.35.—q **Electron paramagnetic resonance (EPR) and relaxation**

33.35.Cv Relaxation phenomena

33.45.+x **Mossbauer spectra**

33.50.—j **Fluorescence and phosphorescence; radiationless transitions (intersystem crossing, internal conversion)** *(for quenching processes, see also 34)*

33.50.Dq Fluorescence and phosphorescence spectra

33.50.Hv Radiationless transitions

33.55.+c **Zeeman and Stark effects; magneto-optical and electro-optical spectroscopy; circular dichroism**

33.60.—q **Photoelectron spectra**

33.60.Cv Ultraviolet and vacuum-ultraviolet photoelectron spectra

33.60.Fy X-ray photoelectron spectra

33.70.—w **Intensities and shapes of molecular spectral lines and bands**

33.70.Ca Oscillator and band strengths, transition moments, and Franck–Condon factors

33.70.Fd Lifetimes, absolute and relative line and band intensities

33.70.Jg Line and band widths, shapes, and shifts

33.80.—b **Photon interactions with molecules**

33.80.Eh Autoionization, photoionization, and photodetachment

33.80.Gj Diffuse spectra; predissociation, photodissociation

33.80.Kn Multiphoton processes

33.90.+h **Other topics in molecular spectra and molecular interactions with photons**

34. Atomic and molecular collision processes and interactions

34.10.+x **General theories and models (including statistical theories, transition state, stochastic and trajectory models, etc.)**

34.20.—b **Interatomic and intermolecular potentials and forces**

34.20.Be General potential functions and intermediate-range forces *(see also 31.70.F and 82.20.K for potential energy surfaces)*

34.20.Fi Long-range forces

34.20.Kn Short-range forces

. . . . . *Molecular solids, see 31.70.K*

34.40.+n **Elastic scattering of atoms and molecules**

34.50.—s **Inelastic scattering of atoms and molecules**

34.50.Ez Rotational and vibrational energy transfer

34.50.Hc Electronic excitation and ionization (including beam-foil excitation and ionization)

34.50.Lf Chemical reactions, energy disposal, and angular distribution, as studied by atomic and molecular beams *(see also 31.70.F and 82.20.K for potential-energy surfaces, 82.40.D Beam reactions)*

34.70.+e **Charge transfer** *(see also 82.30.F Charge transfer reactions)*

34.80.—i **Electron scattering**

34.80.Bm Elastic scattering of electrons by atoms and molecules

34.80.Dp Atomic excitation and ionization by electron impact

34.80.Gs Molecular excitation, ionization, and dissociation by electron impact

34.90.+q **Other topics in atomic and molecular collision processes and interactions**

35. Experimentally derived information on atoms and molecules; instrumentation and techniques

35.10.—d **Atoms**

35.10.Bg Atomic masses, mass spectra, abundances, and isotopes *(for mass spectrometry, see also 07.75)*

35.10.Di Electric and magnetic moments, polarizability

35.10.Fk **Relativistic corrections, fine- and hyperfine-structure constants**

35.10.Hn Ionization potentials, electron affinities

35.20.—i **Molecules** *(see also 61.55, 61.60, and 61.65 for specific structures of elements and alloys, of other inorganic materials, and of organic materials, respectively)*

35.20.Bm General molecular conformation and symmetry; stereochemistry

35.20.Dp Interatomic distances and angles

35.20.Gs Bond strengths, dissociation energies, hydrogen bonding, etc.

35.20.My Electric and magnetic moments (and derivatives), polarizability, and magnetic susceptibility

35.20.Pa Rotation, vibration, and vibration–rotation constants

35.20.Sd Hyperfine- and fine-structure constants

35.20.Vf Ionization potentials, electron affinities, molecular core binding energy

35.20.Yh Correlation times in molecular dynamics

35.80.+s **Atomic and molecular measurement and techniques**

36. Studies of special atoms and molecules

36.10.—k **Exotic atoms and molecules (containing mesons, muons, and other abnormal particles)**

36.10.Dr Positronium, muonium, muonic atoms and molecules

36.10.Gv Mesonic atoms and molecules, hyperonic atoms and molecules

36.20.—r **Macromolecules and polymer molecules** *(for polymer reactions and polymerization, see 82.35; for biological macromolecules and polymers, see also 87.15)*

