Physics is concerned with those aspects of nature which can be understood in a fundamental way in terms of elementary principles and laws. In the opinion of a non-physicist (J Moliere, French playwright), "Physics explains the properties of natural bodies and properties of matter; it discourses on the nature of elements, minerals, plants, rocks and animals, and teaches us the causes of all the meteors, rainbow, aurora borealis, comets, lightening, thunderbolts, rains, snows, hails and whirl winds". In course of time, various specialized sciences broke away from physics to form autonomous fields of investigation. In this process physics retained its original aim of understanding the structure of the natural world and explaining natural phenomenon. Physicists think about what exists and how it works; they also seek to understand reality from possible infinite vastness of the universe down to the infinitesimal particles that form the structure of an atom.

History

The Department of Physics, University of Rajshahi, started functioning in March 1958 and its academic activity started in July 1958 in its own building in the university campus, under the leadership of Late Dr Ahmad Husain with a batch of 15 post-graduate students and three teaching staff members. The teaching was started in December, 1958. A three-year B.Sc. (Honours) course was introduced in 1962. Over the years, the department has grown in every sphere and now assumes the structure of a large department in the university.

The department has been offering a four-year B.Sc. (Honours) course since 1998. At present, there are 28 members of teaching staff and 26 supporting technical and office staff catering the needs of over 500 students including a number of research scholars.

Location

The Department of Physics is located in the first science building, which is surrounded by the scenic beauty of the university. It has a beautiful flower garden inside.

Research Activities

The department has a long tradition of research in various areas of physics under M.Sc., M.Phil. and Ph.D. Programmes. The faculty members along with their research students pursue research in diverse fields which has resulted in a large number of research publications in various journals of international repute, like Nature, Physical Review Letters, Physical Review, Nuclear Physics, Superconductor Science and Technology, Physica C, Journal of Superconductivity, Solid State Communications, Physics Letters, Journal of Materials Science, Journal of Non-Crystalline Solids, Physica Status Solidi, Journal of Physics and Chemistry of Solids, Journal of High Energy Physics, Physics and Chemistry of Glasses, Nuovo Cimento, Annals of Physics, etc. The department is also working under different international collaboration programmes with India, Japan, UK and USA. The current research areas are:

- Nuclear Physics: Nuclear Reaction & Nuclear Structure
- Radiation Physics and Medical Physics
- Atomic Physics
- Condensed Matter Physics

    - Perfect and Defect Crystals- Computer Simulation studies (theoretical)
    - Solid State Reaction (experimental)
- Superconductivity
- Semiconductors: Thin Film Deposition and Characterization
- Structural properties of Glass and Glass Ceramics
- Solar Energy
- High Energy Physics: Lattice QCD

Teaching Activities

The department is at present involved in teaching the following courses:

- Four-year B.Sc. (Honours) degree course (started from the session 1997-98).
- One-year M.Sc. Course in General and Thesis group.

Resources

The department has 29 members of teaching staff consisting of Professor Emeritus, Professors, Associate Professors, Assistant Professors and Lecturers, who cater the needs of nearly 500 undergraduates, post-graduates and research students. A list of members of academic staff is given below:

Name	Specialization
Professor Emeritus	
Dr Arun Kumar Basak *MSc(Raj), PhD(Birmingham), FInstP(London), CPhys*	Nuclear Physics, Atomic Physics
Professors	
Dr M Golam Mortuza *MSc(Raj), PhD(Warwick,UK), C in Comp.(Coventry)*	Condensed Matter Physics, Glass and Glass Ceramics, Superconductivity
Dr M Mozibur Rahman (**Chairman**) *MSc(Raj), PhD(Ukraine)*	Condensed Matter Physics (Expt.), Electronics, Metallurgy
Dr M Khalilur Rahman Khan *MSc(Raj), PhD(Japan)*	Condensed Matter Physics, Mat. Science (Expt.), Thin Films, Superconductivity
Dr Irine Banu Lucy *MSc(Raj), PhD(Brunel,UK)*	Condensed Matter Physics (Expt.)
Dr M Rafiqul Ahsan *MSc(Raj, PhD(Raj)*	Condensed Matter Physics, Glass and Glass Ceramics, X-ray Crystallography
Dr F Nazrul Islam *MSc(Raj), PhD(Raj)*	Condensed Matter Physics (Theory), Superconductivity, Nuclear Physics

Name	Specialization
Dr Saleh Hasan Naqib *MSc(Raj), PhD(Cambridge)*	Superconductivity, Computational Condensed Matter Physics
Dr Abul Kalam Fazlul Haque *MSc(Raj), PhD(Raj)*	Nuclear Physics
Dr Abdullah Shams Bin Tariq *MSc(Raj), PhD(Southampton)*	Particle Physics, Nuclear Physics
Dr Raihana Shams Islam *MPhil(Cambridge),PhD(Cambridge)*	Superconductivity
Dr Fahmida Parvin *MSc(Raj), PhD(Raj)*	Superconductivity, Computational Condensed Matter Physics
Dr M A Razzaque Sarker *MSc(Raj), PhD(Japan)*	Materials Science
Ms Dilruba Akhter Banu *MSc(Raj)*	Nuclear Physics
Dr M Atiqur Rahman Patoary *MSc(Raj), MSc(Japan),PhD(Japan)*	Nuclear Physics, Condensed Matter Physics (Theory)

Associate Professors

Dr Laila Arjumand Banu *MSc(Raj), PhD(Raj)*	Condensed Matter Physics (Expt.)
Dr M Rezaur Rahim *MSc(Raj), PhD(Brunel,UK)*	Condensed Matter Physics (Expt.), Electronics
Dr M Samiul Islam Sarker *MSc(Raj), MSc(Australia), PhD(Japan)*	Nuclear Physics, Fibre-laser, Materials Science
Dr M Monirul Haque *MSc(Raj), PhD(Japan)*	Medical Physics, Radiation and Health Physics
Dr M Saiful Islam *MSc(Raj), PhD(Kyushu, Japan)*	Condensed Matter Physics (Theory & Expt.)
Dr Monira Jannatul Kobra *MSc(Raj), PGD(AS-ICTP), PhD (Kyushu, Japan)*	Nuclear Physics

Assistant Professors

Name	Specialization
Mr M Masum Billah* *MSc(Raj)*	Nuclear Physics
Mr K M Mahmudul Hasan* *MSc(Raj)*	Nuclear Physics
Mr M Leaket Ali *MSc(Raj)*	Condensed Matter Physics
Mr M Ismail Hossain* *MSc(Raj)*	Theoretical Atomic Physics
Mr M Alamgir Hossain* *MSc(Raj)*	Medical Physics

Lecturers

Mr M Saifur Rahman *MSc(Raj)*	Materials Science
Mr M Riju Khandaker *MSc(Raj)*	Materials Science
Mr M Abdur Rashid *MSc(Raj)*	Glass and Glass Ceramics

**On study leave.*

Seminar Library

The department may boast to have the biggest seminar library in the university with text and reference books. It also has some international journals, such as Physical Review, Physical Review Letters, Reviews of Modern Physics, which the department had been receiving as a joint contribution from the Abdus Salam International Centre for Theoretical Physics, Italy and American Physical Society. The library is constantly being updated with reference books and other reading materials. The department has started a rental library for students and they can borrow important textbooks through this service. Besides, a significant number of e-books and a very large number of e-journals are accessible online through the University Central Library.

Computer Facilities

The department has established a computer lab based on an N-computing system for students. This allows students to do their computational work, access internet as well have their computational classes. Research students also have access to computers and internet in their research labs.

Workshop

A mechanical workshop was established in the department from the beginning of the department. The students get training in the workshop on some instrumentation, as a part of their laboratory experiments. It also serves as a centre for minor repairing of laboratory equipment.

From its inception, the Department of Physics is known to be the most disciplined department in the university, both in administration and in academic activities. Academic members are very particular in completing their courses, conducting examinations and publishing results according to the calendar published by the department at the beginning of every academic year. It is the tradition of the department to publish the examination results within the quickest possible time and thus it has become possible for the department to avoid the academic backlog in the university. The department constantly reviews its curriculum and takes steps to enhance facilities to match the present day need and thus prepares the students to face the challenges of the future.

Co- and Extra- Curricular Activities

Physics Club

Physics Club was established in 2011. Since then Physics Club has been providing the students and the faculty members with an open platform to discuss various topics in physics outside the class hours. This club is open to all the students of Department of Physics, University of Rajshahi.

English Club

English Club has been functioning since 2010. This club was established with the aim to develop speaking, reading, and writing skills of the students of this department. Only the members of the English Club are permitted to participate in various club activities.

Study tour

The department arranges study tour within Bangladesh and abroad for the M.Sc. Students each year.

Picnic

Every year students of the department organize annual picnic in cooperation with the academic and non-academic staff.

Physics Association

There is an association in the department called the Physics Association. All students and teachers of the department are members of the association. This Association regularly organizes farewell for the outgoing M.Sc. Students and welcome reception for the freshers admitted in the B.Sc. (Hons) course. Besides, the Association arranges various cultural and sports related activities.

Physics Alumni Association

Department of Physics has an alumni association entitled "Physics Alumni Association of University of Rajshahi (PAARU)". The objectives of this association are to build active communication network among all the present and ex-students of the Department of Physics through various programs and to contribute to the academic development of the department and also to economic development of the country through the dissemination of new concepts in the relevant field.

