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SUPPLEMENT

A BIBLIOGRAPHY OF PHYSICS, ASTRONOMY, ASTROPHYSICS AND GEOPHYSICS IN INDIA: 1800–1950

Part I: INTRODUCTION

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Part I: INTRODUCTION

A BIBLIOGRAPHY OF PHYSICS, ASTRONOMY, ASTROPHYSICS AND GEOPHYSICS IN INDIA: 1800-1950

I: INTRODUCTION

1. Preamble

The present Bibliography is the outcome of a research project submitted in 1985 to the Indian National Commission for the Compilation of History of Science in India, on the development of Physics and other areas of research related to it, such as Astronomy and Astrophysics, Atmospheric Physics and Geophysics, during the nineteenth and the twentieth centuries. Initially, a period of one hundred years from 1850 to 1950 was considered to focus attention on the formative period of physical researches in modern India. The plan was to prepare a bibliography, the history of the development of physical laboratories and monographs in a few major areas of research – a programme of work sufficiently broad in scope and involving several years of sustained effort. Eventually, in view of the time-bound nature of the project, the plan was restricted to the preparation of a bibliography. As the work progressed, we thought it appropriate to extend the period backwards so as to cover the whole of the nineteenth century and the first half of the twentieth century.

The project started in the middle of 1986 under the sponsorship of the Asiatic Society. In April 1988, the project was transferred to the Ramakrishna Mission Institute of Culture under its fostering and encouraging sponsorship. It has been difficult to find experienced research workers in the subject and still more so to retain them when found, leading to frequent changes in the working group and consequent loss of time. The National Commission and the Indian National Science Academy appreciated our difficulties, generously extended the time of completion so as to make good the loss of time and helped us in all possible ways towards the successful completion of the project, for which we place on record our grateful thanks. Our thanks are also due to the Asiatic Society and the Ramakrishna Mission Institute of Culture for sponsoring the project and providing various facilities.

2. Plan of Work

The Bibliography has concentrated primarily on research publications in standard and internationally well-known journals, periodicals, serials, memoirs, notices and the like, in the following order: name of author or authors, title of the paper, name of the journal, periodical, etc. in abbreviated form, the volume number, the page number and the year of publication. Where the author is single, the surname has been given first; in the case of multiple authors only the name of the first author has been so treated. The entries have been divided into 16 main classes as detailed in what follows. Within each class entries are made chronologically, each entry being identified by a number increasing serially. The chronological entries are expected to facilitate the study of the historical development of each broad area of Physics, Astrophysics, etc. as also of its various sub-groups. The main classes have been arranged alphabetically, and the serial numbering has been continued from the first entry to the last. Examples:

I. Acoustics (Ac)

0001 PATERSON, J.D. On the *gramas* or musical scales of the *Hindus*. *Asiat. Res.* **9**: 445, 1807.

0012 RAMAN, C.V. Experimental investigations on the maintenance of vibrations. *Bull. Indian Assoc. Cultiv. Sci. No.* **6**: 1-40, 1920.

II. Astronomy and Astrophysics (AA)

0418 SAHA, M.N. On a physical theory of stellar spectra. *Proc. R. Soc. London. A.* **99**: 135-153, 1921.

0524 NARLIKAR, V.V. and D.N. MOGHE. Steadily expanding universe and the spiral structure of the nebulae. *Observatory.* **58**: 366-368, 1935.

The identification numbers (0001, 0012, 0418, 0524) have been used in the Author Index and the Subject Index. The symbols Ac for 'Acoustics', AA for 'Astronomy and Astrophysics' and so on for other classes have also been used in these indices so as to enable the user of this Bibliography to find out readily the area or areas of research for each investigator noticed.

2.1. *Abbreviations of Journals, Periodicals and Serials*

The abbreviations of journals, periodicals, serials, memoirs, notices and the like, used in this Bibliography, are spelt out in the following, with indication of place of publication wherever possible. The list includes 151 journals, periodicals, etc.

Acta Crystallogr	...	Acta Crystallographica, Copenhagen.
Acta Phys. Polonica.	...	Acta Physica Polonica, Warsaw.
Aircraft Eng.	...	Aircraft Engineering, London.
Akad. Wiss. Wien. Sitz. Ber.	...	Sitzungsberichte der Akademie der Wisseschaften in Wien, Vienna.
Alta Frequenza	...	Alta Frequenza, Milan.
Ann. Phys. (N.Y.).	...	Annals of Physics, New York.
Ann. Phys. (Leipzig)	...	Annalen der Physik, Leipzig.
Ann. Phys. (Fr.)	...	Annales de Physique, Paris.

Ann. Soc. Sci. Bruxelles	...	Annales de la Société Scientifique de Bruxelles, Lauvain.
Appl. Phys. Lett.	...	Applied Physics Letters, New York.
Arkiv Mat. Astron. Fys.	...	Arkiv för Matematik, Astronomi Och Fysik, Stockholm.
Asiat. Res.	...	Asiatick Researches, Calcutta.
Astron. J.	...	Astronomy Journal, New York.
Astron. Nachr.	...	Astronomische Nachrichten, Berlin.
Astrophys. J.	...	Astrophysical Journal, Chicago.
Atti Acad. Sci. Torino	...	Atti della Reale Academie delle Science di Torino, Itali.
Beitr. Phys. Atmosph.	...	Beiträge Zur Physik der Atmosphaere, Weisbaden.
Bombay Mag. Met. Obs.	...	Bombay Magnetical and Meteorological Observatories, Bombay.
British Astron. Assoc.	...	British Astronomical Society, London.
Bull. Acad. Sci. U.P. & Agra	...	Bulletin of the Academy of Science of the United Provinces of Agra and Oudh, Allahabad.
Bull. Amer. Met. Soc.	...	Bulletin of the American Meteorological Society, Boston.
Bull. Astron. Obs. Harvard Univ.	...	Bulletin of the Astronomical Observatory of the Harvard University, Cambridge.
Bull. Bengal Industr. Res. Bd.	...	Bulletin of the Bengal Industrial Research Board, Calcutta.
Bull. Calcutta Math. Soc.	...	Bulletin of the Calcutta Mathematical Society, Calcutta.
Bull Cambridge Math. Soc.	...	Bulletin of the Cambridge Mathematical Society, Cambridge.
Bull. Indian Assoc. Cultiv. Sci.	...	Bulletin of the Indian Association for the Cultivation of Science, Calcutta.
Bull. Kodaikanal Obs.	...	Bulletin of the Kodaikanal Observatory, Madras.
Bull. Lett. Acad. Pol. Sci.	...	Bulletin de l'Academie Polonaise des Sciences Sr. des Sciences de Lettere, Warsaw.

Bull. Patna Sci. Coll. Phil. Soc.	...	Bulletin of the Patna Science College Philosophical·Society, Patna.
Bull. Seism. Soc. Amer.	...	Bulletin of the Seismological Society of America, California.
Calcutta Rev.	...	Calcutta Review, Calcutta.
Calcutta Univ. Mag.	...	Calcutta University Magazine, Calcutta.
C.R. Acad. Sci. (Paris)	...	Comptes Rendus hebdomadiares des Seances de l'Academie des Sciences, Paris.
Chem. Metall. Eng.	...	Chemical and Metallurgical Engineering, New York.
Curr. Sci.	...	Current Science, Bangalore.
Electrician	...	Electrician, London.
Electronics	...	Electronics, New York.
Elekt. Z.	...	Elektrotechnische Zeitschrift, Berlin.
Exp. Wireless	...	Experimetal Wireless, London.
Gazz. Chim. Italiana	...	Gazzeta Chimica Italiana, Rome.
Gerl. Beitr. Geophys.	...	Gerlands Beiträge Zur. Geophysik, Leipzig.
Handb. Phys.	...	Handbuch der Physik, Berlin.
Harvard Coll. Obs. Circ.	...	Circular of the Harvard College Observatory, Cambridge.
Helv Phys. Acta	...	Helvetica Physica Acta, Geneva.
Indian J. Agri. Sci.	...	Indian Journal of Agricultural Science, New Delhi.
Indian J. Met. Geophys.	...	Indian Journal of Meteorology and Geophysics, New Delhi.
Indian J. Phys.	...	Indian Journal of Physics, Calcutta.
Indian Phys.-Math. J.	...	Indian Physico-Mathematical Journal, Dacca.
J. Acoust. Soc. Amer.	...	Journal of the Acoustical Society of America, New York.
J. Amer. Chem. Soc.	...	Journal of the American Chemical Society, Washington.
J. Amer. Orient. Soc.	...	Journal of the American Oriental Society.

J. Appl. Phys.	...	Journal of Applied Physics, New Delhi.
J. Asiat. Soc.	...	Journal of the Asiatic Society (of Bengal), Calcutta.
J. Atmos. Terr. Phys.	...	Journal of Atmospheric and Terrestrial Physics, London.
J. Chem. Phys.	...	Journal of Chemical Physics, New York.
J. Chem. Soc.	...	Journal of the Chemical Society, London.
J. Dept. Sci. Calcutta Univ.	...	Journal of the Department of Science, Calcutta University, Calcutta.
J. Franklin Inst.	...	Journal of the Franklin Institute, Lancaster.
J. Geophys. Res.	...	Journal of the Geophysical Research, Washington.
J. Indian Astron. Soc.	...	Journal of the Indian Astronomical Society.
J. Indian Chem. Soc.	...	Journal of the Indian Chemical Society, Calcutta.
J. Indian Inst. Sci.	...	Journal of the Indian Institute of Science, Bangalore.
J. Indian Math. Soc.	...	Journal of the Indian Mathematical Society, Calcutta.
J. Inst. Petrol.	...	Journal of the Institute of Petroleum, London.
J. Iron Steel Inst.	...	Journal of the Iron and Steel Institute, London.
J. Linn. Soc. (Bot.)	...	Journal of the Linnean Society (Botany), London.
J. Mysore Univ.	...	Journal of the Mysore University, Mysore.
J. Opt. Soc. Amer.	...	Journal of the Optical Society of America, New York.
J. Phys. (Fr.)	...	Journal de Physique, Paris.
J. Phys. Chem.	...	Journal of Physical Chemistry, Washington.
J. Phys. Coll. Chem.	...	Journal of Physical and Colloid Chemistry, Baltimore.

