PHYSICS HANDBOOK

2020-21

ASHOKA UNIVERSITY

DEPARTMENT OF PHYSICS

ASHOKA UNIVERSITY

Contents

Introduction

Physics is a doorway to some of the most beautiful and profound phenomena in the universe like black holes, supernovae, Bose-Einstein condensates, superconductors. It is, simultaneously, a driver of lifestyle-changing technology, e.g., engines, electricity, and transistors; and a powerful way of perceiving and analyzing problems that can be applied in various domains, both within and outside standard physics. The beauty and profundity of the phenomena studied by physicists offer romance and excite passion, and the utility of its discoveries and the power of its methods arouse interest.

These methods can be very intricate and demanding: theoretical physics requires a skilful combination of physical and mathematical thinking, and experimental physics requires in addition the ability to turn tentative ideas into physical devices that can put those ideas to the test. As a result, the successful practice of physics demands rigour, flexibility, mechanical adroitness, persistence, and great imagination. The physicist's imagination is nourished not just by physics but also by other areas of human enquiry and thought, of the kind that an Ashoka undergraduate is expected to encounter.

With all of this in mind, the physics programme has been designed to:

(i) allow students wishing to major in physics to discover real physics and make a wise choice, in the first year;

(ii) provide, throughout, a thorough training in fundamental physics;

(iii) bring together everything learnt earlier, and give students the option to pursue more advanced courses in physics or branch out into other areas, in the third year. The idea is to accompany those wishing to become professional physicists as they take the first steps in that direction, and to introduce everyone who goes through the programme to the physicist's way of thinking.

Physics Major – Typical Trajectory

Semester 2: Discovering UG-level Physics

A student wishing to major, minor, or pursue a concentration in Physics is expected to take the introductory course in calculus (Calculus I) offered by the Mathematics Department. Students wishing to major in Physics should plan to take it in their first semester.

Requirement for Physics major: 13 core physics courses + 2 electives (60 credits)

The physics-major sequence begins in semester 2, with two courses, one in theoretical physics and the other in experimental physics. The first purpose of these courses is to provide an experience of UG level physics on the basis of which a student can decide whether or not to major in physics, i.e., they are gateway courses. The second purpose of these courses is to serve as an introduction to the physicist's way of thinking about problems and solving them, something that has proved useful not just to physicists but also to those in other disciplines that make use of quantitative methods and experiments, e.g., mathematics, computer science, economics, psychology, and biology.

Semester 3, 4 and 5: The Physics Core

The physics courses in these 3 semesters form the core of the physicist's undergraduate canon. Anyone majoring in physics is expected to be thorough in these areas. Each semester has 2-3 theory courses and an accompanying lab.

Semester 6: Exploring more advanced options

The student can opt for elective courses: each student majoring in physics is required to take at least two. From the student's point of view, the electives chosen is likely to indicate a post-graduate direction – towards theoretical physics, towards experimental physics or perhaps away from physics into an allied discipline that would benefit from training in physics.

Physics Minor or Concentration

To Minor in physics a student must do six courses in physics (24 credits). Of these the two gateway courses – MP1 and Lab 1 – are compulsory. At least two more courses should be taken from among the core courses offered in semesters 3, 4, and 5, provided appropriate prerequisites have been satisfied for these courses (recommended courses: Classical Mechanics and Thermal Physics).

The remaining two may be either other compulsory or elective courses offered by the Physics Department or cross-listed with Physics, provided appropriate prerequisites have been satisfied. In place of one elective course, a student may take an Independent Study Module (ISM) of equivalent credit.

For a Concentration in physics a student must do six courses in physics (16 credits). Of these the two gateway courses – MP1 and Lab 1 – are compulsory.

At least two more courses should be taken from among the core courses offered in semesters 3, 4, and 5, provided appropriate prerequisites have been satisfied for these courses (recommended courses: Classical Mechanics and Thermal Physics)

General Information on the Physics Courses

Mathematical level — All theory courses are calculus-based. The level of mathematical sophistication will increase progressively. The mathematical-physics courses will be application-oriented rather than proof-oriented. Familiarity with +2 level physics and mathematics is assumed.

Labs — All lab courses will involve extensive use of instruments to make observations. These experiments will in general illustrate ideas studied in the accompanying theory courses.

The use of computers — Many theory courses will include computational exercises, generally using the programming language Python. Labs will also require the use of computers.

Duration —
Theory courses: two lectures a week each lasting 1.5 hours. In addition, there may be a 1.5-hour tutorial per week.

Laboratory: one 3-hour main lab session per week and one 3-hour extra session per week for lab course.