Sports and Culture

Students of Department of Physics participate in all inter-department games organized by the RU. The department has achieved notable success in sports by winning matches in cricket, football, badminton, table tennis etc. The students of the department have also participated in various cultural events with distinction.

Curriculum for B.Sc. (Hons) in Physics, Session 2019-2023

Title of the Academic Program: Bachelor of Science (Honours) in Physics

Name of the University: University of Rajshahi

Vision of the University
To pursue enlightenment and creativity for producing world-class human resources to cater for the needs of changing time.

Mission of the University
1. To ensure a world-class curriculum with talented academicians and conducive academic and research environment for generation and dissemination of knowledge.
2. To maintain international standards in education with focus on both knowledge and skills, and humanitarian and ethical values to meet the needs of the society and state.
3. To develop strategic partnerships with leading national and international universities, and organizations for academic as well as research collaborations.

Name of the Degree: B.Sc.(Hons) in Physics

Name of the Faculty Offering the Program: Faculty of Science

Name of the Department Offering the Program: Department of Physics

Vision of the Program
To maintain and enhance the reputation of being a disciplined, dedicated and quality programme of undergraduate physics attracting better students, producing graduates with high acceptance amongst employers and serving better input for postgraduate research.

Mission of the Program
To equip students with the understanding and skills of basic and specialized physics and related courses necessary to proceed for postgraduate study and research and produce disciplined, diligent, skilled and morally enriched graduates for employment in physics, physics-related and other disciplines.

Mission and Objectives of the Department

Since its inception in 1958, the mission of the Department of Physics, University of Rajshahi has been to progress the knowledge in various branches of Physics via teaching-learning and research. The academic program is focused on the creation, translation, and dissemination of knowledge on the subject matter. The strategic goals of the Department are to:

- Support the aims and objectives of the University within the capacity of our Departmental program.

- Advance the academic, research, scholarship and service priorities, consistent with a top tier university, and continue to promote growth and national prominence in these areas.
- Train and produce high-quality graduates to meet up national and international requirements in scientific sectors of the job market.
- Enhance the teaching-learning and research capacities of the Department by retaining and recruiting outstanding faculty and staff.
- Enhance the Department's learning environment by attracting and retaining students of high intellectual ability and aptitude.

B.Sc. (Hons.) Program Learning Outcomes (PLOs)

Knowledge and Understanding

The B.Sc. Degree programs offered by the Department cover the fundamental topics of Physics. It also provides a selection of advanced topics and develops experimental, mathematical, computational, and other transferable skills. On successful completion of these programs a student should have-

1. Knowledge and understanding of most fundamental physical laws and principles and competence in the application of these principles to diverse branches of Physics and closely related disciplines.
2. An ability to solve problems in Physics using appropriate mathematical tools.
3. An ability to execute and analyze the results of an experimental investigation or theoretical modeling and to draw valid conclusions with an estimate of the uncertainty in the result. An ability to compare experimental results with the predictions of relevant theories.
4. A knowledge of the fundamental principles and applications of some of them in advanced areas of Physics.
5. An ability to use IT packages and a competence of the usage of analytical software in problem solving.
6. An ability to communicate scientific information verbally and in the form of clear and accurate scientific reports.
7. An ability to make appropriate use information and communication technologies in regard to problem solving in different sectors of Physics.

Knowledge and understanding of areas 1 – 2, and 4 – 7 are acquired through lectures, tutorials, problem classes and guided independent study. The practically oriented knowledge of area 3 is acquired in practical classes, both experimental and computing, and in thesis work.

A B.Sc. student, after completion of his/her degree from the Department is expected to have the following mental attributes:

8. An understanding and appreciation of current issues and debates in various branches of Physics.

9. An understanding and appreciation of the philosophical bases, mathematical structure, methodologies, characteristics of scientific scholarship, research, and creative work.
10. An ability to work independently and in collaboration with others.
11. Personal and professional integrity and an awareness of the requirements of ethical behavior.

At personal level, the graduates are expected to have the following skills:

12. Competence in using computer software and programming languages.
13. Competence in troubleshooting and solving basic problems in electronic equipments and circuits.
14. An ability to prepare multimedia presentations for conveying scientific facts and findings to audience with diverse backgrounds.

Mapping of Programme Learning Outcomes (PLOs) with Course Learning Outcomes (CLOs) of the B.Sc. (Hons) programme in Physics at the University of Rajshahi

Domain	Prog. Learning Outcomes (PLOs)	PH100	PH101	PH102	PH103	PH104	PH105	PH106	PH107	PH108	PH109	PH201	PH202	PH203	PH204	PH205	PH206	PH207	PH208	PH209	PH301	PH302	PH303	PH304	PH305	PH306	PH307	PH308	PH309	PH310	PH401	PH402	PH403	PH404	PH405	PH406	PH407	PH408	PH409	PH410	PH411
Cognitive	**PLO1**		X	X	X		X	X	X			X	X	X	X	X	X	X			X	X	X	X	X		X	X			X	X	X	X	X	X	X	X			
	PLO2					X	X		X						X	X																								X	
	PLO3																			X									X											X	X
	PLO4																																							X	
	PLO5															X				X									X											X	X
	PLO6	X								X									X										X										X	X	
	PLO7																	X			X									X		X									X
Affective	**PLO8**																																				X	X			
	PLO9																										X	X			X										
	PLO10										X									X										X										X	X
	PLO11										X									X										X										X	X
Psycho-motor	**PLO12**															X				X									X											X	
	PLO13																												X												X
	PLO14																																							X	

UNIVERSITY OF RAJSHAHI
FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

B.Sc. (Honours) Curriculum

Session: **2019-2023**

Examinations: **2020** (Part-I); **2021** (Part-II); **2022** (Part-III) and **2023** (Part-IV).

The B.Sc. (Honours) **Credit** courses in Physics spread over **four years** and carry a total of **4000 marks**, **160 Credits.** The marks distribution for the credit courses shall be of 950 marks in each of the First and Second years, and 1050 marks in each of the Third and Fourth years. There shall be a non-credit course of 50 marks on Functional English in the First year. **A full-unit** course shall carry 100 marks and a **half-unit** course 50 marks out of which 80% for the Final Written exam, 15% for In-course evaluation and 5% for Class Attendance. Total number of lectures on a full-unit course has to be 75 and that for a half-unit course would be 40. The duration of examination for the theoretical papers shall be 4 hours for a full-unit and 3 hours for a half-unit course. The minimum marks/grade points required for the promotions to the 2nd year, 3rd year and 4th year and for obtaining the B.Sc. (Honours) degree will be according to the ordinance.

Important points of the Ordinance for the Degree of Bachelor of Science with Honours in Physics:

Grading System

Numerical Grade (NG)	Letter Grade (LG)	Grade Point (GP)
80% and above	**A^{+}** (A Plus)	**4.00**
75% to less than 80%	**A** (A regular)	**3.75**
70% to less than 75%	**A^{-}** (A minus)	**3.50**
65% to less than 70%	**B^{+}** (B Plus)	**3.25**
60% to less than 65%	**B** (B regular)	**3.00**
55% to less than 60%	**B^{-}** (B minus)	**2.75**
50% to less than 55%	**C^{+}** (C Plus)	**2.50**
45% to less than 50%	**C** (C regular)	**2.25**
40% to less than 45%	**D**	**2.00**
Less to than 40%	**F**	**0.00**

LG, GP and Credit Point (CP) for Non-credit courses

Numerical Grade	LG	GP / Unit	CP / Unit
30% and above	**S**	**0.0**	**00**
Less than 30%	**U**	**0.0**	**00**

Here, "S" and "U" refer to "Satisfactory" and "Unsatisfactory", respectively.

Calculation of Grade Point Average (GPA) and Cumulative Grade Point Average (CGPA):

Suppose, there are five theoretical courses in B.Sc. (Honours) part 1 examination and a student has completed the courses with following grades:

1st year courses	Credit Point	Letter Grade (LG)	Grade Point (GP)
PH – 101	2	A	3.75
PH – 102	4	A+	4.00
PH – 103	4	B+	3.25
PH – 104	4	B-	2.75
PH – 105	4	C	2.25

$(GPA)_{1st\ year} = \{2(3.75) + 4(4.00) + 4(3.25) + 4(2.75) + 4(2.25)\} / (2 + 4 + 4 + 4 + 4)$

$= 56.5/18 = 3.138888 = 3.138$

GPA for the other years will be calculated as above and finally the CGPA will be as:

$CGPA = \{(TCP)_{1st\ year} \times (GPA)_{1st\ year} + \ldots + (TCP)_{4th\ year} \times (GPA)_{4th\ year}\} / TCP^*$

* TCP is total credit point, i.e. $TCP = \{(TCP)_{1st\ year} + \ldots + (TCP)_{4th\ year}\}$

GPA Truncation and CGPA Round off

GPA shall be truncated at 3 (three) digits after decimal. For instance GPA=2.1121 shall be recorded as GPA=2.112 and GPA =2.1129 shall also be recorded as GPA =2.112.

CGPA shall be round off up to 2 (two) digits after decimal. For instance CGPA=2.114 shall be round off as CGPA=2.11 and CGPA =2.115 shall be round off as CGPA =2.12.

Duration of the Programme of Study

The programme of study for the degree of B.Sc. (Honours) shall extend over a minimum period of four academic years and **the degree shall be completed within a maximum period of six academic years**.

Continuous Laboratory Assessment

30% of the total practical marks.

In-course evaluation

Every in-course evaluation will be performed by taking two tutorials/terminals one of which will be taken within 3 months and other within 4-6 months from the beginning of the class.