J. Phys. Radium	...	Journal de Physique et le Radium, Paris.
J.R. Asiat. Soc.	...	Journal of the Royal Asiatic Society.
J.R. Met. Soc.	...	Journal of the Royal Meteorological Society, London.
J. Sci. Assoc. Maharaja's Coll. Vizianagram.	...	Journal of the Science Association of the Maharaja's College, Vizianagram, Madras.
J. Sci. Club	...	Journal of Science Club, Calcutta.
J. Sci. Industr. Res.	...	Journal of Scientific and Industrial Research, New Delhi.
J. Sci. Instrum.	...	Journal of Scientific Instruments, London.
J. Univ. Bombay	...	Journal of the University of Bombay, Bombay.
Kolloid Z.	...	Kolloid Zeitschrift, Dresden-Blabewitz, Germany.
Malaviya Comm. Vol.	...	Malaviya Commemoration Volume, Benaras.
Math. Ann. Bel.	...	Mathematische Annales de Belgique
Math. Studies	...	Mathematical Studies.
Mem. Asiat. Soc.	...	Memoirs of the Asiatic Society of Bengal, Calcutta.
Mem. India Met. Dept.	...	Memoirs of the India Meteorological Department, Delhi.
Mem. Kodaikanal Obs.	...	Memoirs of the Kodaikanal Observatory.
Mem. R. Soc. Sci. Göttingen	...	Memoirs of the Royal Society of Science, Göttingen.
Met. Geophys.	...	Meteorology and Geophysics, London.
Met. Mag. (London)	...	Meteorological Magazine, London.
Mon. Not. R. Astron. Soc.	...	Monthly Notices of the Royal Astronomical Society, London.
Mon. Weather Rev.	...	Monthly Weather Review, Washington.
Nature, London	...	Nature, London.
Naturwissenschaften	...	Naturwissenschaften, Berlin.
Nucl. Phys.	...	Nuclear Physics, Amsterdam.
Nucleonics	...	Nucleonics, New York.

Nuovo Cimento	...	Nuovo Cimento, Bologna, Italy.
Observatory	...	Observatory, London.
Optik	...	Optik, Stuttgart.
Patna Univ. J. Nat. Sci.	...	Patna University Journal of Natural Science, Patna.
Phil. Mag.	...	Philosophical Transactions of the Royal Society, London.
Physica	...	Physica, Amsterdam.
Physics	...	Physics, New York.
Phys. Quart.	...	Physics Quarterly.
Phys. Rev.	...	Physical Review, New York.
Phys. Soc. Cambridge	...	Physical Society, Cambridge.
Phys. Z.	...	Physikalische Zeitzschrift, Leipzig.
Pop. Astron.	...	Popular Astronomy, Northfield, Minn.
Proc. Acad. Sci. U.P. (India)	...	Proceedings of the Academy of Science, U.P., Allahabad.
Proc. Asiat. Soc.	...	Proceedings of the Asiatic Society, Calcutta.
Proc. Benares Math. Soc.	...	Proceedings of Benares Mathematical Society, Benares.
Proc. Cambridge Phil. Soc.	...	Proceedings of the Cambridge Philosophical Society, London.
Proc. Imp. Acad. Tokyo	...	Proceedings of the Imperial Academy, Tokyo.
Proc. Indian Acad. Sci.	...	Proceedings of the Indian Academy of Science, Bangalore.
Proc. Indian Assoc. Cultiv. Sci.	...	Proceedings of the Indian Association for the Cultivation of Science, Calcutta.
Proc. Inst. Elect. Eng.	...	Proceedings of the Institution of Electrical Engineers.
Proc. Inst. Radio Eng.	...	Proceedings of the Institute of Radio Engineers, New York.
Proc. Nat. Acad. Sci. India	...	Proceedings of the National Academy of Sciences of India, Allahabad.

Proc. Nat. Acad. Sci. U.S.A.	...	Proceedings of the National Academy of Sciences, U.S.A.
Proc. Nat. Inst. Sci. India	...	Proceedings of the National Institute of Sciences of India, Delhi.
Proc. Phys. Soc. London	...	Proceedings of the Physical Society, London.
Proc. R. Irish Acad.	...	Proceedings of the Royal Irish Academy, Dublin.
Proc. R. Soc. London	...	Proceedings of the Royal Society, London, London.
Publ. Astron. Soc. Pacific	...	Publications of the Astronomical Society of Pacific, San Francisco.
Quart. J. Geol. Min. Met. Soc. India	...	Quarterly Journal of the Geological, Mining and Metallurgical Society of India, Calcutta.
Quart. J.R. Met. Soc.	...	Quarterly Journal of the Royal Meteorological Society, London.
Rep. Prog. Phys.	...	Reports on Progress in Physics, London.
Rev. Mod. Phys.	...	Reviews of Modern Physics, New York.
Rev. d'opt.	...	Revue d'optique, Paris.
Rev. Sci. Instrum.	...	Review of Scientific Instruments.
Sankhya. Indian J. Stat.	...	Sankhya. Indian Journal of Statistics, Calcutta.
Sci. Cult.	...	Science and Culture, Calcutta.
Science	...	Science, Cambridge, Mass.
Sci. Notes India Met. Dept.	...	Scientific Notes of the India Meterological Department, Delhi, Calcutta.
Techn. Phys. USSR	...	Technical Physics of the USSR, Leningrad.
Terr. Mag. Atmos. Elect.	...	Terrestrial Magnetism and Atmospheric Electricity, Baltimore.
Tohoku Math. J.	...	Tohoku Mathematical Journal, Sendai, Japan.
Trans. Amer. Inst. Elect. Eng.	...	Transactions of the American Institute of Electrical Engineers, New York.

Trans. Bose Res. Inst.	...	Transactions of the Bose Research Institute, Calcutta.
Trans. Chem. Soc.	...	Transactions of the Chemical Society, London.
Trans. Faraday Soc.	...	Transactions of the Faraday Society, London.
Trans. Nat. Inst. Sci. India	...	Transactions of the National Institute of Sciences of India, Calcutta.
Trans. Opt. Soc.	...	Transactions of the Optical Society, London.
Trans. R. Soc. Edinburgh	...	Transactions of the Royal Society, Edinburgh.
Z. Angew. Math. Mech.	...	Zeitschrift für Angewandte Mathematik und Mechanik, Berlin.
Z. Astron.	...	Zeitschrift für Astronomie, Berlin.
A. Astrophys.	...	Zeitschrift für Astrophysik, Berlin.
Z. Elektrochem.	...	Zeitschrift für Elektrochemie und angewandte Physikalische Chemie, Berlin.
Z. Instrum.	...	Zeitschrift für Instrumentenkunde, Berlin.
Z. Kristallogr.	...	Zeitschrift für Kristallographie, Frankfurt.
Z. Naturforch.	...	Zeitschrift für Naturforschung, Tübingen.
Z. Phys.	...	Zeitschrift für Physik, Berlin.
Z. Phys. Chem.	...	Zeitschrift für Physikalische Chemie, Leipzig.
Z. Tech. Phys.	...	Zeitschrift für Technische Physik, Leipzig.
Z. Wiss. Phot.	...	Zeitschrift für Wissenschaftliche Photographie, Photophysik und Photochemie, Leipzig.

2.2. Subject Classification with Sub-groups

As already stated, the Bibliography has been divided into 16 main classes, each distinguished by a symbol. Each class has been further divided into a number of sub-groups. The sub-groups have been used in preparing the Subject Index where these have been arranged alphabetically under each main group. In this arrangement, chronological order has been maintained in each sub-group through the use of identification numbers in ascending order. The details of the main classes and their sub-groups are given below.

I. Acoustics (Ac)

I.1. Absorption.

I.2. Impedance (Acoustical).

I.3. Miscellaneous.

I.4. Musical Instruments. Note. Sound.

I.5. Supersonics.

I.6. Ultrasonics.

I.7. Velocity of Sound. Measurements.

I.8. Vibrations (General).

I.9. Vibration of Strings – Bowed, Plucked, Struck, Pianoforte.

I.10. Wave Motion. Waves and Vibrations. Resonance. Beats.

I.11. Whispering Gallery.

II. Astronomy and Astrophysics (AA)

II.1. Apparatus and Instruments. Observatories.

II.2. Comets. Meteors. Meteorites.

II.3. Cosmogony and Cosmology.

II.4. Dynamical Problems (Astronomical).

II.5. History of Astronomy. Hindu Astronomy.

II.6. Latitude and Longitude.

II.7. Miscellaneous.

II.8. Nebulae.

II.9. Planets. Moon.

II.10. Stars. Milky Way. Nova.

II.11 Stellar Spectra.

II.12. Sun.

II.13. Thermal Ionisation. Pressure Ionisation. Radiation Transfer.

III. Atomic and Molecular Structure (AMS)

III.1. Atomic Structure.

III.2. Miscellaneous.

III.3. Molecular Anisotropy.

III.4. Molecular Structure.

III.5. Valency.

IV. Biophysics (BP)

V. Crystal Structure and Properties (CSP)

V.1. Crystal Dynamics.

V.2. Crystal Magnetism.

V.3. Crystal Structure – Diamond and Graphite.

V.4. Crystal Structure – General Theory.

V.5. Crystal Structure – Metals, Alloys, Inorganic Substances.

V.6. Crystal Structure – Organic Substances.

V.7. Miscellaneous.

V.8. Optical and Other Physical Properties.

V.9. Solid State.

VI. Electricity, Electric Conduction and Discharge (EED)

VI.1. Apparatus and Instruments. Electric Measurements.

VI.2. Cathode Rays. Canal Rays. Electric Rays. Positive Rays.

VI.3. Conduction. Conductivity. Resistivity.

VI.4. Dielectrics. Dipole and Electric Moments.

VI.5. Electric Discharge.

VI.6. Electricity (General).

VI.7. Electrochemistry.

VI.8. Miscellaneous.

VII. Electrons. Ions (EI)

VII.1. Apparatus and Instruments.

VII.2. Electrons – Dynamics and Theory.

VII.3. Electron Diffraction. Electron Optics.

VII.4. Electron Properties – Charge, Mass, Structure.

VII.5. Ions. Ionisation. Active Nitrogen.

VII.6. Miscellaneous.

VIII. General Physics (GP)

VIII.1. Aerodynamics. Hydrodynamics. Fluid Dynamics.

VIII.2. Apparatus and Instruments.

VIII.3. Classical Mechanics.

VIII.4. Elasticity.

VIII.5. Mathematical Physics.

VIII.6. Miscellaneous.

VIII.7. Quantum Mechanics. Quantum Statistics.

VIII.8. Relativity. Gravitation.