36.40.+d **Atomic and molecular clusters**

36.90.+f **Other special atoms and molecules**

40. CLASSICAL AREAS OF PHENOMENOLOGY (INCLUDING APPLICATIONS)

41. Electricity and magnetism: fields and charged particles

41.10.−j Classical electromagnetism

. . . . . *Maxwell theory, see 03.50.D*

41.10.Dq Electrostatics, magnetostatics

41.10.Hv Electromagnetic waves: theory

41.70.+t Particles in electromagnetic fields: classical aspects (including synchrotron radiation)

41.80.−y Particle beams and particle optics *(see also 07.77 Particle beam production and handling, 07.80 Electron and ion microscopes and techniques)*

41.80.Dd Electron beams and electron optics

42. Optics *(for properties of gases and of liquids and solids see 51.70 and 78, respectively)*

42.10.−s Propagation and transmission in homogeneous media

42.10.Fa Edge and boundary effects, refraction

42.10.Mg Coherence

42.10.Qj Propagation and transmission in homogeneous and anisotropic media; birefringence

42.20.−y Propagation and transmission in inhomogeneous media

42.20.Gg Scattering from haze, fog, dust, etc. *(see also 42.68 Atmospheric optics)*

42.40.−i Holography

42.40.Kw Holographic instrumentation and techniques

42.50.+q Quantum optics

42.55.−f Lasing processes

42.55.Bi General theory of lasing action

42.55.Fn Inert gas lasers

42.60.−v Laser systems and laser beam applications

42.60.By Design of specific laser systems

42.60.Da Laser resonators and cavities

42.60.Fc Laser beam modulation

42.60.He Optical problems related to properties and interactions of laser beams

42.60.Kg Optical problems related to applications of laser beams

42.65.−k Nonlinear optics

42.65.Bp General theory

42.65.Cq Stimulated Raman, Brillouin, and Rayleigh scattering; parametric oscillations and harmonic generation

42.65.Gv Photon echoes, self-induced transparency, optical saturation, and related effects

42.65.Jx Beam trapping, self focusing, thermal blooming, and related effects

42.68.−w Atmospheric optics

42.68.Vs Clouds, fog, haze, aerosols; effects of air pollution

42.70.−a Optical materials

42.70.Gi Light-sensitive materials

42.80.−f Optical devices, techniques, and applications

42.80.Fn Gratings, échelles

42.80.Mv Fiber optics

42.80.Sa Optical communication devices

43. Acoustics *(for more detailed headings, see Appendix, Sec. 43)*

43.20.+g General linear acoustics *(see also 03.40.K Mathematical problems in waves and wave propagation)*

43.25.+y Nonlinear acoustics and macrosonics

43.35.+d Ultrasonics, quantum acoustics, and physical effects of sound

. . . . . *Phonons in crystal lattices, see 63.20*

. . . . . *Plasma acoustics, see 52.35*

. . . . . *Low-temperature acoustics and sound in liquid helium, see 67*

. . . . . *Acoustical properties of solids, see 62.65; for ultrasonic relaxation, see 62.80*

. . . . . *Acoustical properties of thin films, see 68.60*

. . . . . *Surface waves in solids and liquids, see 68.10 and 68.25*

. . . . . *Acoustoelectric effects and acoustic wave amplification, see 72.50*

. . . . . *Magnetoacoustic effects, oscillations, and resonance, see 72.55 and 75.80*

. . . . . *Acoustic holography, see 43.63; for acousto-optical effects, see 78.20.H*

43.60.+d Acoustic signal processing

. . . . . ***Bioacoustics, see 87.50.C***

43.85.+f Acoustical measurements and instrumentation

44. Heat flow, thermal and thermodynamic processes

44.90.+c Other topics in heat flow, thermal and thermodynamic processes

46. Mechanics, elasticity, rheology

46.20.+e Continuum mechanics *(see also 03.40 —mathematical aspects)*

46.30.−i Mechanics of solids and rheology *(see also 62.20 Mechanical properties of solids, as related to microscopic structure)*

46.30.Jv Viscoelasticity, plasticity, viscoplasticity, creep, and stress relaxation (including rheology of solids)

47. Fluid dynamics

47.10.+g General theory *(see also 03.40.G—General mathematical aspects)*

47.15.−x Laminar flows

47.20.+m Hydrodynamic stability

47.25.−c Turbulent flows, convection, and heat transfer

47.25.Cg Isotropic turbulence

47.25.Jn Turbulent diffusion

47.25.Qv Convection and heat transfer *(see also 44.25 Convective and constrained heat transfer)*