Class Attendance

Table for awarding marks for attendance

Attendance	Marks	Attendance	Marks	Attendance	Marks
95 - 100%	*5.0%*	80 - <85%	*3.5%*	65 - <70%	*2.0%*
90 - <95%	*4.5%*	75 - <80%	*3.0%*	60 - <65%	*1.5%*
85 - <90%	*4.0%*	70 - <75%	*2.5%*	<60%	*00%*

A student with class attendance below 60% will not be allowed to fill-up the examination form.

Award of Degrees, Promotions and Improvement of Results

A) Award of Degree

The degree of Bachelor of Science with Honours in Physics shall be awarded with Cumulative Grade Points Average (CGPA) on the basis of Grade Points Average (GPA) obtained by a candidate in B.Sc. (Honours) Part-1, Part-2, Part-3 and Part-4 examinations. In order to qualify for the B.Sc. (Honours) degree a candidate must have to meet the following requirements:

i. A minimum CGPA of 2.50with at least 34 credits in Part-4 exam.
ii. A minimum GP of 2.00 in the practical courses in each of Part-1, Part-2, Part-3 and Part-4 examinations.
iii. A minimum TCP (Total Credit Points) of 144 out of 160.
iv. "S" letter grade in English course (to be obtained within 4 academic years from the date of admission).

The result shall be given in CGPA with the corresponding Letter Grade (LG) in the bracket. For an example, a result with CGPA of 3.10 will be given as "CGPA = 3.10 (B)".

B) Promotions

In order to be eligible for promotion from one class to the next higher Honours class, a candidate must secure:

i. At least GPA of 2.00 in each of Part-1, Part-2 and Part-3 exams;
ii. At least GP 2.00 in each of Part-1, Part-2 and Part-3 practical exams;

iii. At least CP 30 in each of Part-1 and Part-2, but a TCP of 64 in Part-1 and Part-2 examinations; at least CP of 34 in Part-3 but a TCP of 102 in Part-1, Part-2 and Part-3 examinations; and
iv. **Minimum CP of 34 in Part-4 examinations for considering the award of Honours degree**. In order to have B.Sc. (Honours) degree clause A has to be fulfilled by a student.

C) Course Improvement

A promoted student earning a GP less than 3.00 in individual courses shall be allowed to improve the grades on courses, not more than 8 credits including those of "F" grades, if any, of Part-1, Part-2 and Part-3 examinations or their equivalent courses (in case of changes in the Curriculum), defined by the departmental academic committee, **through the regular examinations of the immediate following batch. However, if the candidate fails to clear his/her "F" grades in the first attempt, he/she shall get a second (last) chance in the immediate next year to clear the "F" grades. No improvement shall be allowed in practical and viva-voce examinations.** If a candidate fails to improve his/her course grade, the previous grade shall remain valid. If a readmitted candidate fails to appear at the regular class assessment or tutorial his/her previous grades shall remain valid.

D) Result Improvement

A candidate obtaining a CGPA of less than 3.00 at the end of the Part-4 examination, within 5 (five) academic years, shall be allowed to improve his/her result, on up to a maximum of 4 (four) full-units (or 16 credit points) of the Part-4 theoretical courses in the immediate next regular examination after publication of his/her result. The year of examination, in the case of a result improvement, shall remain the same as that of his/her regular examination. His/her previous grades for practical courses/viva-voce and class assessment/tutorial shall remain valid. If a candidate fails to improve CGPA, the previous results shall remain valid.

E) Readmission

A candidate, who failed to appear at the examination or failed to pass the examination, may on approval of the Dept. of Physics be readmitted to the immediate following session in the first, second, third or fourth year of the programme. **A readmitted candidate shall have to reappear at all course examinations.**

F) Pass Degree

Candidates failing to obtain required **CGPA 2.50 and 144 Credit:**

i. For promotion in Honours Part-3 examination in 4 (four) academic years, in case of readmission in Part-3 course year, in 5 (five) academic years, with no readmission in Part-3 course year from the date of **1st year admission. But fulfill the following conditions.**

   If a candidate fails to obtain required GPA (2.00) and Credit Point (102) for promotion from Part-3 to Part-4 within 5 academic years from his/her first date of admission in First year but secured CGPA 2.00 and total Credit Point 94 with LG of "S" in the English Course, shall be awarded Pass degree, such candidates shall not be allowed to improve their pass degree. Or

ii. If a candidate fails to obtain a minimum of 34 Credits and GPA (2.00) in his/her Part-4 examination also fails to obtain 144 Credits and CGPA 2.50 within 6 academic years from his/her first date of admission in first year but secured minimum CGPA 2.00, 128 Credits, with LG of "S" in the English Course, shall be awarded Pass degree and such candidates shall not be allowed to improve their Pass degree.

G) Dropping out

Candidates failing to earn the yearly required GPA after completing regular exams and subsequently failed again after taking readmission in 1st, 2nd, 3rd, or 4thyear or to clear his/her "F" grades in the stipulated period, shall be dropped out of the programme.

Subject-wise distribution of Courses in Units

Subject	Physics				Maths	Chemistry	Statistics	Computer	English*	
Year	Theoretical	Practical	VV	**Total**	Theoretical	Theoretical	Theoretical	Theoretical		**Total**
First	*4.0*	*2.0*	*0.5*	**6.5**	*1.0*	*1.0*	*1.0*	-	*0.5**	**9.5**
Second	*4.0*	*2.0*	*0.5*	**6.5**	*1.0*	*1.0*	-	*1.0*	-	**9.5**
Third	*7.5*	*2.5*	*0.5*	**10.5**	-	-	-	-	-	**10.5**
Fourth	*7.5*	*2.5*	*0.5*	**10.5**	-	-	-	-	-	**10.5**
Total	**23.0**	**9.0**	**2.0**	**34.0**	**2.0**	**2.0**	**1.0**	**1.0**	**0.5***	**40.0**

**Non-Credit and optional, not added to the total.*

The Detailed Distribution of Courses

Courses in 1st Year B.Sc. (Honours) Curriculum: Examination 2020

Course no.	Title	Marks	Status	Exam. duration	CP
PH100	Functional English	50	Noncredit	3 hours	00
PH101	Mechanics & Properties of Matter	100	Compulsory	4 hours	04
PH102	Electromagnetism	100	Compulsory	4 hours	04
PH103	Vibrations and Waves	100	Compulsory	4 hours	04
PH104	Mathematical Methods in Phys.-I	100	Compulsory	4 hours	04
PH105R	Differential & Integral Calculus	100	Compulsory	4 hours	04
PH106R	Inorganic & Organic Chemistry	100	Compulsory	4 hours	04
PH107R	Principles of Statistics	100	Compulsory	4 hours	04
PH108	Viva-Voce	50	Compulsory	3 hours	02
PH109	Physics Practical (4 days)	200	Compulsory	4×6 hours	08

Continuous Assessment (30%) = 60 marks
Annual Examination = 140 marks
[3 Experiments: each of 6 hrs (35×3) = 105 marks
Test of basic experimental and problem solving skills and
Defense on experiments (6 hrs) = 35 marks]

Total marks: 950 **TCP: 38**

Courses in 2nd Year B.Sc. (Honours) Curriculum: Examination 2021

Course no.	Title	Marks	Status	Exam.duration	CP
PH201	Optics	100	Compulsory	4 hours	04
PH202	Thermal Physics	100	Compulsory	4 hours	04
PH203	Classical Mechanics	100	Compulsory	4 hours	04
PH204	Mathematical Methods in Phys.-II	100	Compulsory	4 hours	04
PH205R	Numerical Methods	100	Compulsory	4 hours	04
PH206R	Physical Chemistry	100	Compulsory	4 hours	04
PH207R	Basic Electronics, Computer Fund. & Programming	100	Compulsory	4 hours	04
PH208	Viva-Voce	50	Compulsory	4 hours	02
PH209	Physics Practical (4 days)	200	Compulsory	4×6 hours	08

Continuous assessment (30%) = 60 marks
Annual Examination =140 marks
[3 Experiments each of 6 hrs (35×3) =105 marks
Defense on experiments (6 hrs) = 35 marks]

Total marks: 950 **TCP 38**

N.B. In the second year minimum two selected experiments to be presented using multimedia.

Courses in 3rd Year B.Sc. (Honours) Curriculum: Examination 2022

Course no.	Title	Marks	Status	Exam. duration	CP
PH301	Electrodynamics	100	Compulsory	4 hours	04
PH302	Atomic & Molecular Physics	100	Compulsory	4 hours	04
PH303	Nuclear Physics	100	Compulsory	4 hours	04
PH304	Basic Solid State Physics	100	Compulsory	4 hours	04
PH305	Electronics	100	Compulsory	4 hours	04
PH306	Basic Quantum Mechanics	100	Compulsory	4 hours	04
PH307	Statistical Mechanics	100	Compulsory	4 hours	04
PH308	Relativity	50	Compulsory	3 hours	02
PH309	Viva-Voce	50	Compulsory	4 hours	02
PH310	Physics Practical (5 days)	250	Compulsory	5×6 hours	10
	Continuous Assessment (30%)	*= 75 marks*			
	Annual Examination	*= 175 marks*			
	[4 Experiments: each of 6 hrs (35×4)	*= 140 marks*			
	Defense on experiments (6 hrs)	*= 35 marks]*			
	Total marks:	**1050**			**TCP: 42**

N.B. In the 3rd year minimum two selected experiments to be presented using multimedia.