VIII.9. Statistical Mechanics.

VIII.10. Surface Tension.

VIII.11. Theory of Liquids.

VIII.12. Viscosity.

VIII.13. Wave Mechanics. Wave Statistics.

IX. Geophysics (GeP)

IX.1. Apparatus and Instruments.

IX.2. Atmospheric Physics. Atmospheric Constitution.

IX.3. Geodesy.

IX.4. Hydrology and Glaciology.

IX.5. Ionosphere.

IX.6.1. Meteorology – Climatology.

IX.6.2. Meteorology – Dynamical.

IX.6.3. Meteorology – Evaporation. Humidity. Fog.

IX.6.4. Meteorology – Miscellaneous.

IX.6.5. Meteorology – Rainfall. Cloud.

IX.6.6. Meteorology – Cyclone. Dust Storms. Hurricane. Nor'westers. Squalls. Storms. Thunder Storms. Typhon. Wind.

IX.6.7. Meteorology – Temperature. Pressure. Radiation.

IX.6.8. Meteorology – Weather Forecasting.

IX.7. Miscellaneous.

IX.8. Seismology.

IX.9. Soil Physics.

IX.10. Terrestrial Electricity and Magnetism.

X. Heat and Thermodynamics (HT)

X.1. Absorption. Adsorption.

X.2. Apparatus and Instruments.

X.3. Heat Propagation – Conduction. Convection. Radiation.

X.4. Hygrometry.

X.5. Kinetic Theory.

X.6. Miscellaneous.

X.7. Specific Heat. Latent Heat.

X.8. Temperature.

X.9. Thermal Ionisation. Pressure Ionisation.

X.10. Thermodynamics and Chemical Processes.

X.11. Transport Phenomena.

XI. Magnetism and Electromagnetism (ME)

XI.1. Apparatus and Instruments.

XI.2. Crystal Magnetism.

XI.3. Diamagnetism – Diamagnetic Susceptibility.

XI.4. Electromagnetism. Electromagnetic Field. Electrodynamics.

XI.5. Ferromagnetism. Ferromagnetic Susceptibility.

XI.6. Magnetic Anisotropy.

XI.7. Magnetic Properties and Materials.

XI.8. Magnetic Susceptibilities – General.

XI.9. Magneto-Optics.

XI.10. Miscellaneous.

XI.11. Paramagnetism. Paramagnetic Susceptibility.

XI.12. Telegraphy.

XII. Optics. Radiation (OR)

XII.1. Absorption and Transmission.

XII.2. Apparatus and Instruments.

XII.3. Colour Vision.

XII.4. Diffraction.

XII.5. Double Refraction (Birefringence).

XII.6. Electro-optical and Magneto-optical Effects.

XII.7. Fluorescence. Luminescence. Opalescence. Phosphorescence.

XII.8. Interference.

XII.9. Miscellaneous.

XII.10. Photography. Photoelectricity. Photochemistry.

XII.11. Polarisation.

XII.12. Radiation. Blackbody Radiation. Radiation Theories.

XII.13. Reflection. Refraction. Dispersion.

XII.14. Scattering. Optical Anisotropy.

XIII. Radioactivity. Nuclear Physics. Cosmic Rays (RNC)

XIII.1. α-rays. β-rays. γ-rays.

XIII.2. Apparatus and Instruments.

XIII.3. Cosmic Rays.

XIII.4. Mesons.

XIII.5. Miscellaneous.

XIII.6. Neutron. Proton. Nuclear Particles.

XIII.7. Nuclear Reaction, Interaction and Scattering.

XIV. Radiophysics and Electronics (RE)

XV. Spectroscopy (Sp)

XVI. X-Rays (XR)

XVI.3. Diffraction.

XVI.4. Miscellaneous.

XVI.5. Reflection. Refraction. Polarisation.

XVI.6. Scattering.

XVI.7. X-ray Spectroscopy.

2.3. *Author Index and Subject Index*

The method of using identification numbers and main classification symbols in preparing the Author and Subject Indices has already been explained. In the Subject Index the original titles of papers have been slightly shortened or rearranged without compromising the intent. A few examples are given by way of further clarification:

Author Index

BANERJEE, SUDHANSU KUMAR (also BANERJEE, S.K.)
(Ac) 0035, 0038, 0041, ...
(GeP) 2683, 2805, 2813, 2832, ...

BHABHA, H.J.
(GP) 2017, 2137, 2290, 2418, ...
(RNC) 4468, 4477, 4492, 4507, 4538, ...

SARABHAI, VIKRAM
(RNC) 4610, 4653, 4655, 4659, 4727, 4844, ...

Subject Index

II. Astronomy and Astrophysics (AA)

II.10. Stars. Milky Way. Nova.

0269 Astronomical observations at Madras Observatory 1831-37, 1843-47 (Star Catalogue).

0478 Abundance of hydrogen in white dwarfs.

0504 Physical state of matter in the interior of stars.

VIII. General Physics (GP)

VIII.8. Relativity. Gravitation.

1789 Geodesic movements in Einstein gravitation theory.

1848 Dissociation formulae according to relativistic statistics.

2008 Stability of a particle in a gravitational field.

XI. Magnetism and Electromagnetism (ME)

XI.3. Diamagnetism. Diamagnetic Susceptibility.

3479 Diamagnetic susceptibility in liquids and vapours.

3526 Diamagnetism and structure of ethylene, carbon tetrachloride, titanium tetrachloride compounds.

XIII. Radioactivity. Nuclear Physics. Cosmic Rays. (RNC)

XIII.3. Cosmic Rays.

4523 Production of electron showers by cosmic rays.

4546 Cosmic rays, long period variation of.

4612 General cascade theory with collision loss, exact solution of, equations of.

3. Analysis of the Bibliography

The Bibliography contains 6287 entries from 0001 to 6287. A decade-wise distribution of 6287 research papers/publications over 16 main classes is shown in Table 1 for the 19th century and in Table 2 for the first 50 years of the twentieth century. Our survey has identified 338 papers during the nineteenth century and 5949 papers for the period 1900 to 1950. Of the 338 papers, Astronomy and Astrophysics accounted for 80 and Geophysics 200; a few papers appeared in Acoustics-2, Electricity-12, General Physics-13, Heat and Thermodynamics-8; Magnetism and Electromagnetism-12; Optics and Radiation-5, and Radio Physics-6. Understandably enough, subjects like Atomic and Molecular Structure, Biophysics, Electrons and Ions, Radioactivity and Nuclear Physics, and X-rays did not open their accounts in the 19th century, although the absence of any entry under spectroscopy might be due to our inability to lay our hands on all possible sources. Nevertheless, this sample survey indicates that Astronomy and Astrophysics and Geophysics, including Meteorology, Geodesy, Seismology, Geomagnetism and allied areas constituted the main thrust areas in the physical sciences in the nineteenth century. These thrust areas received some momentum from the decade 1830-39 and remained more or less constant for the remaining decades of the century with an average of 45 papers per decade. Most of this work flowed from government surveys and scientific establishments in which European workers were the predominant contributors.

Table 1. Decade-wide distribution of research papers in the nineteenth century (Numbers in 1st row indicate identification numbers, those in the 2nd number of papers)

Main Subject class	1800-1809	1810-1819	1820-1829	1830-1839	1840-1849	1850-1859	1860-1869	1870-1879	1880-1889	1890-1899	Total
I. Acoustics (Ac)	0001 1			0002 1							2
II. Astronomy and Astrophysics (AA)	0261-0264 4	0265-0266 2	0267-0270 4	0271-0285 15	0286-0298 13	0299-0302 4	0303-0314 12	0315-0319 5	0320-0327 8	0328-0340 13	80
III. Atomic and Molecular Structure (AMS)											
IV. Biophysics (BP)											
V. Crystal Structure and Properties (CSP)											
VI. Electricity, Electric Conduction and Discharge (EED)				1228 1	1229-1231 3					1232-1239 8	12
VII. Electrons, Ions (EI)											
VIII. General Physics (GP)	1690 1			1691-1693 3	1694 1	1695 1	1696 1	1697-1698 2	1699-1700 2	1701-1702 2	13
IX. Geophysics (GeP)	2421-2423 3	2424-2426 3	2427-2429 3	2430-2452 23	2453-2489 37	2490-2528 39	2529-2542 14	2543-2573 31	2574-2603 30	2604-2620 17	200

X. Heat and Thermo-dynamics (HT)	3238 3239 2			3240- 3242 3	3243 1	3244- 3245 2					8
XI. Magnetism and Electromagnetism (ME)							3450 1	3451-59 9	3460- 3461 2		12
XII. Optics, Radiation (OR)				3764 1				3765- 3766 2		3767- 3768 2	5
XIII Radioactivity, Nuclear Physics, Cosmic Rays (RNC)											
XIV Radiophysics and Electronics (RE)										4845- 4850	6
XV. Spectroscopy (Sp)											
XVI. X-Rays (XR)											
Total	11	5	7	47	55	46	28	49	42	48	338

Table 2. Decade-wise distribution of research papers during 1900 to 1950 with total for the period 1800-1950 (Numbers in 1st row indicate identification numbers, those in 2nd number of papers)

Main Subject Class	1900-1909	1910-1919	1920-1929	1930-1939	1940-1949	1950	Total	
							20th Cent.	19 + 20th Cent.
I. Acoustics (Ac)	0003-0005	0006-0047	0048-0109	0110-0189	0190-0247	0248-0260		
	3	42	62	80	58	13	258	260
II. Astronomy and Astrophysics (AA)	0341-0355	0356-0402	0403-0447	0448-0596	0597-0759	0760-0771		
	15	47	45	149	163	12	431	511
III. Atomic and Molecular Structure (AMS)			0772-0788	0789-0836	0837-0870	0871-0875		
			17	48	34	5	104	104
IV. Biophysics (BP)	0876-0879	0880-0899	0900-0910	0911	0912-0914			
	4	20	11	1	3		39	39
V. Crystal Structure and Properties (CSP)			0915-0930	0931-1045	1046-1198	1199-1227		
			16	115	153	29	313	313
VI. Electricity, Electric Conduction and Discharge (EED)	1240-1242	1243-1255	1256-1332	1333-1470	1471-1579	1580-1599		
	3	13	77	138	109	20	360	372
VII. Electrons. Ions (EI)		1600-1601	1602-1616	1617-1647	1648-1685	1686-1689		
		2	15	31	38	4	90	90
VIII. General Physics (GP)	1703-1706	1707-1727	1728-1811	1812-2130	2131-2385	2386 2420		
	4	21	84	319	255	35	718	731