47.30.+s Rotational flows and vorticity

47.35.+i Hydrodynamic waves

47.55.−t Nonhomogeneous flows

47.60.+i Flows in ducts, channels, and conduits

. . . . . ***Biological fluid dynamics, see 87.45***

47.65.+a Magnetohydrodynamics and electrohydrodynamics *(for MHD in plasma, see 52.30)*

47.90.+a Other topics in fluid dynamics

50. FLUIDS, PLASMAS, AND ELECTRIC DISCHARGES

(FOR FLUID DYNAMICS, SEE 47; FOR CONDENSED MATTER, SEE 60 AND 70)

51. Kinetic and transport theory of fluids; physical properties of gases

51.10.+y Kinetic and transport theory

51.20.+d Viscosity and diffusion: experimental

51.40.+p Acoustical properties of gases; ultrasonic relaxation *(see also 43 Acoustics; for liquids see 62.60 and 62.80)*

51.50.+v Electrical phenomena in gases *(see also 52 The physics of plasmas and electric discharges)*

51.60.+a Magnetic phenomena in gases *(for liquids, see 75)*

51.70.+f Optical phenomena in gases *(for liquids, see 78)*

51.90.+r Other topics in the physics of fluids

60. CONDENSED MATTER: STRUCTURE, MECHANICAL AND THERMAL PROPERTIES

65.40.−f **Heat capacities of solids** *(for specific heat of superconductors, see 74.30.E.; for specific heat of magnetic systems, see 75.40)*

65.40.Em Lattice and electron heat capacity

65.40.Hq λ and Schottky anomalies

65.50.+m **Thermodynamic properties and entropy**

65.70.+y **Thermal expansion and thermomechanical effects** *(see also 64.30 Equations of state)*

..... ***Thermal conduction in nonmetallic liquids, see 66.60; for nonmetallic solids, see 66.70***

..... ***Electronic thermal conduction, see 72.10, 72.15 and 72.20***

..... ***Thermal conductivity of superconductors, see 74.30.E***

..... ***Pyroelectric and electrocaloric effects, see 77.70***

66. Transport properties of condensed matter (nonelectronic)

66.10.−x **Diffusion and ionic conduction in liquids**

66.10.Cb Diffusion and thermal diffusion

66.10.Ed Ionic conduction *(see also 82.45 Electrochemistry)*

66.30.−h **Diffusion in solids**

66.30.Dn Theory of diffusion and ionic conduction in solids

66.30.Fq Self-diffusion in metals, semimetals, and alloys

66.30.Hs Self-diffusion and ionic conduction in nonmetals

66.30.Jt Diffusion, migration, and displacement of impurities

66.30.Lw Diffusion, migration, and displacement of other defects

66.30.Ny Chemical interdiffusion

66.60.+a **Thermal conduction in nonmetallic liquids** *(for thermal conduction in liquid metals, see 72.15.C)*

66.70.+f **Nonelectronic thermal conduction and heat-pulse propagation in nonmetallic solids** *(for statistical mechanics of lattice vibrations, see 63.70.; for thermal conduction in solid metals, see 72.15.C and 72.15.E)*

66.90.+r **Other topics in nonelectronic transport properties**

67. Quantum fluids and solids; liquid and solid helium *(see also 05.30 Quantum statistical mechanics)*

67.20.+k **Quantum effects on the structure and dynamics of nondegenerate fluids**

67.40.−w **Boson degeneracy and superfluidity of helium-4**

67.40.Bz Phenomenology and two fluid models

67.40.Db Quantum statistical theory; ground state, elementary excitations

67.40.Fd Dynamics of relaxation phenomena

67.40.Hf Hydrodynamics in specific geometries, flow in narrow channels

67.40.Kh Thermodynamic properties

67.40.Mj First sound

67.40.Pm Transport processes, second and other sounds, and thermal counterflow

67.40.Rp Films and weak link transport

67.40.Vs Vortices and turbulence

67.40.Yv Impurities and other defects

67.50.−b **Fermi fluids; liquid helium-3**

67.50.Dg Normal phase

67.50.Fi Superfluid phase

67.60.−g **Mixed systems; liquid helium-3, -4 mixtures**

67.60.Fp He II–^{3}He

67.70.+n **Films (including physical adsorption)**

67.80.−s **Solid helium and related quantum crystals**

67.80.Cx Lattice dynamics and sound propagation

67.80.Gb Thermal properties

67.80.Jd Magnetic properties and nuclear magnetic resonance

67.80.Mg Defects, impurities, and diffusion

67.90.+z **Other topics in quantum fluids and solids (e.g., neutron-star matter)**

68. Surfaces and interfaces; thin films and whiskers (structure and nonelectronic properties) *(for crystal growth, see 61.50.C; for impact phenomena, see 79.20; for corrosion, oxidation, and surface treatments, see 81.60)*

68.10.−m **Fluid surfaces and fluid–fluid interfaces**

68.10.Cr Surface energy (surface tension, interface tension, angle of contact, etc.)