Courses in 4th Year B.Sc. (Honours) Curriculum: Examination 2023

Course no.	Title	Marks	Status	Exam. Duration	Unit	CP
PH401	Quantum Mechanics	100	Compulsory	4 hours	1.0	04
PH402	Pulse & Digital Electronics	100	Compulsory	4 hours	1.0	04
PH403	Nuclear & Particle Physics	100	Compulsory	4 hours	1.0	04
PH404	Solid State Physics& Materials Science	100	Compulsory	4 hours	1.0	04
PH405	Medical & Radiation Physics	100	Compulsory	4 hours	1.0	04
PH406	Crystallography & X-Ray Spectroscopy	100	Compulsory	4 hours	1.0	04
PH407	Reactor Physics	100	Compulsory	4 hours	1.0	04
PH408	Non-conventional Energy	50	Compulsory	3 hours	0.5	02
PH409	Viva-Voce	50	Compulsory	3 hours	0.5	02
PH410	Project (report-30+presentation-20)	50	Compulsory		0.5	02
PH411	Physics Practical (4 days)	200	Compulsory	4×6 hours	2.0	08
	Continuous Assessment (30%)	*= 60 marks*				
	Annual Examination	*= 140 marks*				
	[3 Experiments: each of 6 hrs (35×3)	*= 105 marks*				
	Defense on experiments (6 hrs)	*= 35 marks]*				
	Total marks: 1050					**TCP: 42**

Distribution of courses offered by the Department of Physics, R.U.
Total credit for B.Sc. (Hons) in Physics: 160

Course	Course type	Credit point
Core	Theory	92
	Practical	34
	Project	02
Related Science	Mathematics	08
	Chemistry	08
	Statistics	04
	Computer Fundamentals and Programming	04
Humanities	English	Non-credit
Viva-voce		08

Teaching-Learning Strategies

Interactive teaching method is adopted by the department of physics: This is designed to ensure that the participants share their impressions and feelings and express their wishes to Teacher/Instructor.

Student Feedback

An anonymous student evaluation system has been introduced under which each student scores each of his/her teachers in the current year. It may be noted that this is the first time such a system has been introduced in a department of this university, and perhaps in any public university.

Assessment and Evaluation

Assessment Strategy	In-course assessment is done by • Class tests • Quizzes and assignments • Viva-voce • Lab notebook/report evaluation	Final evaluation is done by • Final written examination • Viva-voce • Laboratory examination
Evaluation Policy	For the final written examination, two examiners evaluate the written script and average is taken. In case of a discrepancy of ≥20%, a third examiner marks the script and average is taken among the nearest two.	

PH100 FUNCTIONAL ENGLISH (Non-credit Compulsory) (~ 40 *lectures*)

Course Type: Non-Major *Credit Point: 00*

Full Marks: ***50*** (*5 questions to be answered*) *Examination duration:* ***3*** *hours*

Prerequisites: Grammatical as well as reading, writing and understanding proficiency of HSC level English are essential.

Course Objectives and Course Summary: The course teaches functional English, dictation writing, comprehension of scientific passages and scientific report writing. This course is designed to help the physics freshman study physics courses in English.

1. **Functional English:** Tense and its Forms (Conjugation); Articles; Basic Structure– Simple, Compound and Complex Sentences; Use of Appropriate Preposition; Use of the Passive Voice; Correction of Sentences; Dictation Writing; Freehand Writing, Reading Comprehension.

   Learning outcomes: Successful students should be able to:
   (i) Read and understand undergraduate Physics textbooks.
   (ii) Improve their scientific vocabulary.

2. **Scientific Writing for Experiments and Projects:** Distinctive Features of Scientific Writings: Figures, Tables, Equations, Captions, Numbering, Title and Section Headings; Professional Research Reporting: Author, Affiliation, Keyword, References.

   Learning outcomes: Successful students should be able to:
   (i) Understand the basic features of scientific report writing including laboratory note books.
   (ii) Write freehand paragraphs on various physical phenomena.

Books Recommended

Text Books

Allen, WS	Living English Structure
Fitikides, TJ	Common Mistakes in English

Reference Books

Ahmed, S	Learning English, The Easy Way
Thomson, AJ and Martinet, AV	A Practical English Grammar
Swales, J	Writing Scientific English
Wren, PCand Martin, H	English Grammar and Composition
Vallins, GH	Good English
Hornby, AS	The Teaching of Structural Words and Sentence Patterns (Stages 1-2 and 3-4)
Sinclair, J (Editor-in-Chief)	Collins Cobuild English Grammar

PH101 MECHANICS AND PROPERTIES OF MATTER (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: Intermediate level vector algebra, mechanics and general physics.

Course Objectives and Summary: This is a basic course in physics to describe translational and rotational motion and motion in a gravitational field. This course also provides with an idea about the properties of matter like elasticity, surface tension, viscosity, etc.

1. **Motion:** Implications of Newton's Laws of Motion; Kinematics in two and three Dimensions; Projectile Motion; Uniform Circular Motion; Conservative and Non-Conservative Forces; Friction in Dynamical Problems; Potential Energy Function; Conservation of Energy and Momentum; Collision Problems; Center of Gravity and Mass.

   Learning outcomes: Enable the successful students to:
   - **(i)** **C**alculate the angle at which an object can be thrown to a maximum distance.
   - **(ii)** Explain the performances of athletes, cannon firing, bombing from airplane.
   - **(iii)** Analyze the use of potential energy and kinetic energy in different mechanical systems.
   - **(iv)** Apply the conservation principles to different dynamical phenomena.
   - **(v)** Separate the conservative and non-conservative forces.
   - **(vi)** Find out the mechanism of calculating the center of mass and center of gravity of a system.

2. **Rotational Dynamics:** Torque and Angular Momentum; Conservation of Angular Momentum; Kinetic Energy of Rotation and Rotational Inertia; Theorems of Parallel and Perpendicular Axes for Calculations of Moment of Inertia; Calculations of Moment of Inertia of Solids of Different Shapes; Combined Translational and Rotational Motion of a Rigid Body.

   Learning outcomes: Enable the successful students to:
   - **(i)** Apply the conservation of angular momentum to different dynamical problems.
   - **(ii)** Calculate moment of inertia for different geometrical shapes for various axes of rotation.
   - **(iii)** Solve problems involving complex (translational plus rotational) motion.
   - **(iv)** Explain the mechanism of storing energy and its uses in industry using devices like flywheels.

3. **Gravitation:** Law of Universal Gravitation; Determination of Universal Gravitation Constant G; Inertial and Gravitational Mass; Variation in Acceleration due to Gravity; Gravitational Field and Potential; Gravitational Field Equations; Motion of Planets and Satellites, Kepler's Laws; Gravitational Potential Energy and Escape Velocity.

   Learning outcomes: Enable the successful students to:
   (i) Relate the concepts of gravitational field intensity to gravitational potential at a point.
   (ii) Calculate gravitational potentials and gravitational fields for different mass distributions.
   (iii) Derive the equation for the orbit of a mass under central force.
   (iv) Explain and derive Kepler's law of planetary motion.
   (v) Calculate the escape velocity.
   (vi) Explain the basics of satellite motion.
   (vii) Describe the use of gravitational force in our daily life events.

4. **Mechanics of Elastic Media:** Elastic Constants and their Relationships; Theory of Bending Beams; Torsion of Cylinder; Flat and Non-flat Springs.

   Learning outcomes: Enable the successful students to:
   (i) Calculate the amount of load to be borne by a cantilever.
   (ii) Calculate the depressions of cantilever and beams and explain their uses in structural engineering.
   (iii) Determine the effective mass of a spring.
   (iv) Explain the impact of negative effective mass.
   (v) Determine the modulus of rigidity of the materials.

5. **Surface Tension:** Molecular Phenomenon; Surface Energy; Curvature; Pressure and Surface Tension; Angle of Contact; Shape of Liquid Meniscus and Rise of Liquid in a Capillary Tube; Theory of Ripples and Problem of a Floating Needle.

   Learning outcomes: Enable the successful students to:
   (i) Learn why some insects can float on the surface of water?
   (ii) Calculate the angle of contact and explain the reasons for formation of obtuse and acute angles.
   (iii) Distinguish between surface tension and surface energy.
   (iv) Demonstrate the effect of adhesive and cohesive force.
   (v) Calculate the pressure inside a bubble.

6. **Fluid Dynamics:** Streamline and Turbulent Flow; Equation of Continuity; Bernoulli's Equations and its Applications; Poiseuille's Equation for Fluid Flow; Stoke's Law – Measurement of Viscosity; Effects of Temperature and Pressure on Viscosity.

Learning outcomes: Enable the successful students to:

- **(i)** Differentiate between streamline and turbulent flow.
- **(ii)** Learn the mechanism of congestion in water line.
- **(iii)** Learn the mechanism of a sprayer.
- **(iv)** Calculate the viscosity as a function of temperature.
- **(v)** Demonstrate the working principle of viscometer.
- **(vi)** Calculate the terminal velocity of a falling particle through a viscous fluid.

Books Recommended

Text Books

Halliday & Resnick and Walker, J	Fundamentals of Physics (10th editions)
Halliday, D and Resnick, R	Physics Part I (and later editions)
Mathur, DS	Elements of Properties of Matter
Newman, FH and Searle, VHL	General Properties of Matter
Champion, FC and Davy, N	Properties of Matter

Reference Books

Symon, KR	Mechanics
Spiegel, MR	Vector Analysis
Young, et al	University Physics
Heuvelen, AV	Physics
Constant, FW	Theoretical Physics (Part I)
Spiegel, MR	Theoretical Mechanics

PH102 ELECTROMAGNETISM (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: Concepts of electric charge, flow of charge through a medium, electric potential, electric field and production of e.m.f.