IX. Geophysics (GeP)	2621- 2648 28	2649- 2662 14	2663- 3711 49	2712- 2982 271	2983- 3184 202	3185- 3237 53	617	817
X. Heat and Thermo-dynamics (HT)	3246- 3247 2	3248- 3249 2	3250- 3294 45	3295- 3367 73	3368- 3443 76	3444- 3449 6	204	212
XI. Magnetism and Electro-Magnetism (ME)	3462 1	3463- 3464 2	3465- 3498 34	3499- 3681 183	3682- 3754 73	3755- 3763 9	302	314
XII. Optics, Radiation (OR)	3769- 3778 10	3779- 3808 30	3809- 3996 188	3997- 4235 239	4236- 4404 169	4405- 4427 23	659	664
XIII. Radio-activity, Nuclear Physics, Cosmic Rays (RNC)		4428- 4432 5	4433- 4445 13	4446- 4556 111	4557- 4803 247	4804- 4844 41	417	417
XIV. Radiophysics and Electronics (RE)	4851- 4854 4	— —	4855- 4868 14	4869- 4931 63	4932- 5013 82	5014- 5030 17	180	186
XV. Spectroscopy (Sp)	5031 1	5032- 5035 4	5036- 5155 120	5156- 5692 537	5693- 6012 320	6013- 6051 39	1021	1021
XVI X-Rays (XR)			6052- 6103 52	6104- 6185 82	6186- 6282 97	6283- 6287 5	236	236
Total	75	202	842	2440	2079	311	5949	6287

The scenario in the first half of the twentieth century presents a striking contrast to what obtained in the nineteenth century. The number 5949 in the first 50 years represents nearly an eighteen-fold increase over that for the whole of the nineteenth century. The rapid, almost exponential, decade-wise increase in the number of research papers is reflected in the following figures:

1900-1909	75 papers
1910-1919	202 papers
1920-1929	842 papers
1930-1939	2440 papers
1940-1949	2079 papers

These figures are in agreement with the organisation of post-graduate studies and research in Indian universities in the decade 1910-1919 and a few private institutions such as the Indian Association for the Cultivation of Science, the Indian Institute of Science, and the Bose Institute. The participants in this research effort are now predominantly Indian, as is clearly evident from the Author Index. The peak reached in the decade 1930-1939 appears to be attributable in no small measure to the quality work done by a number of leading physicists of the preceding decades, which attracted international recognition, including the award of a Nobel Prize. The slight fall in the decade 1940-1949 was due probably to difficult war-time conditions disrupting free flow of research information and material.

Another notable feature of the first half of the twentieth century is the diversification of research in new fields in keeping with the new trends in the international arena. The old subjects of Astronomy and Astrophysics and Geophysics not only received greater attention but became more sophisticated through application of new methods and procedures, both experimental and theoretical. Astrophysical research, in particular, became firmly established through the mastery of thermodynamical, statistical-quantum mechanical and relativistic procedures. In Geophysics, while geodesy, meteorology and atmospheric physics were strengthened, new areas like ionosphere emerged through the development of radiophysics and electronics. As to the new subjects, optical researches commanded the greatest attention. In fact, optics and radiation, spectroscopy, X-rays, radioactive emanations, atomic, molecular and crystal structural studies – all of which emerged as distinct areas of investigations by their own right – originally belonged to the broad area of optical research. On the eve of his embarking in a systematic way upon his optical researches, Prof. C.V. Raman made the following observations before a Science Convention held on 2 and 3 March 1919 at the Indian Association for the Cultivation of Science (Sen, S.N., *Prof. C.V. Raman: Scientific Work at Calcutta,* 1988, p. 147):

"The science of optics occupied what could be regarded as a privileged place in the scheme of physical science. A careful student of the history of scientific progress would find that the great majority of the epoch-making advances in physics made during the past hundred years really arose from an intensive study of optics in relation to cognate objects. As instances could be cited Herschel's discovery of invisible radiations, the discovery of spectrum analysis on which practically the whole of modern astrophysics is based, Maxwell's electromagnetic theory which was suggested by the observed relations of light and magnetism, the discovery of radio-activity, which owed its origin to the study of phosphorescence by Becquerel, the discoveries of Zeeman and Stark which threw a flood of light on the structure of the atom, and Laue's discovery of the action of crystals on X-rays which was really suggested by the optical analogy of the action of a grating on light.''

As one browses through the Bibliography, its Author and Subject Indices, one can readily find out in what decade and generally from when research workers in Physics in India developed capabilities in areas like quantum mechanics and quantum statistics, statistical mechanics, wave mechanics, relativity, ionospheric research, dia-, para- and ferromagnetic studies, X-rays and crystal physics, cosmic rays and mesons, optical spectroscopy, to mention a few, and started making significant original contributions. A few remarks on each of the 16 main classes may be helpful.

3.1. *Acoustics (Ac)*

Acoustical research in India opened up in the first half of the nineteenth century with the investigation on Indian musical scales and instruments by two European workers. Modern researches in acoustics, however, started in right earnest after C.V. Raman appeared in the field in the first decade of the twentieth century. A glance at the Subject Index will immediately make it evident that research was largely concentrated on problems of vibrations in general, vibrations of strings in particular, musical instruments, supersonics and ultrasonics, although absorption, impedance, velocity of sound and whispering galleries received some measure of attention. A total of 108 investigators produced 260 research papers (Table 3). Research workers who contributed 10 or more papers during the period of this bibliographical study were as follows:

1.	C.V. Raman	58 papers
2.	R.N. Ghosh	29 papers
3.	M. Ghosh	15 papers
4.	S. Parthasarathy	13 papers
5.	K.C. Kar	11 papers

Vibrations and Sound

From 1909 to 1916, C.V. Raman published a series of papers on problems of vibrations in general, e.g. maintenance of forced oscillations, experimental demonstration and mathametical analysis of such vibrations, combinational vibration of strings under simple harmonic forces, etc. He extended these

Table 3. Subject (main class), total number of publications and number of authors producing (a) one or more and (b) ten or more publications in the subject.

Subject (Main class)	Total No. of publications	No. of authors with 1 or more publications	No. of authors with 10 or more publications
I. Acoustics	260	108	5
II. Astronomy and Astrophysics	511	181	15
III. Atomic and Molecular Structure	104	96	—
IV. Biophysics	39	12	1
V. Crystal Structure and Properties	313	141	6
VI. Electricity, Electric Conduction and Discharge	372	295	6
VII. Electrons. Ions	90	85	1
VIII. General Physics	731	358	14
IX. Geophysics	817	350	20
X. Heat and Thermodynamics	212	152	2
XI. Magnetism and Electromagnetism	314	159	10
XII. Optics. Radiation	664	319	11
XIII. Radioactivity, Nuclear Physics, Cosmic Rays	417	197	10
XIV. Radiophysics and Electronics	186	130	3
XV. Spectroscopy	1021	337	40
XVI. X-Rays	236	123	6

investigations to clarify other types of vibrations such as sounds of splashes, Hertz's theory of impact, etc. Contributions from other workers who either worked with C.V. Raman or were inspired by his investigations started to appear from 1916 onwards. These included Asutosh Dey's experimental work on maintenance of vibrations by a periodic field of force (0028), Sudhansu Kumar Banerjee's theoretical work on vibration of elastic shells partly filled with liquid (0041), N.C. Krishnaiyar's investigations of vibrations of wire by electrical heating and amplitude of vibrations maintained by forced double frequency (0047, 0069) and Bhabonath Banerjee's mechanical illustrations of the theory of large oscillations and combinational tones (0056). N.R. Sen and A.L. Narayan who were later on to make important contributions to astrophysics initially tried their hands in acoustics by grappling with problems concerning vibrations of thin elastic spherical shells (0061) respectively. In the thirties, J. Ghosh studied the vibrations of an annular plate of variable thickness (0124), M. Ghosh longitudinal vibration of a bar excited by impact (0125), and B.B. Sen radial vibration of spheres under variable radial forces and transverse vibration of rotating rods (0146, 0160).

Vibration of Strings – Violin, Pionoforte

Under vibration of strings activated by bowing, plucking and striking, the problems of bowed strings and pionoforte received a good deal of attention. Raman produced an elaborate monograph on the mechanical theory of vibrations of bowed strings and musical instruments of the violin family (0036), and a study of the kinematics of bowed strings (0043). K.C. Kar specifically dealt with the action of bow in stringed instruments (0070) and M.N. Mitra discussed the general laws of bowed strings.

Attracted by Kaufmann's classical work on the pionoforte string published in the *Annalen der Physik* (**54**, 675, 1895), Raman and Banerjee initiated further studies on the impact of pianoforte hammer (0054). This lead was quickly followed by a series of papers. P. Das studied the vibrations of pionoforte string, pressure exerted by elastic hammer on the string, the nature of impact of the elastic hammer and proposed a general theory of such impact (0063, 0088, 0095, 0101). The problem of the elastic impact of hammer on the pianoforte string was also attacked, both theoretically and experimentally by S. Bhargava, R.N. Ghosh and J.N. Dey jointly and severally (0080, 0081, 0084, 0087, 0091, 0093, 0107, 0136, 0137). K.C. Kar studied the general theory of struck string with special reference to the pionoforte (0104). In collaboration with M. Ghosh, Kar investigated the problem of the pianoforte struck by a hard hammer (0112, 0114, 0115) and also developed a general theory of struck string (0118, 0120). M. Ghosh further carried out experimental studies on damped pianoforte string, dynamics of pianoforte string struck by elastic and hard hammer and the general problems of struck string (0120, 0131, 0168, 0179, 0180, 0195).

Musical Instruments

Raman's investigations on musical instruments and their notes went concurrently with his work on vibrations of strings and other modes. These concerned the musical note of estara (0003), 'wolf-note' of violin and cello and bowed stringed instruments in general (0025, 0027, 0030, 0032, 0037, 0039), musical drums (0048, 0072), mechanical violin player (0051, 0053), Indian stringed instruments (0064), subjective analysis of musical tones (0090), etc. Deodhar studied the Indian Israj (0082) and L.D. Mahajan carried out a systematic investigation of the vibrations of the different parts of the pianoforte sound board (0108, 0121, 0129). R.N. Ghosh studied the tone quality of the pianoforte, the theory of the clarinet, and the acoustics of harmonics (0135, 0142, 0170, 0221, 0245).