List of Physics Courses

Compulsory/Core Courses

Mathematical Physics 1 (Gateway course: semester 2)

This course aims to familiarise the student with a variety of mathematical techniques which every student of physics should be conversant with. Having taken the course, you should be comfortable with casting a wide variety of physics problems in mathematical language and being able to analyse and solve them subsequently. The course will also include an introduction to programming with Python. Within the physics curriculum at Ashoka university, this course is an essential prerequisite for Classical Mechanics and Electricity and Magnetism in Light of Relativity offered in the third semester.

Pre-requisites: Students who have not done mathematics at the 12th-grade level are required to take Calculus I.

Physics Lab 1 (Gateway course: semester 2)

An introduction to physics through experiments. The goal of this introductory lab is to help students develop the skills needed for experimental physics. Students will be introduced to the basic concepts of data collection, analysis, and interpretation over the span of the course by working on different experimental problems which have been carefully selected to represent different branches of physics.

Pre-requisites: none.

Classical Mechanics (semester 3)

Newtonian mechanics and an introduction to Lagrangian and Hamiltonian mechanics. Newtonian mechanics is, both historically and otherwise, the starting point of all of physics. The Lagrangian and Hamiltonian formulations of classical mechanics allow a more profound vision of the subject while also introducing the language in which much of higher-level theoretical physics is expressed.

Pre-requisites: MP1

Electricity & Magnetism in Light of Relativity (semester 3)

The beautiful theory of electricity and magnetism is, with classical mechanics, the heart of classical physics. What is often not appreciated at the undergraduate level is that electricity and magnetism are related in a way that reveals the structure of space-time. In this course relativity will be used from the beginning to relate electric and magnetic fields, so that their unity, as components of the electromagnetic field are revealed and used in the study of Maxwell's Equations.

Pre-requisites: MP1

Physics Lab 2 (semester 3)

Designed to accompany the theory courses Classical Mechanics and Electricity & Magnetism in Light of Relativity, this laboratory course explores their experimental foundations. Students will be introduced to video-analysis and modelling to study elastic and inelastic collisions, uniformly accelerated motion, and terminal velocity. In addition, students will also be introduced to physical systems exhibiting electromagnetic damping, resonant electronics circuits, and two-dimensional electrostatics.

Pre-requisites: Physics Lab 1

Mathematical Physics 2 (semester 4)

This mathematical physics course aims to be an introduction to differential equations. Besides standard topics in ordinary and partial differential equations, nonlinear dynamical systems will be studied and nonlinear ODEs will be analysed using geometric and computational tools. Fourier series will also be studied.

Pre-requisites: MP1

Thermal Physics (semester 4)

An Integrated Approach to Thermodynamics and Kinetic Theory. There are three approaches to study systems with large numbers of atoms and molecules, which exhibit properties like temperature and entropy: kinetic theory, classical thermodynamics, and statistical mechanics. In this course, these three approaches will be taught in an integrated fashion.

Pre-requisites: Mathematical Physics 1.

Oscillations, Waves, and Optics (semester 4)

Oscillatory phenomena appear in all areas of physics, both classical and quantum (to the point where a famous textbook begins by saying that the domain of physics is all phenomena that can be reduced to coupled oscillators). The methods used to study oscillatory motion are powerful and wide-ranging in their utility.

Pre-requisites: MP1, Classical Mechanics and Electricity & Magnetism.

Physics Lab 3 (semester 4)

Designed to accompany the theory courses Thermal Physics and Oscillations, Waves & Optics, this laboratory course explores their experimental foundations. Students will be introduced to the properties of light as a wave: interference, diffraction, and polarisation, through conceptually rich experiments like the Michelson Interferometer. In addition, mechanical systems which exhibit oscillatory behaviour, like coupled pendula and capillary waves, will also be studied. Students will also be introduced to ideas of thermometry and calibration.

Pre-requisites: Physics Lab I.

Quantum Mechanics (semester 5)

This course is an introduction to Quantum Mechanics (QM). Starting with a historical introduction and motivation, it goes on to introduce probability amplitudes as the fundamental physical basis for QM. Using the Dirac bra-ket notation, the fundamental postulates are then introduced and their consequences worked out. The basic physical concepts are illustrated through spin-½ systems and one-dimensional wave mechanics. Symmetries and Conservation laws in QM are discussed, an introduction to the basic theory of angular momentum and spin is given, and the course culminates with the first major triumph of QM - a quantum mechanical understanding of the hydrogen atom.

Pre-requisites: Classical Mechanics, Mathematical Physics I and II.

Strongly recommended: Linear Algebra (Department of Mathematics).