Course Objectives and Summary: All fundamental laws of electricity and interaction between current and magnet are discussed in the course. Nature of DC and AC currents and their responses on the circuits with L, C and R combinations are explained. Effect of temperature in electricity is also included. The constructions and working principles of different devices e.g. analog meters, galvanometer, motor, generator, transformer and thermocouple are explained in the course.

1. **Electrostatics:** Coulomb's Law; Electric Field; Electric Potential and Potential Function; Gauss' Law and its Applications; Electric Dipole and Quadrupole; Electric Field in Dielectric Media; Polarization; Gauss' Law for Dielectrics; Permittivity; Condensers; Boundary Value Problems- Poisson's and Laplace's Equations.

   Learning outcomes: Enable the successful students to:
   - **(i)** Calculate force acting between two charges.
   - **(ii)** Calculate electric field for different kinds of charge distribution.
   - **(iii)** Visualize electric field using field strength, field lines and potential.
   - **(iv)** Explain the effect of dielectric materials on electric field.
   - **(v)** Calculate electric field for symmetric charge distribution using Gauss's law.
   - **(vi)** Explain the mechanism of storing energy in a capacitor.

2. **Electric Current:** Ohm's Law; Current Density; Conductivity; Resistivity; Kirchhoff's Laws and their Applications.

   Learning outcomes: Enable the successful students to:
   - **(i)** Characterise ohmic materials using current-voltage plot.
   - **(ii)** Explain why the resistivity is constant but resistance is not for a material.
   - **(iii)** Analyze both single and multi loop circuits.

3. **Electromagnetic Induction:** Faraday's and Lenz's Laws; Self and Mutual Induction; Solenoids; Growth and Decay of Current in LR Circuits; Charging and Discharging a Capacitor through RC, LC and LCR Series Circuits; Time Constant and Natural Frequency of the Concerned Circuits; Concept of Electric Generator and Motors.

   Learning outcomes: Enable the successful students to:
   - **(i)** Learn the mechanism of producing e.m.f. and the process of increasing it.
   - **(ii)** Find the direction of e.m.f. when a current carrying conductor is placed in a magnetic field.
   - **(iii)** Calculate the self and mutual inductance induced in coils.
   - **(iv)** Explain the charging and discharging mechanisms of dc RC, RL and LCR circuits using the numerical values of current as a function of time.
   - **(v)** Calculate and visualize the growth and decay of currents in the above circuits.
   - **(vi)** Explain the operation of motor and generator.

4. **Magnetic Fields and Interactions:** Magnetic Force on Charge and Current; Magnetic Effects of Current; Lorentz Force; Moving Coil Galvanometers: Dead Beat and Ballistic Galvanometer; Determination of Specific Charge of Electron; Analog Multimeter; Biot-Savart Law and its Applications; Ampere's Law and its Applications.

Learning outcomes: Enable the successful students to:

- **(i)** Calculate the amount of magnetic force on charge and current carrying conductors.
- **(ii)** Explain the interaction of parallel and anti-parallel current.
- **(iii)** Calculate magnetic field for general current distribution using Biot-Savart law.
- **(iv)** Calculate magnetic field for symmetric current distribution using Ampere's law.
- **(v)** Have practical knowledge while a current carrying coil is placed in magnetic field.
- **(vi)** Convert galvanometer into an ammeter and a voltmeter.

5. **Thermoelectricity:** Thermoelectric Phenomenon and Relation; Thermoelectric Power; Thermoelectric Diagrams; Thermocouples.

Learning outcomes: Enable the successful students to:

- **(i)** Learn the reason for production of e.m.f. due to temperature difference at the two junctions of two different kinds of metals.
- **(ii)** Demonstrate the deficiency of Peltier effect that leads to Thomson effect.
- **(iii)** Calculate thermoelectric power.
- **(iv)** Describe the basics of thermoelectric generator.
- **(v)** Construct thermopile and explain its effect in thermal measurements.

6. **Alternating Current:** AC Fundamentals; Power and Power Equations; AC Circuits with L, C and R only and their Combinations; Use of Complex Quantities and Phasor Diagrams of Reactances and Voltages in AC Circuits; Resonant and Anti-Resonant Circuits; Q Factors; Transformers; AC Measuring Instruments, AC Bridge; Oscilloscope.

Learning outcomes: Enable the successful students to:

- **(i)** Distinguish between ac and dc circuits using graphical representations.
- **(ii)** Explain the mechanism of LC oscillations, generation of ac voltage and current.
- **(iii)** Analyze pure resistive, capacitive and inductive circuits.
- **(iv)** Analyze RC, LC, series LCR and parallel LCR circuits using conventional method as well as phasor diagram.
- **(v)** Calculate and visualize graphically the growth and decay of currents in the above circuits.
- **(vi)** Calculate the half power point, band width and Q value of LCR series and parallel circuits.

Books Recommended

Text Books

Halliday, D, Resnick and R, Walker	Fundamentals of Physics
Rafiqullah, AK et al.	Concepts of Electricity and Magnetism
Tewari, KK	Electricity and Magnetism
Islam, AKMA et al.	Tarit Chumbak Tatwa O Adhunik Padarthavijnan *(in Bangla)*
Theraja, BL	Text Book of Electrical Technology

Reference Books

Kip, A	Fundamentals of Electricity and Magnetism
Young, HD et al.	University Physics
Duffin, WJ	Electricity and Magnetism
Page, L and Adams, NI	Principles of Electrical Technology
Purcell, EM	Electricity and Magnetism
Agarwal, JP	Circuit Fundamentals and Basic Electronics
Griffiths, D	Introduction to Electrodynamics

PH103 VIBRATIONS AND WAVES (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: HSC level waves and sound.

Course Objectives and Summary: This course aims to provide students with an overview of the simple harmonic motion in various circumstances as well as waves in various forms. The course addresses free, damped, forced and coupled oscillators, and resonance, leading into normal modes in discrete and continuous systems. Students will gain useful concepts and mathematical tools to explain broad range of problems related to vibrations and waves from this course.

1. **Free Vibration:** Harmonic Motion; Mathematical Representation; Boundary Conditions; Vector Representation: Velocity; Acceleration and their Phase Relationship; Energy of a Harmonic Oscillator; Physical and Torsional Pendulums; Plasma Vibration.

   Learning outcomes: Enable the successful students to:
   - **(i)** Explain harmonic motion.
   - **(ii)** Explain the origin of restoring force from potential gradient and the mechanism of simple harmonic motion.
   - **(iii)** Demonstrate the variation of kinetic and potential energies of a harmonic oscillator.

(iv) Explain the vibrations in outer space plasma.

2. **Damped and Forced Vibration:** Damping Forces; Types of Damping; Logarithmic Decrement; Relaxation Time and Quality (Q) Factor; Electromagnetic Damping; Forced Oscillation; Steady State and Transient Solutions; Variation of Driving Frequency; Examples of Resonance.

Learning outcomes: Enable the successful students to:

(i) Explain the effect of damping force on free vibrations.
(ii) Explain different types of damping and use it in engineering purposes such as circuits, construction of dead beat and ballistic galvanometer etc.
(iii) Explain forced oscillations and the resonance phenomenon.

3. **Coupled Oscillators and Normal Modes of Continuous System:** Coupled Oscillators; Normal Coordinates and Normal Modes; Forced Vibration of a Coupled Oscillator; N-Coupled Oscillator, Wave Motion as a Limit of Coupled Oscillation.

Learning outcomes: Enable the successful students to:

(i) Explain coupled oscillations.
(ii) Calculate normal frequencies and normal modes.
(iii) Design of a mass tuned damper.
(iv) Demonstrate the forced vibration of a coupled oscillator.
(v) Demonstrate the destruction of Tacoma narrow bridge.

4. **Fundamentals of Waves**: Wave Motion, Types of Waves; Wave Generation; Wave Equation and Solution; Energy Power and Speed of Traveling Waves; Plane and Spherical Waves; Introduction to some Wave Phenomena in Physics.

Learning outcomes: Enable the successful students to:

(i) Visualize wave motion and develop intuition about waves. Understand how waves travel through a medium.
(ii) Understand the difference between transverse and longitudinal waves.
(iii) Become familiar with the properties of sinusoidal waves, such as wavelength, wave speed, amplitude, and frequency.
(iv) Study the properties of common waves - waves on strings, sound waves, and light waves.
(v) Apply energy and power concepts to waves.

5. **Superposition of Periodic Motions:** Principle of Superposition; Superimposed Vibration of Equal and Different Frequencies; Stationary Waves; Beats; Combination of two Vibrations at Right Angles; Lissajous Figures.

Learning outcomes: Enable the successful students to:

(i) Explain the principle of superposition.
(ii) Explain the production of standing wave and the basics of harmonics.

(iii) Describe the production of beats and the details of tuning a musical instrument.
(iv) Describe the production of Lissajous figure for different combinations.

6. **Sound Waves and Acoustics:** Sources; Propagation and Speed of Sound in Fluid and Solid Media; Musical Sound; Doppler's Effect; Infrasonics and Ultrasonics; Recording and Reproduction of Sound, General Idea of Acoustics, Reverberation.