Supersonics

In the decade 1930-1939, acoustical research in India became strengthened through the induction of studies on supersonics and ultrasonics. In 1933, K. Prosad and S. Sharan set up supersonic vibrations in a zinc bar undergoing transverse vibrations (0130). Five years later, Nagendra Nath and Levi studied the transmission of supersonic waves through a rigid sheet (0167). The study of the propagation of supersonic waves through a liquid medium proved more rewarding. A.K. Dutt observed dispersion of such waves (0173), Nagendra Nath obtained diffraction patterns of a beam of light traversing a liquid medium subjected to supersonic waves (0174), and Ram Parshad noticed that supersonic wave propagation through liquids provided a method for studying intermolecular forces and intermolecular action (0197, 0209, 0236). Determination of supersonic velocities in gases and vapours, air, carbon dioxide, carbon disulphide, etc. formed the subject of a series of investigations by S.K.K. Jatkar (0171, 0172, 0181, 0183, 0184).

Ultrasonics

Ultrasonic studies in India opened up when S. Parthasarathy measured the velocity of ultrasonic wave propagation in 52 organic compounds (0140). In his further studies in the same field he included organic liquids like esters and ethers, and various other related organic compounds (0149-0152, 0156, 0157). S. Bhagavantam determined adiabatic compressibilities from ultrasonic velocities (0186); K.G. Krishnan investigated the dispersion of ultrasonic velocities in liquids, including organic liquids (0187, 0202), Sibaiya and Narasimhaiya measured ultrasonic velocities in solutions (0199); R. Parshad studied the refraction of ultrasonic waves in coloured liquids and solids and measured their velocities in extended solids (0215, 0220). Diffraction of light by ultrasonic waves engaged the attention of C.V. Raman (0148), and S. Bhagavantam and B.R. Rao (0224). Pisharoty and Nagendra Nath studied the visibility of ultrasonic waves (0155, 0158). Problems of ultrasonic absorption in acetic acid, in liquids, including organic liquids, interested a number of workers (0250, 0252, 0256, 0258).

3.2. *Astronomy and Astrophysics (AA)*

In Astronomy and Astrophysics, we have identified 181 authors contributing a total of 511 papers, including monographs and memoirs listed in this Bibliography. The list of 15 contributors having 10 or more papers to their credit is as follows:

1.	S. Chandrasekhar	78 papers
2.	J. Evershed	47 papers
3.	T. Royds	26 papers
4.	M.N. Saha	26 papers
5.	N.R. Sen	26 papers
6.	D.S. Kothari	20 papers
7.	A.C. Banerjee	14 papers
8.	A.K. Das	13 papers
9.	A.L. Narayan	12 papers
10.	H.K. Sen	12 papers
11.	U.R. Burman	11 papers
12.	P.R. Chidambara Iyer	11 papers
13.	V.V. Narlikar	11 papers
14.	P.L. Bhatnagar	10 papers
15.	C. Michie Smith	10 papers

A glance at the Subject Index leaves no doubt that the sun, stars, milky way and nova, including solar physics, stellar spectroscopy and ionisation problems, received the greatest attention. The old subjects of comets, meteors and meterorites, planets, latitude and longitude determinations received varying degrees of attention. No less interesting is the growing interest in sophisticated areas like cosmogony and cosmology, nebular astronomy and astrophysics and many dynamical problems in the light of modern mathematics, including relativity.

Astronomical Work in the Nineteenth Century

During the nineteenth century, the main interest in astronomy centred round mapping the positions of stars by their right ascensions and declinations, observations of transits and zenith distances of heavenly bodies, eclipses of the sun and the moon, Jupiter's satellites, comets and meteors. Ancient Indian astronomy, instruments and observations also attracted some attention. The oldest observatory set up in Madras in 1792 naturally led the way. John Goldingham, first Government Astronomer and Superintendent of the observatory carried out his observations with Troughton horizontal and vertical circles, Ramsden's portable transit instrument, Dollond's telescopes and astronomical clocks and produced an enormous number of observations, preserved mostly in manuscript form. Two volumes, however, appeared in print in 1824-25 (0268). A more systematic and accurate study of stellar positions was carried out by T.G. Taylor with improved transit instrument leading to his compilation of the well-known Madras General Catalogue of 11015 stars which received international recognition (0275, 0296). The next great effort in the compilation and refinement of star catalogues was due to Norman Robert Pogson whose observations of fixed stars with the Troughton meridian circle appeared in a series of volumes under his editorship and also of Mickie Smith between 1888 and 1894 (0327, 0328, 0329, 0331, 0334).

Observations of a number of solar eclipses during the century included the determination of annularity of the solar eclipse of 7 July 1861 by J.F. Tennant (0306), a full report by the Madras Government Astronomer on the total solar eclipse of 18 August 1868 observed at Musalipatam, Vunpurthy, Madras and other stations in South India (0312), the photographic study by Naegamvala of the spectrum of the solar eclipse 'flash' of 21 January 1898, and the St. Xavier's College Jesuit Fathers' work on the same eclipse of 1898 (0337, 0339, 0342).

Halley's comet was observed and studied at the Madras Observatory by Taylor in 1835 (0283). The Comet of July 1861 was observed by Rev. Mackay and J. Obbard (0304, 0308, 0309). Meteorites and aerolites were studied more from consideration of their geological rather than astronomical interest. The phenomena of the appearance of meteors in the night sky were observed by Middleton, Boileau and Shortrede (0284, 0287, 0291); Piddington described and analysed a large iron meteorite which fell near Monghyr (0298); Peppe observed the fall of aerolites and meteorites; and D. Waldie analysed the Khettree meteorite in 1869 (0314).

Among the various instruments and observatories noticed, special mention may be made of the astrolable, the medieval astronomical instrument *par excellence* (0286, 0288), account of various errors in optical instruments and their rectification and descriptions of the king of Aude's observatory at Lucknow set up in 1835, the Poona Observatory (0292) and St. Xavier's College Observatory (0319).

Astrophysics in the Twentieth Century

The twentieth century opened up with a marked interest in astrophysical research in general and solar physics in particular. During the first two decades, 1900 to 1919, John Evershed, Director of the Kodaikanal Observatory, successor to the old Madras Observatory played the leading role along with his colleagues

Michie Smith and T. Royds. Naegamvala who had already proved his mark by his eclipse research was joined by a few other young physicists, namely, G. Nagaraja, Sitarama Aiyar and A. Narayana Aiyar.

Sun-spots and Prominences

Evershed concentrated on two important solar phenomena, viz. sun-spots and prominences. Between 1905 and 1916, Evershed studied the sun-spots in ultraviolet spectra, sun-spot spectra in general and established radial movements in sun-spots; Michie Smith showed the existence of a magnetic field in sun-spots, while Royds compared the periodicities of sun-spots and prominences (0344, 0351, 0353, 0354, 0358, 0359, 0370, 0377, 0387, 0389). Nagaraja studied the weakened and obliterated lines in sun-spot spectra. Evershed's research on solar prominences started with his investigation of the prominences of 1907. With Michie Smith, he measured the angular speed of rotation of long enduring prominences. A number of papers dealt with the correlation between prominences and sun-spots. T. Royds studied the prominence periodicities, planetary effects on the distribution of prominences. On solar spectra, in general, Michie Smith recognised D_3 as a dark line (0343). Evershed measured the wavelength of H-delta and H-epsilon, the displacement of solar lines towards the red, and studied the general radiation of the sun and the displacement of spectra in the sun's limb (0349, 0373, 0376, 0379). Narayana Aiyar showed that such displacement of spectra in the sun's limb could be due to pressure and density.

In stellar research, Naegamvala studied the Nova in Perseus (0341); Evershed obtained the sectrum of Nova Aquilae, detected calcium clouds in the Milky Way, and discussed the pulsation theory of the cepheid variables.

Solar and Stellar Surface Phenomena – Theory of Thermal Ionisation

Evershed and Royds, particularly the latter, continued to make important contributions to solar prominences and other areas of solar characteristics. But from 1920 onwards, Indian participation in astrophysical research became more and more significant. In 1920, M.N. Saha published two papers in *Phil. Mag.*, one on the ionisation of the solar chromosphere and the other on the elements in the sun (0409, 0410). In the first paper, Saha explained, through his famous ionisation formula, the enhancement of the chromospheric spectra being due to a reduction of pressure in the chromosphere. In the 'Elements of the Sun', Saha further explained on the basis of his theory why certain elements (Rb, Cs) are completely ionised and others are not due to their high ionisation potentials. These ideas were further elaborated and applied in various situations in a series of papers, e.g. application of electron-chemistry to problems of radiation and astrophysics (0413), H- and K-lines of calcium in stellar atmosphere (0414), ionisation in stellar atmosphere (0415), rubidium in the sun (0416), finally culminating in his 'Physical Theory of Stellar Spectra' published in *Proc. R. Soc. London* (0418). During 1921-28, Saha contributed to the theory of continuous radiation from the sun, pressure in stellar reversing layers, ionisation in stellar atmospheres and steric factor, nitrogen in sun, origin of nebulium spectrum and the origin of the spectrum of solar corona (0424, 0427, 0430, 0433, 0440, 0441).

The research in sun-spots now attracted new faces. P.R. Chidambara Aiyer, in a series of papers, investigated two longitudinal zones of apparent inhibition of sun-spots on the solar disc (0468, 0475, 0481). M. Salaruddin and C.K. Ananthasubrahmanyam worked on the problem of magnetic storms associated with sun-spots (0596, 0612). In 1947, Ananthakrishnan, K. Setumadhavan and A.K. Das studied the activity of the sun-spot cycle obtaining in that year. In the study of solar prominences, Royds was joined by N.K. Sur, C.P.S. Menon, A.L. Narayan, A.K. Das, M. Salaruddin and K. Setumadhavan. Problems studied included the role of selective radiation pressure and accelerated motion of Ca^+ vapour in eruptive prominences (0431); hydrogen content of prominences (0487); Oxygen in solar prominence (0550, 0556); influence of earth on solar prominences (0601), and so on.