68.10.Gw Interface activity, spreading

68.10.Jy Kinetics (evaporation, adsorption, condensation, catalysis, etc.) *(see also 82.65 Surface processes)*

68.15.+e **Liquid thin films**

68.20.+t **Solid surface structures**

68.25.+j **Mechanical and acoustical properties of solid surfaces and interfaces** *(for tribology, see 62.20.P; for friction, lubrication, and wear, see 81.40.P)*

68.30.+z **Dynamics of solid surfaces and interface vibrations**

68.40.+e **Surface energy of solids; thermodynamic properties** *(see also 82.65.D Thermodynamics of surfaces)*

68.45.−v **Solid–fluid interface processes** *(see also 82.65.M Sorption and accommodation coefficients)*

68.45.By Sorption equilibrium

68.45.Da Evaporation and condensation; adsorption and desorption kinetics

68.48.+f **Solid–solid interfaces (including bicrystals)** *(for grain boundaries, see 61.70.N)*

68.55.+b **Thin film growth, structure, and epitaxy** *(for techniques of crystal growth and film deposition, see 81.10 and 81.15, resp.)*

68.60.+q **Physical properties of thin films, nonelectronic**

68.90.+g **Other topics in the structure and nonelectronic properties of surfaces and thin films**

70. CONDENSED MATTER: ELECTRONIC STRUCTURE, ELECTRICAL, MAGNETIC, AND OPTICAL PROPERTIES

71. Electron states *(see also 63 Lattice dynamics, 73 Electronic structure and electrical properties of surfaces, interfaces, and thin films)*

71.10.+x **General theories and computational techniques**

71.20.+c **Electronic density of states determinations (including energy states of liquid semiconductors)** *(see also 65.40.E Electronic heat capacity)*

71.25.−s **Nonlocalized single-particle electronic states**

71.25.Cx Techniques of band-structure calculation (general theory, applications of group theory, analytic continuation, etc.)

71.25.Hc Measurement of Fermi surface parameters (including dHvA, magnetoacoustic, positron annihilation, and cyclotron resonance studies, etc.)

71.25.Jd Effective mass and g-factors

71.25.Lf Electron energy states in liquid metals

71.25.Mg Electron energy states in amorphous and glassy solids

71.25.Pi Band structure of crystalline metals

71.25.Rk Band structure of crystalline elemental semiconductors

71.25.Tn Band structure of crystalline semiconductor compounds and insulators

75.10.Dg Crystal-field theory and spin Hamiltonians
75.10.Hk Ising and other classical spin models
75.10.Jm Heisenberg and other quantized localized spin models
75.10.Lp Band and itinerant models

75.20.—g Diamagnetism and paramagnetism
75.20.Ck Nonmetals
75.20.En Metals and alloys
75.20.Hr Local moment in dilute alloys; Kondo effect *(see also 72.15.Q Electronic conduction)*

75.25.+z Spin arrangements in magnetically ordered materials (neutron studies, etc.)

75.30.—m Magnetically ordered materials: other intrinsic properties *(for critical point effects, see 75.40)*
75.30.Cr Saturation moments and magnetic susceptibilities
75.30.Ds Spin waves *(see also 76.50 Spin-wave resonance)*
75.30.Et Exchange and superexchange interactions *(see also 71.70 Level splitting and interactions)*
75.30.Gw Anisotropy
75.30.Hx Magnetic impurity interactions
75.30.Kz Magnetic phase boundaries (including magnetic transitions, metamagnetism, etc.)