Learning outcomes: Enable the successful students to:
(i) Explain the properties of musical sound.
(ii) Explain Doppler's effect and its basic uses in astronomy, medical imaging, flow measurement, radar etc.
(iii) Explain the basics of sound record and reproduction.
(iv) Explain the basic idea of noise control using acoustical engineering.
(v) Explain reverberation and can construct a model of an auditorium.

Books Recommended

Text Books

Main, IG	Vibrations and Waves in Physics
Puri, SP	Vibrations and Waves
Pain, HJ	Physics of Vibrations and Waves

Reference Books

French, AP	Vibrations and Waves
Halliday, D and Resnick, R	Fundamentals of Physics
Morse, PM	Vibration and Sound
Smith, WF	Waves and Oscillations: A Prelude to Quantum Mechanics

PH104 MATHEMATICAL METHODS IN PHYSICS-I (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered taking at least 2 questions from each group out of total 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: HSC level vector algebra and calculus.

Course Objective and Summary: This course includes vector algebra, vector differentiation, integration and different integral theorems. Curvilinear coordinates are described in this course. The differential equations of various types and their solution methods are also discussed in this course.

Group A: Vector Analysis

1. **Vector Sum and Products:** Applications of Dot and Cross Products of Vectors; Scalar Triple Product; Vector Triple Product.

   Learning outcomes: Enable the successful students to:
   - **(i)** Represent one-, two- and three-dimensional vectors graphically.
   - **(ii)** Understand the physical meanings of scalar and vector products.
   - **(iii)** Use these products in different physical problems such as to calculate work, torque, angular momentum, magnetic force etc.
   - **(iv)** Evaluate triple product and use it in physical problems like lattice vector calculations.

2. **Vector Differentiation:** Ordinary Derivatives of Vectors; Space Curves; Differentiation Formulae; Partial Derivatives of Vectors; Differentials of Vectors.

   Learning outcomes: Enable the successful students to:
   - **(i)** Compute ordinary and partial derivatives, and differentials of vectors and vector functions.
   - **(ii)** Calculate arc length and curvatures of space curves.
   - **(iii)** Calculate velocity and acceleration of a particle moving along a space curve.

3. **Gradient, Divergence and Curl:** Vector Differential Operator Del; Gradient; Divergence; Curl and their Physical Significance; Formulae Involving Del.

   Learning outcomes: Enable the successful students to:
   - **(i)** Evaluate gradient, divergence and curl and explain their physical significance.
   - **(ii)** Use these in the physical problems of electrodynamics, thermodynamics etc.
   - **(iii)** Solve problems using the formulae involving the operator Del.

4. **Vector Integration:** Ordinary Integrals of Vectors; Line Integrals; Surface Integrals; Volume Integrals.

   Learning outcomes: Enable the successful students to:
   - **(i)** Evaluate vector line integrals, surface integrals and volume integrals.
   - **(ii)** Use this integrals in solving physical problems.

5. **Theorems Relating Different Integrals:** Divergence Theorem of Gauss; Green's Theorem in the Plane; Stoke's Theorem.

   Learning outcomes: Enable the successful students to:
   - **(i)** Prove divergence theorem, Green's theorem and Stoke's theorem.
   - **(ii)** Visualize these theorem using real life events and use these in the problems where dimension(s) of integration are needed to be altered.

(iii) Use these theorems in deriving equations and to solve problems.

6. **Curvilinear Coordinates:** Frames of Reference – Rectangular; Spherical Polar and Cylindrical Coordinates; Concept of Curvilinear Coordinates; Unit Vectors in Curvilinear Systems; Line arc Length, Surface and Volume Elements in Different Coordinates.

Learning outcomes: Enable the successful students to:
- **(i)** Demonstrate the concept of curvilinear coordinates.
- **(ii)** Visualize rectangular, spherical and cylindrical coordinate systems and use these for suitable symmetry.
- **(iii)** Calculate length, surface and volume element in different coordinate systems.

Group B: Differential Equations

1. **Basic Concepts:** Classification of Differential Equations, their Origin and Solutions; Initial-value Problems; Boundary-value Problems; Existence of Solutions.

Learning outcomes: Enable the successful students to:
- **(i)** Analyze boundary value problems and use this in number of physical problems.

2. **First Order Differential Equations:** Exact Differential Equations and Integrating Factors; Separable, Homogeneous and Linear Equations.

Learning outcomes: Enable the successful students to:
- **(i)** Solve exact differential equation.
- **(ii)** Solve separable differential equation.

3. **Higher Order Linear Differential Equations:** Basic Theory of Linear Differential Equations; Homogeneous Linear Differential Equations with Constant Coefficients.

Learning outcomes: Enable the successful students to:
- **(i)** Demonstrate the basic theory of linear differential equations.
- **(ii)** Solve homogeneous linear differential equations.

4. **Non-homogeneous Differential Equations:** Method of Undetermined Coefficients; Variation of Parameters.

Learning outcomes: Enable the successful students to:
- **(i)** Find a particular solution for inhomogeneous ordinary differential equations and recurrence relations.
- **(ii)** Demonstrate the use of variation of parameters to solve inhomogeneous linear ordinary differential equations.

5. **Series Solutions of Linear Differential Equations:** Power Series Solutions about an Ordinary Point; Series Solutions about Regular Singular Points.

Learning outcomes: Enable the successful students to:

(i) Solve linear differential equations using power series solutions.

(ii) Solve Hermite, Legendre and Bessel differential equations about regular singular points.

6. **Partial Differential Equations:** Some Basic Concepts.

Learning outcomes: Enable the successful students to:

(i) Have some basic knowledge of partial differential equation.

Books Recommended

Text Books

Spiegel, MR	Vector Analysis and an Introduction to Tensor Analysis
Lass, H	Vector and Tensor Calculus
Ross, SL	Differential Equations

Reference Books

Simmons, GF and Robertson, JS	Diff. Eqs. With Applications and Historical Notes
Arfken, GB	Mathematical Methods in Physics
Wong, CW	Introduction to Mathematical Physics
Davis, HF and Snider, AD	Introduction to Vector Analysis
Griffths, DJ	Introduction to Electrodynamics

PH105R DIFFERENTIAL AND INTEGRAL CALCULUS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisite: HSC level calculus.

Course Objective and Summary: Calculus is an important tool for a physicist. This is a generalized basic undergraduate mathematics course taught by teacher from the Mathematics department. It covers differential and integral calculus and provides students with skills and tools required in physics problems.

1. **Functions:** Domain; Range; Inverse Function and Graphs of Functions; Limits; Continuity and Indeterminate Form.

Learning outcomes: Enable the successful students to:

(i) Recognize the properties of functions and their inverses.

(ii) Learn meaning of domain and range of a function, dependent and independent variables and plot the functions accordingly.
(iii) Evaluate limits involving indeterminate forms using L-hospitals rule.
(iv) Evaluate the discontinuities of a function.

2. **Ordinary Differentiation:** Differentiability; Differentiation; Successive Differentiation and Leibniz Theorem.

Learning outcomes: Enable the successful students to:
(i) Learn how a variable changes with respect to another variable.
(ii) Perform different forms of differentiation.
(iii) Learn how to differentiate the integral transforms.

3. **Expansions of Functions:** Rolle's Theorem; Mean Value; Taylor's and Maclaurin's Formulae.

Learning outcomes: Enable the successful students to:
(i) Find out the stationary point of a function which has the same two values at particular intervals.
(ii) Find out the point(s) between two end points of a function, at which the tangent to the arc is parallel to the secant through its endpoints.
(iii) Evaluate the decreasing or increasing behavior of a function.
(iv) Explain Taylor's and Maclaurin's Formulae and use these theorems in mathematical and physical problems.

4. **Maxima and Minima of Functions of One Variable.**

Learning outcomes: Enable the successful students to:
(i) Find out the extrema of physical system (function) by equating the first derivative to zero and maxima and minima from the second derivatives test.
(ii) Find out the intervals on which a function is increasing/decreasing.

5. **Partial Differentiation:** Euler's Theorem; Tangents and Normals.

Learning outcomes: Enable the successful students to:
(i) Explain the behavior of a function that changes with more than one variable.
(ii) Implement the use of partial differentiation in demonstrating physical situation, e.g., temperature gradients along three directions, horizontal and vertical damages caused by pollutants, velocity field of a moving fluid, magnetic field etc.

6. **Asymptotes.**

Learning outcomes: Enable the successful students to:
(i) Demonstrate the asymptotic behavior of a function.
(ii) Evaluate asymptotes of curves of different patterns.

7. **Indefinite Integral:** Method of Substitutions; Integration by Parts; Special Trigonometric Functions and Rational Fractions.

   Learning outcomes: Enable the successful students to:
   (i) Evaluate the integration of a product by parts.
   (ii) Evaluate integration of trigonometric functions.
   (iii) Evaluate integration of rotational functions.

8. **Definite Integrals:** Fundamental Theorem; General Properties; Evaluations of Definite Integrals and Reduction Formulae.

   Learning outcomes: Enable the successful students to:
   (i) Evaluate definite integrals.
   (ii) Implement definite integration in calculating and analyzing number of physical problems, e.g., work, magnetic field, circuits, decay etc.

9. **Multiple Integrals:** Determination of Lengths, Areas and Volumes.

   Learning outcomes: Enable the successful students to:
   (i) Evaluate length, surface areas, and volumes using multiple integration.