Stellar Interior, White Dwarfs, Energy Problem

From towards the end of the 20s, stellar research assumed greater interest. From problems concerning the surface and atmosphere of the sun and stars, Indian astrophysicists increasingly concentrated on those concerning the interior of the stars, the state of matter in stellar interior, source of stellar energy, stellar models and the problems of white dwarfs and highly condensed stars. The handling of these problems was now rendered possible by the new statistics of Fermi and Dirac applicable to degenerate electron gas. The problem of stellar interior and the question of the white dwarf went hand in hand. S. Chandrasekhar's early work was concerned with the thermodynamics of the Compton effect with reference to the interior of the stars (0443). His work on white dwarfs started with his estimation of the maximum mass of an ideal object of this class (0451). In the study of dwarfs, an important element is the opacity coefficient of degenerate matter essential for the calculation of the temperature of this type of stars. D.S. Kothari and R.C. Majumdar, jointly and severally, and Chandrasekhar independently worked on the problem of stellar coefficients of opacity and absorption in a series of papers (0456, 0457, 0462, 0463, 0464). In their studies on white dwarf, Chandrasekhar and Kothari determined the density (0458, 0459); Kothari discussed the neutron degeneracy (0562) and mass-radius relations (0609). The physical state of matter and pressure in the interior of stars, as also the constitution of stellar interior formed the subject of yet another series of papers by Chandrasekhar (0479, 0504, 0512, 0523, 2537, 0551, 0593). In the course of these studies carried out in the thirties, Chandrasekhar suggested his famous mass-limit of a star that may eventually evolve into a white dwarf, a neutron star or a black hole.

D.S. Kothari, N.R. Sen and U.R. Burman made important contributions to problems of stellar energy. Thus, Kothari obtained a lower limit to energy evolution in stellar matter (0579) and considered the source of energy in white dwarfs (0613); N.R. Sen and U.R. Burman developed stellar model on the basis of Bethe's formula of energy generation and suggested the nature of internal constitution of stars with small masses (0647, 0648, 0669, 0701).

Research on Variable Stars and Nebulae

Variable stars, cepheid variables in particular and the pulsation theories were intensively studied by the Allahabad group of astronomers and astrophysicists, A.C. Banerjee, H.K. Sen, P.L. Bhatnagar, D.S. Kothari and S.K. Roy (0634, 0641, 0646, 0685, 0690, 0708, 0709, 0737).

In nebular research, S.N. Shiveshwarkar investigated the radial velocities of globular clusters and nebulae (0514). S. Chandrasekhar studied the nebulium emission in planetary nabulae and the problems of radiative equilibrium in planetary nebulae and the special case of such a nebula in expansion (0529, 0531, 0704). On spiral bebulae, V.V. Narlikar studied their recession (0519); A.C. Banerjee, Nazimuddin and P.L. Bhatnagar their spiral arms (0592); and D.N. Moghe the theory of formation of spiral nebulae. The expansion of nebulae was dealt with by N.R. Sen and D.N. Moghe (0554, 0588).

Cosmogony and Cosmology

N.R. Sen jointly with M.V. Laue made a critical study of de Sittar's universe (0426). Sen then discussed the nature and problem of radiation in an expanding universe (0470). In his treatment of Eddington's problem of expansion of the universe (0495), he showed that stability in Einstein universe would be possible if matter were packed in spherical condensations, but then it would require a slightly greater total mass than given by Einstein. This extra mass necessary for equilibrium would also be responsible for the expansion of the universe. N.K. Chatterjee in his paper on the expansion of Einstein universe by condensation (0486) showed that the results would be the same for non-homogeneous condensations. Sen further refined his ideas on the stability of cosmological model (0507, 0532). V.V. Narlikar, in his paper on world criterion, obtained a λ-term from his field equations which also explained the breaking up of the Einstein universe into discrete material condensations (0476). Narlikar and Moghe, in another paper, worked out the relationship between the spiral structure of nebulae and the expanding universe (0524). The cosmological significance of the occurrence of elements and their relative abundance, including the isotopes, was discussed by M.F. Soonawala and S. Chandrasekhar (0450, 0631). P.C. Vaidya and G.K. Patwardhan studied the problem of the relativistic distribution of matter of radial symmetry and the centres for the absorption of radiation in a non-statical homogeneous universe (0664, 0768).

3.3. *Atomic and Molecular Structure (AMS)*

Knowledge about atomic and molecular structures developed, it need hardly be emphasised, out of scattering, magnetic and electrical, optical and X-ray spectroscopic studies in which radiation in various forms interacted with atoms and molecules of materials in various physical situations. In 1925, D.M. Bose determined the distribution of electrons among inner quantum levels of atoms of different elements (0778). M.N. Saha and B.B. Ray discussed the Mainsmith-Stoner scheme of building up the atom through the filling up of shells with electrons (0784, 0785). S.S. Bhatnagar, Balwant Singh and Abdul Ghani suggested the electronic constitution of some simple and complex derivatives of copper on the basis of their magnetic studies (0796). V.V. Narlikar showed that there should be an upper limit of the atomic number, that is, of the maximum number of electrons that could be accommodated within an atom (0798). T.S. Subbaraya *et al.* studied the interaction of atomic energy levels.

C.V. Raman and K.R. Ramanathan utilised the property of optical anisotropy of molecules determined from light scattering experiments in suggesting possible molecular structures, e.g. benzene and cyclohexane (0772, 0775, 0777, 0781). Likewise, D.M. Bose established the relationship between magnetism and structure of some simple and complex molecules (0786). P.C. Mahanti and P.N. Ghosh gave a molecular model of tri-atomic gases like CO_2, CS_2, NO_2, H_2O, H_2S and N_2O (0787, 0794). C.V. Raman characterized his own discovery as a method of investigating molecular structures by light scattering (0788). S.S. Bhatnagar and his coworkers determined the molecular structures of chromium and manganese compounds from their magnetic susceptibility measurements (0792, 0827, 0835). R.S. Krishnan provided optical evidence of molecular clustering in fluids, binary liquid mixtures, and in fatty acids (0810, 0812, 0814, 0817). Mata Prasad and S.S. Dharmatti determined by magnetic methods the molecular structure of selenium compounds. A number of workers studied problems of valency, such as bond energies from Raman frequencies and thermochemical data (0808), experimental determination of electron affinity of chlorine (0825) and so on.

3.4. *Biophysics (BP)*

We shall indicate in a subsequent section how J.C. Bose pioneered electrical researches in India by investigating the optical characteristics of Herzian Waves in the last decade of the nineteenth century. Later on, he became interested in plant physiological investigations by means of physical methods. The term 'biophysics' did not emerge in his time, but these investigations, as we know today, constituted the early beginnings in a new area of physics of great importance. We have noted 39 papers contributed by 12 authors. J.C. Bose, singly and in collaboration with his coworkers, accounted for 35 papers. Produced between 1900 and 1927, these papers concerned similarity of effect of electric stimulus on inorganic and living substances, electric response in ordinary plants under mechanical stimulus, electric pulsation accompanying automatic movements in *Desmodium gyrans,* researches on growth and movements in plants by means of high magnification crescograph, response of plants to wireless stimulation, physiological anisotropy induced by gravitational stimulus, etc. (0876-0910). Other workers in the subject include D.M. Bose, N.K. Sen and S.K. Pain.

3.5. *Crystal Structure and Properties (CSP)*

In Crystal Structure and Properties, 143 research workers contributed 313 papers. Leading authors who produced 10 or more papers noticed in this Bibliography include:

1.	K.S. Krishnan	45 Papers
2.	C.V. Raman	35 Papers
3.	S. Bhagavantam	16 Papers
4.	K. Banerjee	15 Papers
5.	S. Banerjee	13 Papers
6.	R.S. Krishnan	11 Papers

Optical and Physical Properties

Of the nine sub-groups into which the main classification has been divided, a large number of papers naturally concerned optical and various physical properties of crystals. Raman and Tamma observed a new optical property of biaxial crystals (0917); with K. Banerjee, Raman studied the optical properties of amethyst quartz (0921). The relation between pleochroism and crystal structure, specially the birefringence of NO_3-ion in crystals, was studied by K.S. Krishnan in collaboration with A.C. Dasgupta and B. Mukhopadhyay (0932, 0942, 0947). S. Ramachandra Rao observed the secondary electron emission from a single crystal face of nickel (0934). K.S. Krishnan and L.K. Narayanaswamy studied the photodissociation of single crystals of potassium and sodium nitrates under polarized light (0968, 0980). Crystal rectification under the influence of heat, ultraviolet light and X-rays and also crystal rectification by volume were studied by A.K. Dasgupta, S.R. Khastgir and B.K. Sen (0972, 0990, 1072). Raman spectra of crystals were studied by K.S. Krishnan and I. Ramakrishna Rao shortly after the discovery of the Raman effect. S. Bhagavantam and T. Venkatarayudu studied the Raman effect in relation to crystal structure (1039); T.A.S. Balakrishnan showed the effect of crystal orientation on Raman spectra of barytes (1061), while Roop Kishore studied the Raman spectra of crystals excited by mercury resonance radiation (1076). S. Bhagavantam and J. Bhimasenachar developed a new method for determining the elastic constants of crystals (1103).

Crystal Magnetism

Of the various physical properties of crystals, the magnetic properties, or simply crystal magnetism, received considerable attention from Indian workers, of whom K.S. Krishnan and his collaborators made the most significant contribution. In 1920, K. Seshagiri Rao carried out some studies on the magneto-crystalline properties of Indian braunites (0915). During 1927-29, C.V. Raman and K.S.

Krishnan, singly and jointly, studied the magnetic anisotropy of crystalline nitrates and carbonates, magnetic behaviour of organic crystals, diamagnetism and its relation to crystal structure (0925, 0927, 0928). About this time, S.S. Bhatnagar, R.N. Mathur and G.S. Mahajani became interested in the question of the relationship between magnetic susceptibilities and crystal structure, the problem of ferromagnetic crystals and the like (0929, 0930). From the beginning of the thirties, Krishnan and his collaborators, S. Banerjee, B.C. Guha, N.C. Chakravorty, A. Mookerjee and a few others, intensively pursued the study of crystal magnetic susceptibilities and magnetic anisotropy of a large number of organic and inorganic crystals. K.S. Krishnan, B.C. Guha and S. Banerjee carried out detailed investigations of magnecrystallic action, with special reference to diamagnetics (0951); with N. Ganguly, Krishnan demonstrated the abnormal unidirectional diamagnetism of graphite crystals (0956); with S. Banerjee, Krishnan developed a simple method of studying the magnetic susceptibility of very small crystals (0957). Likewise, magnecrystalline action of paramagnetics was studied by K.S. Krishnan, N.C. Chakravorty, S. Banerjee and A. Mukherjee (0952, 0992, 1026). Krishnan and his collaborators measured the magnetic anisotropies of paramagnetic crystals, rare-earth sulphates, copper sulphate and coordinated Co^{+} ions in crystals (0941, 1010-1013). Other workers in crystal diamagnetism included S.R. Rao, A.S. Narayanaswami, S.R. Govindarajan and in paramagnetism D.M. Bose and his coworkers. A few more papers have been noticed under Magnetism and Electromagnetism.