75.40.—s Critical-point effects, specific heats, short-range order *(see also 65.40 Heat capacities)*
75.40.Bw General theory
75.40.Dy Ising and other classical spin models
75.40.Fa Heisenberg and other quantized spin models

75.50.—y Studies of specific magnetic materials *(see also 81.40.R Magnetic properties related to materials treatment)*
75.50.Bb Ferromagnetism of Fe and its alloys
75.50.Cc Ferromagnetism of other metals
75.50.Dd Ferromagnetism of nonmetals
75.50.Ee Antiferromagnetics
75.50.Gg Ferrimagnetics
75.50.Kj Amorphous magnetic materials
75.50.Mm Magnetic liquids

75.60.—d Domain effects, magnetization curves, and hysteresis
75.60.Ch Domain walls and domain structure *(for magnetic bubbles, see 75.70.K)*
75.60.Ej Magnetization curves, hysteresis, Barkhausen and related effects

75.70.—i Magnetic films and plates
75.70.Dp Properties in uniform state
75.70.Kw Domain structure (magnetic bubbles)

75.80.+q Magnetomechanical and magnetoelectric effects, magnetostriction

..... *Galvanomagnetic effects, see 72.15.G and 72.20.M*

..... *Magneto-optical effects, see 78.20.L*

75.90.+w Other topics in magnetic properties and materials

76. Magnetic resonances and relaxations in condensed matter; Mössbauer effect

76.20.+q General theory of resonances and relaxations

..... *Measurement techniques, see 07.58*

76.30.—v Electron paramagnetic resonance and relaxation
76.30.Da Ions and impurities: general
76.30.Fc Iron group (3*d*) ions and impurities (Ti–Cu)
76.30.He Platinum and palladium group (4*d* and 5*d*) ions and impurities (Zr–Ag and Hf–Au)
76.30.Kg Rare-earth ions and impurities
76.30.Mi Color centers and other defects
76.30.Pk Conduction electrons
76.30.Rn Free radicals

76.40.+b Diamagnetic and cyclotron resonances

76.50.+g Ferromagnetic, antiferromagnetic, and ferrimagnetic resonances; spin-wave resonance *(see also 75.30.D Spin waves)*

76.60.—k Nuclear magnetic resonance and relaxation
76.60.Cq Chemical and Knight shifts
76.60.Es Relaxation effects
76.60.Gv Quadrupole resonance
76.60.Jx Effects of internal magnetic fields
76.60.Lz Spin echoes

76.70.—r Magnetic double resonances and cross effects
76.70.Dx Electron–nuclear double resonance (ENDOR)
76.70.Ey Dynamical nuclear polarization
76.70.Fz Double nuclear magnetic resonance (DNMR)
76.70.Hb Optical double magnetic resonance (ODMR)

76.80.+y Mössbauer effect; other γ-ray spectroscopy

76.90.+d Other topics in magnetic resonances and relaxations

77. Dielectric properties and materials

(for conductivity phenomena, see 72.20 and 72.80)

77.20.+y Permittivity

77.30.+d Polarization and depolarization effects

77.40.+i Dielectric loss and relaxation

77.55.+f Dielectric thin films

77.60.+v Piezoelectricity and electrostriction *(for piezo-optical effects, see 78.20.H)*

77.70.+a Pyroelectric and electrocaloric effects

77.80.—e Ferroelectricity and antiferroelectricity
77.80.Bh Transitions and Curie point
77.80.Dj Domain structure and effects; hysteresis

77.85.+x Electrical resonances

77.90.+k Other topics in dielectric properties and materials

78. Optical properties and condensed-matter spectroscopy and other interactions of matter with particles and radiation *(for phonon spectra, see 63)*

78.20.—e Optical properties and materials *(see also 42.65 Nonlinear optics, 81.40.T Optical properties related to materials treatment; for masers and lasers, see 42.52, 42.55, and 42.60, respectively)*
78.20.Bh General theory (for pure homogeneous materials)
78.20.Dj Optical constants and parameters
78.20.Ek Optical rotatory power
78.20.Fm Birefringence (including stress birefringence, flow birefringence, etc.)
78.20.Hp Piezo-, elasto-, and acousto-optical effects
78.20.Jq Electro-optical effects
78.20.Ls Magneto-optical effects
78.20.Nv Thermo-optical effects

78.30.—j Infrared and Raman spectra and scattering
78.30.Cp Infrared and Raman spectra in liquids
78.30.Er Infrared and Raman spectra in solid metals
78.30.Gt Infrared and Raman spectra in nonmetallic inorganic crystals
78.30.Jw Infrared and Raman spectra in organic crystals

78.35.+c Brillouin and Rayleigh scattering

78.40.—q Visible and ultraviolet spectra
78.40.Dw Liquids
78.40.Fy Tetrahedrally bonded nonmetals
78.40.Ha Other nonmetals
78.40.Kc Metals, semimetals, and alloys

78.45.+h Stimulated emission *(see also 42.65.C —in nonlinear optics)*

78.50.—w Impurity and defect absorption in solids
78.50.Ec Insulators
78.50.Ge Semiconductors
78.50.Jg Metals, semimetals, and alloys