Books Recommended

Text Books

Das, BC and Mukherjee, BN	Differential Calculus
Das, BC and Mukherjee, BN	Integral Calculus
Muhammad, K and Bhattacherjee, PK	Differential Calculus
Muhammad, K and Bhattacherjee, PK	Integral Calculus

Reference Books

Edwards, J	Differential Calculus
Williamson, RE	Integral Calculus
Thomas and Finny	Calculus and Analytical Geometry
Swokowsky, E	Calculus and Analytical Geometry
Ayres, F	Calculus
Spiegel, MR	Schaum's Outline of Advanced Calculus

PH106R INORGANIC AND ORGANIC CHEMISTRY (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisite: HSC level chemistry.

Course Objective and Summary: Chemistry is a closely connected discipline to physics. There are significant areas of overlap and useful applications of chemistry concepts in the study of synthesis and properties of materials. This is a basic undergraduate course covering key concepts in inorganic and organic chemistry and is taught by teachers from the Chemistry department.

1. **Atomic Structure:** Elementary Ideas on Atomic Structure; Electronic Configuration of Elements.

   Learning outcomes: Enable the successful students to:
   - **(i)** Describe atomic structure.
   - **(ii)** Demonstrate the electronic arrangement in different s, p, d, f etc. orbitals of various elements.

2. **Periodic Classification of Elements:** Modern Periodic Table; Periodic Classification of Elements; Correlation of Periodic Classification with Electronic Configuration; Investigation on some Periodic Properties; Atomic Radius; Ionic Radius; Covalent Radius; Ionization Potential; Electron Affinity; Electronegativity.

   Learning outcomes: Enable the successful students to:
   - **(i)** Have knowledge of periodic table.
   - **(ii)** Organize a set of element or monoatomic ions in order of increasing atomic radius, ionic radius, first ionization energy and electronegativity
   - **(iii)** Explain electronegativity, electron affinity and ionization potential

3. **Group Study of Elements:** Alkali Metals; Alkaline Earth Metals; Halogens; Inert Gases; Transition and Rare Earth Elements.

   Learning outcomes: Enable the successful students to:
   - **(i)** Explain the properties of alkali metals, alkaline earth metals, halogens, Inert Gases and Transition Elements.
   - **(ii)** Demonstrate the use of inert gases in refrigerator, superconducting magnets, MRI, radiotherapy, laser surgery etc.
   - **(iii)** Demonstrate the use of halogens as disinfectants for drinking water.

4. **Chemical Bond:** Different Types of Chemical Bonding; Hybridization of Atomic Orbitals and Shapes of Molecules; Molecular Orbitals; Bond Length and Bond Strength.

   Learning outcomes: Enable the successful students to:
   - **(i)** Understand the hybridization and geometry of atoms and the three-dimensional structure of organic molecules
   - **(ii)** Determine whether a bond is metallic, ionic, covalent or polar covalent
   - **(iii)** Explain the interaction of molecular orbitals and hence demonstrate different types bonding and symmetry.

5. **Aliphatic Compounds:** Nomenclature of Organic Compounds; Preparation and Properties of Alcohols; Halides; Aldehydes; Ketones and Carbooxylic Acids; Coordination Compounds.

Learning outcomes: Enable the successful students to:

(i) Find out the name of organic compound recommended by IUPAC.

(ii) Prepare and explain the properties of alcohols, halides, aldehydes, ketones and Carbooxylic Acids.

(iii) Demonstrate the use of Coordination Compounds in dying, electroplating, in identifying unknown substances in a liquid.

6. **Aromatic Compounds:** Aromaticity; Orientations; Preparations and Properties of Benzene; Phenol; Nitrobenzene and Aniline; Elementary Idea on Alicyclic and Heterocyclic Compounds.

Learning outcomes: Enable the successful students to:

(i) Describe the preparation and explain the properties of Benzene, phenol, nitrobenzene and aniline.

(ii) Have basic knowledge of alicyclic and heterocyclic compounds.

(iii) Demonstrate the production and reactions of benzene.

(iv) Describe the health issue of benzene.

7. **Synthesis:** Synthesis Involving Grignard Reagent; Malonic Ester; Aceto-Acetic Ester and Diazonium Salts.

Learning outcomes: Enable the successful students to:

(i) Describe the mechanism of different types of synthesis involving Grignard reagent, malonic ester and diazonium salt.

(ii) Demonstrate the use of diazonium in dye and pigment industry.

Books Recommended

Text Books

Haider, SZ	Modern Inorganic Chemistry
Ahmed, M &Jabbar, A	Organic Chemistry

Reference Books

Moeller, T	Modern Inorganic Chemistry
Gilreath, E	Fundamental Concepts of Inorganic Chemistry
Seberra, DK	Electronic Structure and Chemical Bonding
Finar, IM	Organic Chemistry
Bahl, BS and Bahl, A	Advanced Organic Chemistry
Ahmed, S and Hossain, ML	Snatak Ajaiba Rasayan (*in Bangla*)
Ahmed, AKS	Ajaiba Rasayan (*in Bangla*)

PH107R PRINCIPLES OF STATISTICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: **100** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* **4** *hours*

Prerequisite: HSC level mathematics

Course Objective and Summary: In the analysis of any type of data, statistical tools and concepts are essential. This is an introductory course covering key concepts of statistics and is taught by teachers from the Statistics department. It equips students with tools and skills required in analyzing data that are needed, in particular, in the practical courses and in research.

1. **Statistics:** Meaning and Scope; Variables and Attributes; Collection and Presentation of Statistical Data; Frequency Distribution and Graphical Representation.

   Learning outcomes: Enable the students to:
   - **(i)** Represent data in a statistical manner.
   - **(ii)** Tabulate data using frequency distribution and use it to find central tendency, mean, median and standard deviation.

2. **Analysis of Statistical Data:** Location; Dispersion and their Measures; Skewness; Kurtosis and their Measures; Moment and Cumulants.

   Learning outcomes: Enable the students to:
   - **(i)** Find whether a data is stretched or squeezed.
   - **(ii)** Measure the symmetry of a distribution and test the perfection of a sample data.
   - **(iii)** Measure the kurtosis of a distribution.
   - **(iv)** Understand moments and use it in physical calculations and definitions.

3. **Probability:** Concept of Probability; Sample Space; Events; Union and Intersection of Events; Probability of Events; Addition law of Probability; Conditional Probability; Multiplication law of Probability; Baye's Theorem.

   Learning outcomes: Enable the students to:
   - **(i)** Have the knowledge of probability.
   - **(ii)** Calculate union and intersection of events.
   - **(iii)** Use addition law and multiplication law of probability in solving problems.

4. **Random Variables and Probability Distribution:** Basic Concepts; Discrete and Continuous Random Variables; Density and Distribution Functions; Mathematical Expectation and Variance; Joint, Marginal and Conditional Density Functions; Conditional Expectation and Conditional Variance;

Chebyshev's Inequality; Moments and Cumulant Generating Functions; Study of Binomial, Poisson and Normal Distributions.

Learning outcomes: Enable the students to:

(i) Have the knowledge of discrete distribution and continuous distribution and use these to solve problems.
(ii) Calculate expected value of two random variables.
(iii) Use the concept of moments and Cumulant generating functions.

5. **Correlation and Regression:** Bivariate Data; Scatter Diagram, Marginal and Conditional Distributions; Correlation; Rank Correlation; Partial and Multiple Correlations; Contingency Analysis; Linear Regression for two Variables; Principle of Least Squares Method; Lines of Best Fit and Residual Analysis.

Learning outcomes: Enable the students to:

(i) Demonstrate marginal and conditional distributions.
(ii) Construct a graphical model using a sample data and use that model for solving problems.
(iii) Compute Partial and Multiple Correlations.

Books Recommended

Text Books

Cramer, H.	The Elements of Probability Theory
Gupta, S.C. and Kapoor, V.K.	Fundamentals of Applied Statistics, 3rd Edn.

Reference Books

Anderson, AJB	Interpreting Data
Mosteller, F., Rourke and Thomas	Probability with Statistical Appl., 2nd Edn.
Ross, S.M.	Introduction to Probability Models, 3rd Edn.
Yule, G. U. and Kendall, M. G.	An Intro.To the Theory of Statistics, 14th Edn.
Hoel, PG	Introduction to Probability Theory
Lipschutz, S	Probability

PH109 PRACTICAL (Mechanics, Waves and Electricity)

Course Type: Major *Credit Point: 08*

Full Marks: ***200*** (*Continuous Assessment 60 marks, Practical Examination 140 marks*)

(*3 days for Experiments and 1 day for Defense on Experiments.*)

Examination duration: (***6+6+6+6***) *hours*

In the beginning of the 1st Year B.Sc. (Honours) Laboratory work, students will have to undertake a course on Basic measurements, Basic electricity, Curve plotting, Significant figures, Treatments of errors, etc. A total of 10 marks will be reserved on these Laboratory items from the marks allotted for the continuous assessment.

Prerequisite: HSC level theoretical and experimental physics.

List of Experiments

1. Data Processing in a Personal Computer.

Learning outcomes: Successful students should be able to:
- **(i)** Analyze and plot experimental results in a personal computer.

2. Determination of Moment of Inertia of a Flywheel.

Learning outcomes: Successful students should be able to:
- **(i)** Determine the moment of inertia of a flywheel.
- **(ii)** Link the concept of energy conversion in different forms with the concept of conservation of energy.
- **(iii)** Estimate the amount of friction and understand its role on the motion of the flywheel.

3. Study of Two-Body Collisions in Two Dimensions.

Learning outcomes: Successful students should be able to:
- **(i)** Determine frictional loss in collision in two dimensions.
- **(ii)** Apply the principle of conservation of energy and momentum in collision problems.