Diamond and Graphite

Diamond and graphite comprised another intensive sub-area of crystal physics in which C.V. Raman and his coworkers played a leading role. In 1943, Raman initiated a general discussion on the structure and properties of diamond (1082) and dwelt on the crystal symmetry and structure of diamond (1113). Bhagavantam studied the normal oscillations of diamond structure (1090), and determined the elastic constant of diamond (1111). G.N. Ramachandran obtained X-ray topographs of diamond (1102), determined the crystal structure of diamond (1129), and explained the nature and origin of the laminations observed in diamond crystals (1143). S. Ramaseshan described the crystal forms of the famous Panna diamonds (1117), discussed the physical significance of its crystal forms (1140), and also developed a theory to account for such crystal forms (1146). R.S. Krishnan produced experimental evidence for the existence of four possible crystal structures of diamond (1116).

A glance at the Subject Index will give an idea as to the variety of inorganic and organic crystals whose crystal structures were studied in India during the thirties and the forties.

3.6. *Electricity, Electric Conduction and Discharge (EED)*

In this section, we have noted 295 investigators contributing 372 papers. Six contributors who produced 10 or more papers are:

1.	P.C. Mahanti	15 papers
2.	S.K. Kulkarni Jatkar	14 papers
3.	G.N. Bhattacharyya	12 papers
4.	N.R. Dhar	12 papers
5.	S.R. Khastgir	12 papers
6.	S.S. Joshi	10 papers

In the Subject Index, papers have been shown under 8 sub-groups. A large number of papers were concerned with dielectrics and measurements of dielectric constants and determination of dipole moments of various substances. These investigations were generally carried out in the applied electrical departments of universities and research institutes. Electrochemistry included in this section also recorded a large number of papers contributed generally by the physical chemists.

Early in the 19th century, galvanic batteries and simple electrical experiments with them attracted the attention of a few workers interested in the new phenomenon of galvanic electricity. William Brooke O'Shaughnessy developed a device for exploding gunpowder with electric current from a galvanic battery (1228). He also realized the possibility of using lightning conductors for protecting powder magazines from atmospheric electric discharges. R.B. Smith also worked on galvanic batteries as an igniting agent (1230). Electric research in India, however, received a new direction with the appearance of J.C. Bose in the field. In 1895, J.C. Bose, inspired by Herz's work on electric rays, studied the properties of such rays and published a series of papers in the *Electrician* and in the *Journal of the Asiatic Society*, e.g. polarisation of electric rays by double refracting crystals (1232, 1235), double refraction of the electric ray be a strained dielectric (1233), and a new electropolariscope (1234). In 1897, Bose delivered a Friday evening lecture at the Royal Institution of London on his recent investigations on electromagnetic radiation and polarisation of the electric ray. The same year, he published in the *Proceedings of the Royal Society of London* three papers, viz. selective conductivity exhibited by certain polarising substances, determination of refractive indices of substances for electric ray, and influence of thickness of air space on total reflection of electric radiation. At the Calcutta Presidency College, where J.C. Bose carried out his above-mentioned experiments, a few other professors and research workers also became interested in electrical researches. J.A. Cunningham and Satish Chandra Mukherjee studied the electrical state of nascent gases (1241); Mukherjee published a note on the uses of storage cells in Bengal (1243); V.H. Jackson and Asutosh Mukherjee made improved measurements with quadrant electrometers. With the organisation of an electrical department at the Indian Institute of Science, Bangalore, Alfred Hay and his coworkers, M.H. Bhat, J.M. Parikh and F.N. Mowdawalla, produced papers on the skin effect (1245), field distortion in continuous current generators (1246), experiments on brush contact resistance (1247), dielectric strength of biotite mica from Kodarma forest (1248), and analytical investigations on the working of synchronous machines with alternating currents (1249) – all experimental investigations of an applied nature.

From towards the end of the second decade of the twentieth century, electrical researches in India started to be diversified. A small group of workers now became interested in cathode rays, and in due course, in canal or positive rays. During 1918-20, H.E. Watson and G.R. Paranjpe carried out experiments on the cathode fall (1252). S.C. Roy studied the emission of ions from hot metals and used the quantum theory for a proper understanding of the law of emission (1289). H. Rakshit investigated the problem of space charge distribution between plane hot cathode and the parallel anode (1339). C.K. Sundarachar studied the cathode fall of potential in the arcs, while R.K. Cowsik worked on the cathode sputtering of metals (1367, 1370). B. Dasannacharya and his coworkers, V.T. Chiplonkar, L.G. Sapre, G.K. Das and C. Dakshinamurti, singly and jointly, studied a number of problems associated with positive rays, such as ring deposit on glass by positive ray bombardment, Doppler effect in hydrogen positive rays, ionisation potential and Doppler effect in hydrogen positive rays and ring deposition on surfaces bombarded by canal rays (1402, 1522, 1523, 1540).

The spurt of efforts directed towards the study of dielectrics and the measurements of dielectric constant and electric moments of a large number of organic substances in liquids and mixtures, crystals, polyatomic molecules, oils, varnishes and insulating materials, gases as well as ionised media, was clearly dictated by the theoretical importance of such studies as also by their industrial implications. In 1926, K.S. Krishnan and C.V. Raman published a small note in *Nature* on the electrical polarity of molecules (1294). A few years later, Krishnan published in the *Proceedings of the Royal Society* a paper on the influence of molecular form and anisotropy on the refractivity and dielectric behaviour of liquids (1324). P.N. Ghosh, P.C. Mahanti, D.N. Sengupta, R.N. Dasgupta and T.P. Chatterjee, of the Applied Physics Department, University College of Science, measured the dielectric constants and electric moments of a large number of organic substances, e.g. methylene chloride, methylene bromide, primary alcohols, binary mixtures of methylene and ethyledene halides in benzene, members of homogeneous series, amines, alkyl monohalides, etc. for obtaining an understanding of the relationship between electric moments and chemical constitution (1304, 1311, 1315, 1318, 1319, 1331, 1342, 1355, 1403). Similar investigations were carried out by H.E. Watson (ammonia, phosphine and arsine), M.A. Govinda Rau, B.N. Narayanaswamy and N. Anantanarayan (1404, 1405, 1439). S.K. Kulkarni Jatkar studied the dipole moments of polyatomic molecules to obtain an insight into their molecular structure (1521, 1558, 1595). D.A.A.S. Narayana Rao investigated the dielectric constants of crystals and the anisotropy of rocks (1565, 1566).

In the measurement of dielectric coefficients of gases, H.E. Watson, G. Gundu Rao and K.L. Ramaswamy selected hydrogen, rare gases, lower hydrides of carbon, silicon, oxygen, nitrogen and oxides of nitrogen, allene, allylene, butanes, butylenes, cyanogin and hydrogen cyanide, and fluorides of boron, nitrogen and carbon (1356, 1383, 1423, 1424). S.K. Mitra and S.S. Banerjee measured the dielectric constants of ionised air and gas (1391, 1401). Mitra and K.K. Roy studied the anomalous dielectric constant of artificial ionosphere. Dielectric constants of a space containing electrons as also of ionised gases were measured by S.R. Khastgir and his coworkers (1427, 1457, 1464, 1474, 1475, 1503) and by S.P. Prasad and M.N. Verma (1426, 1445).

Dielectric studies from industrial considerations included the effect of superimposed magnetic fields on breakdown voltage of dielectrics, effect of successive discharges of the dielectric strength of liquids, effect of impurities on breakdown voltage of transformer oils, all studied variously by B.S. Ramaswamy, N.V. Narayanaswami and F.N. Mowdawalla (1385, 1386, 1387). Dielectric properties of Indian vegetable oils were intensively investigated by G.N. Bhattacharyya, G.R. Paranjpe, P.C. Mahanti and S. Krishnamurty (1411, 1418, 1419, 1492, 1589). Bhattacharyya also determined the dielectric constants of a large number of insulating materials like shellac varnishes for coating graphite, lac and lac moulded materials, dipole moments of chief constituents of lac and resin, dammar and mastic resins (1483, 1496, 1501, 1512, 1514, 1515, 1517).

In electric discharge, D.N. Mallik and A.B. Das studied a number of cases of electric discharge, including one through hydrogen and advanced a quantum theory of electric discharge (1260, 1266, 1271). S.S. Joshi studied the decomposition of nitrous oxide in silent electric discharge (1302, 1326, 1327). B.D. Chatterjee and P.N. Ghosh worked in the area of high frequency discharge through gases like air, nitrogen, oxygen, CH_4, CH_3Cl, CH_2Cl_2, $CHCl_3$ and CCl_4 (1346, 1349); D. Banerjee, R. Ganguly and D. Bhattacharyya determined the space potential in high frequency discharge, and studied the deposits of mercury and other elements by H.F. discharge (1337, 1380, 1390). R. Krishnan and S.K. Kulkarni Jatkar observed the dissociation of O_2 and formation of O_3 in silent electric discharge (1452). S.S. Joshi and G.S. Deshmukh also employed silent electric discharge in studying the interaction of nitrous oxide and hydrogen (1535). A number of workers studied the Joshi effect in bromine vapour under silent electric discharge, in chlorine under full and semi-ozoniser excitation, in mercury and iodine vapours, and various other situations and gave a theoretical explanation of the effect (1553, 1560, 1575, 1576, 1580, 1583, 1584).

Electrochemistry, as has already been remarked, was largely the field of work of the physical chemists. Between 1919 and 1925, some pioneering contributions came from N.R. Dhar and J.C. Ghosh. Dhar's investigations concerned polarisation tensions of iron in solutions of its complex salts, coagulation of manganese dioxide sol by electrolytes, negative and positive catalysis and activation of molecules, viscosity of colloids in the presence of electrolytes (1253, 1270, 1274, 1280, 1283). J.C. Ghosh worked on the abnormality of strong electrolytes and gave a theory on the basis of regular arrangement of ions, which attracted considerable attention at that time.