Statistical Mechanics (semester 5)

Statistical mechanics allows one to solve problems involving large numbers of particles by exploiting statistical regularities. When combined with quantum mechanics, it helps physicists to understand some of the most fascinating phenomena in the universe. This course is an introduction to the essential concepts of the subject.

Pre-requisites: Thermal Physics.

Physics Lab 4 (semester 5)

Designed to accompany the two theory courses Quantum Mechanics and Statistical Mechanics; this laboratory course explores their experimental foundations. Students will be introduced to some of the experiments which require Quantum Mechanics in order to be explained, notably discrete atomic spectra and the Zeeman Effect. The lab will also contain experiments on Brownian Motion and the determination of other properties of matter like magnetic susceptibility.

Pre-requisites: Physics Lab I.

The Physics of Matter (semester 6)

In real physical systems the various areas of fundamental physics that are studied separately in previous semesters are usually required all at once. The purpose of this course is to show how fundamental physics can be used to study a number of interesting phenomena.

Pre-requisites: All mandatory courses in the physics-major sequence.

Elective Physics Courses

Elective courses (for the 3rd and 4th year) are listed below. Please refer to the course webpage for further details. These courses may be at the advanced UG or beginning graduate level. Note that all electives may not be offered every year.

Quantum Mechanics 2: a natural sequel to Quantum Mechanics in semester 5.

Mathematical Physics 3: focusing mainly on complex analysis and integral transforms.

Computational Physics: This course introduces different numerical techniques useful in solving problems of interest in physics.

Cosmology (first offered in Monsoon 2020 by Prof. Vikram Vyas)

Soft Matter Physics (first offered in Monsoon 2020 by Prof. Gautam Menon)

Non-equilibrium Statistical Mechanics (first offered in Spring 2021 by Prof. Somendra Bhattacharjee)

Symmetry in Physics: Lie Algebras, Groups and Representations (first offered in Spring 2021 by Prof. Amin A. Nizami)

Cross-listed Elective Courses

Students can take, as electives, for credit the following cross-listed courses from other departments. They need to have taken the required prerequisite courses or otherwise have consent from the instructor.

PHY1001/ MAT1001: Linear Algebra (cross-listed with Department of Mathematics)

PHY3513/ PHY6313/ BIO3513/ BIO6313: Computational and Mathematical Biology (cross-listed with the Department of Biology.

PHY301/ BIO211: Biophysics (cross-listed with the Department of Biology)

PHY3020/ BIO3020: Ecology (cross-listed with the Department of Biology)

PHY3314/BIO3314: Forces and Motion in Biology (cross-listed with the Department of Biology)

PHY1208/ CS1208: Probability and Statistics (cross-listed with the Department of Computer Science)

PHY1101/ CS1101: Introduction to Programming (cross-listed with the Department of Computer Science).

PHY1390/ CS1390: Introduction to Machine Learning (cross-listed with the Department of Computer Science)

PHY3901/ ES3901: Remote Sensing (cross-listed with the Department of Environmental Studies)

Physics ASP (Fourth Year)

The fourth year ASP provides the opportunity for students to study physics at a level more advanced than the usual undergraduate level. Alternatively, students wishing to broaden their education further can use it to take a minor/concentration in any other subject or simply take whatever courses in any department they wish to.

Advanced Major

The advanced major is for students intending to pursue higher studies and research in physics. It would enable them to take some advanced physics courses as well as get an idea of research through the capstone project/thesis.

Requirements:
7th Semester: Required to take 16 credits of which the capstone project comprises 8 credits. The students can opt for 1 or 2 courses comprising 4 credits/course.

8th Semester: Required to take 16 credits of which the capstone project comprises 8 credits. The students can opt for 1 or 2 courses comprising 4 credits/course.

Over the whole year (2 semesters), some courses apart from Thesis may also be taken from outside the physics department.

Capstone Project and Thesis:

Interested students should talk, in their 6th semester, to prospective advisors about possible projects. After mutual agreement - the advisor agrees to guide the student and the student agrees to work on one of the projects suggested by the advisor - students should start with necessary background reading / preliminary work over the summer before the start of the fourth year.

At the end of the 7th semester the project would be assessed with a presentation and report - this will be evaluated by the physics faculty. Students without satisfactory progress at this stage may not continue for the thesis subsequently.

At the end of the 8th semester the thesis has to be submitted and defended before a panel which may also include some external members. It is mandatory to successfully complete the capstone project and thesis to be eligible for the advanced major.

Other options (Minor/Concentration)

Students not opting for the advanced major can take courses as per their interest in the fourth year. It is recommended that physics majors take two physics electives over the year. Those minoring in physics (or taking it as a concentration) may take physics courses accordingly to meet the necessary requirements.