78.55.—m Photoluminescence
78.55.Ds Tetrahedrally bonded nonmetals
78.55.Fv Solid alkali halides
78.55.Hx Other solid inorganic materials
78.55.Kz Solid organic materials

78.60.—b Other luminescence and radiative recombination
78.60.Fi Electroluminescence

80. CROSS-DISCIPLINARY PHYSICS AND RELATED AREAS OF SCIENCE AND TECHNOLOGY

81. Materials science

82. Physical chemistry

85. Electrical and magnetic devices

90. GEOPHYSICS, ASTRONOMY, AND ASTROPHYSICS

Summary of Scheme

GENERAL

01. Communication, education, history, and philosophy
02. Mathematical methods in physics
03. Classical and quantum physics; mechanics and fields
04. Relativity and gravitation
05. Statistical physics and thermodynamics
06. Measurement science, general laboratory techniques, and instrumentation systems
07. Specific instrumentation and techniques of general use in physics

THE PHYSICS OF ELEMENTARY PARTICLES AND FIELDS

11. General theory of fields and particles
12. Specific theories and interaction models; particle systematics
13. Specific reactions and phenomenology
14. Properties of specific particles and resonances

NUCLEAR PHYSICS

21. Nuclear structure
23. Nuclear decay and radioactivity
24. Nuclear reactions and scattering: general
25. Nuclear reactions and scattering: specific reactions
27. Properties of specific nuclei listed by mass ranges
28. Nuclear engineering and nuclear power studies
29. Experimental methods and instrumentation for elementary-particle and nuclear physics

ATOMIC AND MOLECULAR PHYSICS

31. Electronic structure of atoms and molecules: theory
32. Atomic spectra and interactions with photons
33. Molecular spectra and interactions of molecules with photons
34. Atomic and molecular collision processes and interactions
35. Experimentally derived information on atoms and molecules; instrumentation and techniques
36. Studies of special atoms and molecules

CLASSICAL AREAS OF PHENOMENOLOGY (INCLUDING APPLICATIONS)

41. Electricity and magnetism: fields and charged particles
42. Optics
43. Acoustics
44. Heat flow, thermal and thermodynamic processes
46. Mechanics, elasticity, rheology
47. Fluid dynamics

FLUIDS, PLASMAS, AND ELECTRIC DISCHARGES

51. Kinetic and transport theory of fluids; physical properties of gases
52. The physics of plasmas and electric discharges

CONDENSED MATTER: STRUCTURE, MECHANICAL AND THERMAL PROPERTIES

61. Structure of liquids and solids; crystallography
62. Mechanical and acoustical properties of condensed matter
63. Lattice dynamics and crystal statistics
64. Equations of state, phase equilibria, and phase transitions
65. Thermal properties of condensed matter
66. Transport properties of condensed matter (nonelectronic)
67. Quantum fields and solids; liquid and solid helium
68. Surfaces and interfaces; thin films and whiskers (structure and nonelectronic properties)

CONDENSED MATTER: ELECTRONIC STRUCTURE, ELECTRICAL, MAGNETIC, AND OPTICAL PROPERTIES

71. Electron states
72. Electronic transport in condensed matter
73. Electronic structure and electrical properties of surfaces, interfaces, and thin films
74. Superconductivity
75. Magnetic properties and materials
76. Magnetic resonances and relaxations in condensed matter; Mössbauer effect
77. Dielectric properties and materials
78. Optical properties and condensed-matter spectroscopy and other interactions of matter with particles and radiation
79. Electron and ion emission by liquids and solids; impact phenomena

CROSS-DISCIPLINARY PHYSICS AND RELATED AREAS OF SCIENCE AND TECHNOLOGY

81. Materials science
82. Physical chemistry
*84. Electromagnetic technology
*85. Electrical and magnetic devices
87. Biophysics, medical physics, and biomedical engineering
*89. Other areas of general interest to Physicists

GEOPHYSICS, ASTRONOMY, AND ASTROPHYSICS

91. Solid Earth physics
92. Hydrospheric and atmospheric geophysics
93. Geophysical observations, instrumentation, and techniques
94. Aeronomy and space physics
95. Fundamental astronomy and astrophysics; instrumentation, techniques, and astronomical observations
96. Solar system
97. Stars
98. Stellar systems; galactic and extragalactic objects and systems; the Universe

**These Sections are outside the ICSU/AB International Classification for Physics*