3.7. *Electrons. Ions (EI)*

This is a relatively small section focussing attention on a number of electron properties, electron dynamics and theory, ions, ionisation and active nitrogen, having overlapping areas with those of the preceding section. A number of e/m measurements include one by D.S. Kothari with electrode valve, another by K. Krishnamurti from the mass and charge of colloid particles and yet another by M. Santra by means of a triod valve (1609, 1629, 1633). G.B. Banerjee and B. Pattanaik determined electronic charge from the viscosity of air (1642). Photoelectric emission from phototropic mercury compounds was studied by S.V. Raghava Rao and H.E. Watson (1613). Secondary electron emission from various metals was examined by S.R. Rao, Bhawalkar, P.S. Varadachari, R.M. Chaudhury and A.W. Khan (1624, 1627, 1638, 1650, 1651, 1672). K.C. Kar studied the properties of an electron cloud (1619). On electron scattering problems, K.C. Kar and S.S. Gupta and P.C. Chatterjee considered the scattering of fast electrons by atoms (1663, 1686); A.B. Bhatia and K.S. Krishnan discussed diffused scattering of Fermi electrons in monovalent metals (1679); and N.D. Sengupta studied the scattering of electromagnetic waves by free electrons (1681). K.S. Singwi investigated the magnetic waves by free electrons (1681). K.S. Singwi investigated the magnetic behaviour of free electrons and S.N. Gupta the magnetic polarisability of electrons (1677, 1684).

The problem of active nitrogen received the attention of a number of workers. M.N. Saha, N.K. Sur and L.S. Mathur dwelt on the problem of the active modification of nitrogen and discussed the available theories in this regard (1605, 1635). S.K. Mitra and his student J.S. Chatterjee organised and performed several experiments concerning active nitrogen and N_2^+ (x)ions, ionisation in active nitrogen, recombination of N_2^+ (x)ions and also proposed a new theory (1653, 1654, 1655, 1659, 1660, 1661, 1663, 1676, 1689). S.K. Mitra also dealt with the formation of active nitrogen in auroras (1688).

On electron theory and dynamics, M.N. Saha's early papers concerned the dynamics of the electron published in *Phil. Mag.* in 1918 and the mechanical and electrodynamical properties of the electron in *Physical Reviews* in 1919 (1600, 1601). N.R. Sen studied the equations of electronic theory and Dirac's wave equation (1620), while S. Gupta dwelt on the angular momentum and virial equations of Dirac electron (1621). K.C. Kar and K.K. Mukherjee explained wave statistical theory of electron spin. H.J. Bhabha gave a lucid account of the classical theory of electrons (1647), and B.M. Sen a new classical theory of photon and electron (1669). The mechanics of the motion of an electron in the Hartree field of a hydrogen atom was described by S. Chandrasekhar and H. Breen (1667).

3.8. *General Physics (GP)*

General physics provided, in a sense, the mathematical foundation for both classical and new physics as also for much of theoretical astrophysics. The subject covered a wide area of research such as aerodynamics, hydrodynamics and fluid dynamics, classical mechanics, elasticity, quantum mechanics and quantum statistics, relativity and gravitation, statistical mechanics, wave mechanics and wave statistics, surface tension and viscosity. To this we have added a sub-section on mathematical physics to draw attention to contributions of a purely mathematical character having relevance to physical problems. The great attention paid to the subject by Indian physicists and applied mathematicians is reflected in 731 papers contributed by 358 contributors. The following 14 research workers with 10 or more papers to their credit have been identified in this Bibliography:

1.	B.B. Sen	30 papers
2.	V.V. Narlikar	29 papers
3.	D.S. Kothari	21 papers
4.	B.R. Seth	20 papers
5.	F.C. Auluck	16 papers
6.	Ganesh Prasad	16 papers
7.	L.D. Mahajan	14 papers
8.	N.R. Sen	13 papers
9.	B. Sen	11 papers
10.	M. Roy	11 papers
11.	B.S. Madhava Rao	11 papers
12.	K.C. Kar	11 papers
13.	S. Ghosh	10 papers
14.	S. Chandrasekhar	10 papers

Work on general physics is noticed in India from the closing years of the eighteenth century. Thus, we have Francis Balfour's paper on the barometer in the 4th volume of *Asiatick Researches* appearing in 1795. During the 19th century, about 12 papers have been noticed, which dealt with barometers, including their application in the determination of heights of mountains, elasticity of Indian woods, specific gravity of sea-water, Indian balance, weights and measures and the mensuration of the Vedic sacrificial altars under the title *Śulvasūtras*. Towards the end of the century, Asutosh Mukherjee struck a new note with his papers on plain analytical geometry (1699), Clebsch's transformation of the hydrokinetic equations (1701), and a note on Stoke's theorem and hydrokinetic circulation (1702).

Asutosh Mukherjee's influence as an applied mathematician and his efforts in founding the Departments of Applied Mathematics and Physics bore fruit in producing a band of young applied mathematicians who were soon destined to make important contributions in classical and newly emerging areas of general physics. A few examples may be given from the old subject of elasticity and the new sophisticated areas of quantum mechanics, quantum statistics, relativity, gravitation, statistical mechanics, wave mechanics and wave statistics.

Elasticity

It is interesting to observe that some of our leading theoretical physicists had their initial experience in solving problems connected with elasticity. Thus, in 1918, Meghnad Saha worked on a new theorem in elasticity (1722), S.N. Bose discussed the stress equations of equilibrium (1725), N.R. Sen studied the propagation of waves in elastic media (1757), and D.S. Kothari (with G.B. Deodhar) investigated the problem of the elastic behaviour of Indian rubber (1794). Among those who carried out systematic and sustained investigations on elasticity, special mention may be made of S. Ghosh, N.M. Basu, B.B. Sen and B.R. Seth. S. Ghosh investigated cases of plane strain and stress in rotating elliptic cylinders and discs, flexture of beams, plane strain in an infinite plate with an elliptic hole, distribution of stress in three dimensions, stress distribution in a heavy disc held with its plane vertical, and two-dimensional problem of elasticity (1796, 1932, 1992, 1993, 1994, 1996). N.M. Basu discussed the application of new methods of the calculus of variations to problems in the theory of elasticity, torsion problem in elasticity theory, and the case of the bending of a thin elastic circular plate (with H.M.S. Gupta) (1827, 1828, 1855). Starting in 1930, B.B. Sen investigated a large number of problems in elasticity, which included stresses in circular rings under the action of isolated forces on the rim, stresses in elastic spheres having discontinuous distribution of normal pressures on the surface, stresses due to a small elliptic hole on the normal axis of a deep beam under constant bending moment, stresses due to a small spherical cavity in a uniform beam bent by terminal couples, effect of small cavities and cracks in a cylinder twisted by torsional and shearing stresses, two-dimensional problems of elasticity connected with plates having triangular boundaries, application of trilinear coordinates in problems of elasticity and hydrodynamics, torsional vibrations of cylindrical rods under variable forces, stresses in rotating circular discs of varying thickness (1813, 1842, 1853, 1897, 1908, 1943, 1942, 1946), to mention a few out of his 30 papers recorded in the Bibliography. Another successful worker in the field of elasticity was B.R. Seth, younger contemporary of B.B. Sen. Seth studied the finite strain in elastic problems, flexture of beams of polygonal cross-section, symmetrical flexture of an angle iron, problems of finite strain in several parts, Guest's law of elastic failure and several others (1950, 2015, 2047, 2108, 2110, 2166). There were also a few odd studies on elasticity connected with the internal structure of materials and crystals. Thus, Kedareswar Banerjee studied the problem of permanent deformation produced by contact of solids and the theory of photoelasticity (1781, 1793). P. Rama Pisharoty determined Young's modulus of diamond (2141) and Bishambhar Dayal Saxena calculated the elastic constants of quartz at room temperature (2246).

Quantum Mechanics. Quantum Statistics

In the early twenties, K.C. Kar discussed the theory of generalised quanta and the relativistic Newtonian motion (1744), quantum statistics (1788) and the wave statistical theory of spinning electrons (1883). D.N. Mallik discussed quantum theory postulates (1767) and S.C. Roy studied the applicability of the idea of light quanta in the theory of chemical reactions (1771). But the fundamental work that immediately attracted wide attention was S.N. Bose's deduction of Planck's radiation formula directly from statistical considerations of an assembly of photons, entered in this Bibliography under Optics and Radiation (3887, 3888). Bose's work led to the development of a new method in quantum statistics, recognised by Einstein and applied by him in the case of a degenerated gas. M.N. Saha, in his 'Progress of Physics in India during the past twentyfive years' observed that Bose's work 'was responsible for stimulating the work of Fermi and Dirac on the alternative statistics which apply to most elementary material particles (Fermi-Dirac Statistics)' (*Progress of Science in India*, 716). D.S. Kothari, R.C. Majumdar, F.C. Auluck, B.N. Singh and B. Nath, singly and jointly, used the methods of statistical quantum mechanics in the analysis of a theorem on Poisson in classical dynamics, in the theory of internal constitution of planets, problems of energy levels of artificially bounded linear oscillator, degeneracy according to Bose-Einstein statistics, Fermi-Dirac functions; and condensation in Fermi-Dirac statistics (1919, 2027, 2150, 2176, 2194, 2222, 2270). B.N. Srivastava applied relativistic quantum statistics in problems of effusion and thermal transpiration (2086, 2128); A.G. Choudhuri and B.N. Singh estimated energy and wavelength maxima from Fermi-Dirac and Bose-Einstein distributions (2135); D.V. Gogate, Y.V. Kathavate and R.N. Rai studied the effusion phenomena and flow of liquid helium II on the basis of Bose-Einstein degeneracy (2197, 2240), while S.N. Gupta developed a theory of longitudinal photon in quantum electrodynamics (2408).

Relativity. Gravitation

In relativity, gravitation and allied fields, the research workers who established an early reputation included N.R. Sen, S.C. Kar, J. Ghosh, V.V. Narlikar and his coworkers, D.N. Moghe, P.C. Vaidya, G.K. Patwardhan and K.R. Karmakar, S.M. Sulaiman, B.C. Mukherjee, and a few others. N.R. Sen's work on relativistic cosmology has already been referred to. His other early studies concerned the boundary conditions for the gravitational field equations on surfaces of discontinuity, Fresnel's convection coefficient in general relativity, and energy of electrified particle according to Einstein's modified field equations (1756, 1790, 1792). S.C. Kar worked on Einstein's gravitation equations and geodesic movements in Einstein's gravitation theory (1778, 1789). Another consistent worker was J. Ghosh who dealt with gravitational field of an ideal fluid,