TF/TA-ship Policy

- The Teaching Fellows are recruited after a departmental screening process.

- Fourth year (ASP) physics students can be TAs for some of the introductory physics courses. This depends on the departmental requirement and the position may be offered either for credits or may be a paid position.

- MLS students are assigned to be TAs as a part of their academic requirements.

Independent Study Module (ISM)

- Students may opt for an ISM if interested and if a faculty member is available for this purpose.

- A successfully completed ISM would contribute 2 to 4 credits to the student's GPA.

- Students who wish to take up an ISM should contact the Professor under whose guidance they wish to work to discuss details.

Faculty

Somendra M. Bhattacharjee

Head of the Department, Physics

Professor of Physics

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Somendra Mohan Bhattacharjee received his Ph.D. in Physics from Carnegie Mellon University, Pittsburgh, USA, B. Sc in Physics (Honours) from Presidency College, Calcutta, and M. Sc. in Physics from the University of Calcutta. After doing post-doctoral research at the University of Massachusettes, Amherst, USA, and Bell Labs, Murray Hill, he joined the Institute of Physics, Bhubaneswar as a faculty member and continued till April 2019.

His research interest is in theoretical condensed matter physics and biology-inspired physics mostly related to phase transitions. The force-induced unzipping transition of DNA is one of his most important contributions. He is a fellow of the Indian National Science Academy and Indian Academy of Sciences, and a J C Bose National Fellow. He was a Regular Associate of ICTP, Trieste, Italy.

Sabyasachi Bhattacharya

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Professor Sabyasachi Bhattacharya is a physicist and works on dynamical aspects of disordered condensed matter systems. He is a Distinguished Professor at the Tata Institute of Fundamental Research (TIFR) of which he was the former Director. Professor Bhattacharya received his B.Sc. at the Presidency College, Kolkata, M.Sc. at the University of Delhi, and his Ph.D. at Northwestern University, all in Physics. He conducted post-doctoral research at the National Magnet Laboratory at MIT, University of Rhode Island. He was at the University of Chicago as a James Franck Distinguished Fellow before joining the Exxon Corporate Research Laboratory. He subsequently worked at the NEC Research Institute at Princeton where he was the Chair of the NEC Board of Fellows.

Professor Bhattacharya currently serves, among other organizations, on the Editorial Board of the Reports on Progress in Physics, the Technology Advisory Council of British Petroleum, the IIT-Council of the Ministry of Human Resource Development and the Council of IIT-Bombay and the Mentor Group of Presidency University, Kolkata. He is a frequent visitor to the New York University, the University of Chicago, the Cavendish Laboratory and the Trinity College at the University of Cambridge. He is a

Fellow of the American Physical Society. Apart from Physics, he is interested in higher education policy in India related specially to science and technology research.

Professor Bhattacharya was a Non-Resident Senior Fellow at CASI from September 2012 through August 2013.

Gautam Menon

Professor of Physics and Biology,

Ashoka University.

Ph.D. Indian Institute of Science,

Bangalore

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Gautam I Menon is a Professor of Physics and Biology at Ashoka University. Prior to joining Ashoka, he was a Professor with the Theoretical Physics and Computational Biology groups at the Institute of Mathematical Sciences, Chennai, where he was the founding Dean of the Computational Biology group. He is currently an adjunct Professor in the Department of Biological Sciences at the Tata Institute of Fundamental Research, Mumbai, India.
He completed a BSc. (Hons) in Physics at St. Stephens College, Delhi, an MSc from IIT Kanpur, and a Ph.D. from the Indian Institute of Science, Bangalore. Following post-doctoral work at the Tata Institute of Fundamental Research in Mumbai and the Simon Fraser University in Vancouver, Canada, he joined the Institute of Mathematical Sciences. His research work, spread over approximately 80 papers, covers a range of areas in both physics and biophysics. He has written several articles on the interface of science and society as well as on science policy.
He was awarded a DST Fast Track Fellowship for Young Scientists in 2002 and the Swarnajayanti Fellowship of the DST in 2005. He was named a DAE-

SRC Outstanding Research Investigator in 2010. He was named an Outstanding Referee by the American Physical Society in 2012, as well as recognized as an Outstanding Reviewer of the UK-based "Reports on Progress in Physics" in 2016. He was a Visiting Professor at the Mechanobiology Institute and the Department of Biological Sciences at the National University of Singapore between 2011-2013. He has served on scientific review committees of several international agencies, including the Human Frontier Science Program and the Wellcome Trust-DBT India Alliance. His research has been funded by several national and international agencies, including the European Union, the Indo-French CEFIPRA as well as the DBT, DST and DAE in India. He has lectured in universities and scientific conferences around the world and in India, including in the USA, Canada, France, Germany, Switzerland, Singapore, the Netherlands and the UK. He was elected a Fellow of the National Academy of Sciences, India in 2019.

He works on a number of biophysical problems including nuclear architecture, axonal transport, collective cell migration and cell adhesion, all in the general field of mechanobiology. The modeling of infectious disease and its implications for public policy is a long-standing interest of his, while the use of machine learning methods in clinical contexts is a more recent one.

Amin Nizami

Assistant Professor of Physics,

Ashoka University

Ph.D. University of Cambridge

(Current Course coordinator of Physics)

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Amin received his PhD in Theoretical Physics from the University of Cambridge (working at the Department of Applied Mathematics and Theoretical Physics). His main research interests include various aspects of quantum field theory, quantum chaos, quantum information and holography. His main area of specialisation is in conformal field theory and the conformal bootstrap.

Earlier he obtained his BSc in Physics (with Mathematics and Statistics) from AMU, Aligarh, India and Masters (Part III of Mathematical Tripos) in Theoretical Physics from the University of Cambridge.

Prior to joining Ashoka he was a postdoctoral fellow at the International Centre for Theoretical Sciences (ICTS-TIFR) and a research associate at the Centre for High Energy Physics, Indian Institute of Science.

Pramoda Kumar

Ph.D. Coordinator of Physics,

Assistant Professor of Physics,

Ashoka University

Ph.D. Centre for Liquid Crystal Research

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Research Experience:

- The Jacob Blaustein Institutes for Desert Research - Ben Gurion University of the Negev, Israel (Blaustein Postdoctoral Fellow Nov. 2015 - Feb. 2019)
- Centre for Nano and Soft Matter Sciences, Bangalore (Visiting Scientist, May 2015 – Sept. 2015)
- Harvard-School of Engineering and Applied Sciences, Cambridge (Postdoctoral fellow, Sept. 2013 - Feb, 2015).
- Weizmann Institute of Science, Israel (Feinberg Graduate School Postdoctoral Fellow, Dec. 2012– Aug. 2013)
- Max-Plank Institute for Dynamics and Self-Organization, Goettingen (Postdoctoral Fellow, Sept. 2010 - Oct.2012)

Research Interest:

Experimental soft-condensed matter physics, pattern formation in dissipative systems, interface instability, charge transport phenomena in ion-selective membranes, bio-physics and non-Newtonian hydrodynamics

Frequently Asked Questions

1. What are going to be the mandatory courses to pursue a minor in Physics?

Answer: The gateway courses (Mathematical and Computational Toolkit and Laboratory 1) are the mandatory courses to pursue a physics minor. Apart from these two, the student is expected to take 4 courses of their choice. Of these 4 courses at least two should be taken from among the other core courses. The remaining two can be core or elective courses and one of them can also be an ISM. So, in total a student has to do 6 courses to complete a minor in Physics.

2. What are the mandatory courses for a concentration in Physics?

Answer: The gateway courses (Mathematical and Computational Toolkit and Laboratory 1) are the mandatory courses to pursue a physics concentration. Apart from these two, the student is expected to take 2 courses of their choice from among the core courses. So, in total a student has to do 4 courses to complete a concentration in Physics.

3. What are the mandatory courses for the Ashoka Scholar Programme (ASP) students?

Answer: A project (Capstone project) and the Capstone thesis are mandatory for an Advanced Major in Physics.

4. Will the mandatory courses be offered every semester?

Answer: The mandatory gateway courses are offered in the spring semesters. Other core courses are spread throughout the 6 semesters. All courses are not offered in every semester.

5. What are the prerequisites to major in Physics?

Answer: The student is expected to have a science/mathematics background in their high school (at +2 level). Calculus is a recommended course to be taken in their first semester.

6. I am interested in doing a TAship/writing a thesis although I'm not in my fourth year as yet.

Answer: The current TAship policy doesn't allow students (except 4th years) to become TAs.

7. Who should I contact in case I have further questions?

Answer: You can reach out to the Academic Representative of the Department.

8. Is thesis mandatory for ASP students?

Answer: Thesis is mandatory for an Advanced Major in Physics. See also Q9.

9. Do the ASP 4th year count as an Advanced Major?

Answer: Yes. But only if the capstone project + thesis option is chosen. Otherwise, the fourth year may be used to get a double major / minor in other subjects.

10. Will the labs be independent of the theory courses - in terms of number of credits?

Answer: Yes. They are independent of the theory courses in terms of the number of credits - 4 credits for each theory course or lab.