4. Determination of g by and K of a Compound Pendulum.

Learning outcomes: Successful students should be able to:
- **(i)** Determine the acceleration due to gravity and radius of gyration a compound pendulum.
- **(ii)** Demonstrate how the time–period of oscillation varies with the length between the point of suspension and the centre of mass.

5. Determination of Young's Modulus of a Material by the Method of Bending.

Learning outcomes: Successful students should be able to:
- **(i)** Determine the Young's modules of the material of a bar by the method of bending.
- **(ii)** Demonstrate how the depression of a bar depends on the geometrical factions.
- **(iii)** Appreciate how physically measurable geometrical parameters can be related to intrinsic materiel property- elasticity.

6. Determination of Rigidity Modulus of a Material by the Statical Method.

Learning outcomes: Successful students should be able to:
- **(i)** Determine rigidity modules by statical method.
- **(ii)** Relate geometrical factors and angle of twist to the rigidity modulus.

7. Using a Flat Spring:

a) Verification of Hooke's Law and Hence Determination of Stiffness Constant;
b) Determination of g and the Effective Mass of the Spring.
c) Determination of Modulus of Rigidity of the Material of a Spring.

Learning outcomes: Successful students should be able to:
- **(i)** Verify Hooke's law and determine stiffness constant , effective mass of spring, and modulus of rigidity of the material of the spring.
- **(ii)** Understand the origin of effective mass of the spring.
- **(iii)** Relate the geometrical factors with the stiffness constant.

8. Determination of Elastic Constants (Y, n, K and σ) of the Material of a Wire by Searle's Method.

Learning outcomes: Successful students should be able to:
- **(i)** Calculate various elastic parameters and establish relations among them.

9. Determination of the Surface Tension of Water by Capillary Rise Method ($1/r$ versus h curve is to be plotted).

Learning outcomes: Successful students should be able to:
- **(i)** Determine surface tension from the capillary effect of a liquid in a fine tube.
- **(ii)** Understand the role of cohesive and adhesive forces behind the observed phenomenon.

10. Determination of the Surface Tension and Angle of Contact of Mercury by Quincke's Method.

Learning outcomes: Successful students should be able to:
- **(i)** Determine the surface tension of mercury and angle of contact of mercury – glass system.
- **(ii)** Understand the role of various energies in determining the shape of the mercury drop on the glass plate.

11. Determination of the Surface Tension of a Liquid by the Method of Ripples.

Learning outcomes: Successful students should be able to:
- **(i)** Determine the surface tension of a liquid from the ripple parameters.
- **(ii)** Understand the waves in liquids controlled by gravity and surface tension.

12. Determination of Viscosity of Water by Capillary Flow Method.

Learning outcomes: Successful students should be able to:
- **(i)** Determine viscosity of a liquid from the capillary flow rate.
- **(ii)** Explain the principle of a capillary flow viscometer.

13. Calibration of a Meter Bridge.

Learning outcomes: Successful students should be able to:
- **(i)** Understand the importance of calibration.
- **(ii)** Calibrate the meter bridge wire.

14. Determination of Specific Resistance of a Wire by Wheatstone's Bridge with End Corrections.

Learning outcomes: Successful students should be able to:
- **(i)** Understand the different sources of end-corrections and their sign.
- **(ii)** Determine the end-corrections and use those in determining the resistance of a sample.

15. Determination of Galvanometer Resistance.

Learning outcomes: Successful students should be able to:
- **(i)** Understand the construction and function of a galvanometer.
- **(ii)** Understand the role of shunt resistance in this experiment.

16. Measurement of Low Resistance by the Method of Fall of Potential.

Learning outcomes: Successful students should be able to:
- **(i)** Determine low-resistance with a meter bridge.
- **(ii)** Understand the concept of electrical potential and drop of electrical potential in a circuit.

17. Determination of Galvanometer Constant (calculated current vs. Deflection curve is to be plotted).

Learning outcomes: Successful students should be able to:
- **(i)** Determine the galvanometer constant.
- **(ii)** Understand the link between galvanometer constant and galvanometer sensitivity.

18. Investigation of the Relation between the Current and Voltage for a Tungsten and a Carbon Filament Lamp.

Learning outcomes: Successful students should be able to:
- **(i)** Differentiate between the temperature dependent resistivity of metal and semi conduction.
- **(ii)** Understand the origin of non-linear relation between current and voltage.

19. Determination of the frequency of a tuning fork using Melde's method.

Learning outcomes: Successful students should be able to:
- **(i)** Demonstrate how standing waves are formed.
- **(ii)** Determine the frequency of a tuning fork using Melde's method.

Books Recommended

Text Books

Chawdhury, SA and Basak, AK	Byaboharik PadarthaVidya (*in Bangla*)
Ahmed, G and Uddin, MS	Practical Physics
Din, K	Practical Physics

Reference Books

Nelkon, M and Ogborn, JM	Advanced Level Practical Physics
Tyler, F	Laboratory Manual of Physics
Worsnop, BL and Flint, HT	Advanced Practical Physics
Topping, W	Errors of Observations

PH201 OPTICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisite: Basics of intermediate level knowledge about all aspects of light.

Course Objectives and Summary: The course objective is to study the concepts of electromagnetic waves including dual nature of light, and their propagation in a medium, the optical phenomena such as interference, diffraction, and to explain their application in lasers, as well as in fiber optics communication. It also provides a basis for further study in optoelectronics.

1. **Light and Images:** Nature of Light; Electromagnetic Spectrum and Energy; Huygen's Principle; Fermat's Principle; Ray Matrix Method; Aberrations in Optical Images.

   Learning outcomes: Enable the students to:
   - **(i)** Learn what does light mean.
   - **(ii)** Represent pictorially the electromagnetic spectrum/spectra.
   - **(iii)** Know pictorial representation of wavelet, wave-front and propagation of wave-front, refractive index, total internal reflection.
   - **(iv)** Calculate the least time required to propagate a light wave through a medium.
   - **(v)** Draw the figures to demonstrate the effect of various aberrations using incident and reflected waves.
   - **(vi)** Mechanism of photography and optical vision.

2. **Interference:** Superposition of Waves; Concept of Coherence; Types of Interference; Young's Experiment; Bi-prism; Thin Film Interference; Newton's Rings; Fabry-Perot Interferometer; Michelson's Interferometer.

   Learning outcomes: Enable the students to:
   - **(i)** Understand the result of the overlapping of two or more waves
   - **(ii)** And formation of maxima and minima in the resultant wave using graphical representation.
   - **(iii)** Learn different ways of formation of coherent sources.
   - **(iv)** Derive the equations for interference and hence find out the conditions for constructive and destructive interference.
   - **(v)** Calculate the wavelength of light.

3. **Diffraction:** Types of Diffraction; Fraunhofer Diffraction; Single, Double and Multiple Slits Diffraction; Grating; Resolving Power of Grating; Rayleigh Criteria; Fresnel Diffraction; Zone Plate, Diffraction by a Circular Aperture, Diffraction by a Narrow Slit, Cornu's Spiral, Fresnel's Integral.

   Learning outcomes: Enable the students to:

(i) Differentiate between interference and diffraction.
(ii) Effect of sources at finite and infinite distances.
(iii) Production of diffraction pattern using diffraction grating.
(iv) Know why and how the diffraction pattern arises on the both sides of the central maximum.
(v) Know the condition of diffraction for a particular wavelength of light through a particular slit.
(vi) Use the Fresnel' integral in describing Fresnel diffraction.

4. **Polarization:** Types of Polarization; Production and Detections of Polarization; Nicol Prism; Optical Activity; Fresnel's Theory of Optical Rotation; Polarimeter.

Learning outcomes: Enable the students to:
(i) Know the mechanism of polarization of light.
(ii) Differentiate among plane polarized, circularly polarized and elliptically polarized light (pictorial representations are essential).
(iii) Differentiate between optically active and inactive substances.
(iv) Calculate the optical rotation in a material medium.
(v) Determine the amount of solute in a solvent.

5. **Lasers:** Radiative Transitions; Einstein's Co-efficient; Light Amplification; Production of Population Inversion; Basic Principle of Lasing Action; Threshold Condition; Types of Lasers; Characteristics and Applications of Laser, Basic Concepts of Holography.

Learning outcomes: Enable the students to:
(i) Explain creation of population of inversion.
(ii) Demonstrate the formation of resonator cavity.
(iii) Know the process of generation of new wavelength of light.
(iv) Explain the beam profile.

6. **Nonlinear optics:** Nonlinear polarization, Harmonic generation, Phase matching, Nonlinear optical susceptibilities, Nonlinear optical materials, Nonlinear refraction and absorption, Two photon absorption, Third order nonlinearity measurement techniques: ZSCAN.

Learning outcomes: Enable the students to:
(i) Explain the nonlinear response of the material.
(ii) Demonstrate self-focusing and defocusing phenomena.
(iii) Apply two photon absorption concepts to measure nonlinearity through ZSCAN technique.

7. **Fibre Optics:** Graded Index (GRIN) Lens; Theory of Refractive Gradients; Fibre Optics; Ray Transmission; Basic Terms in Fiber Optics; Modes in Optical Fibre; Loss Mechanisms; Integrated Optics.

Learning outcomes: Enable the students to:

- **(i)** Explain the propagation of light through optical fibre.
- **(ii)** Explain the refractive index profile of optical fibre.
- **(iii)** Explain different modes involved in optical fibre.
- **(iv)** Calculate the signal loss in optical fibre.
- **(v)** Develop optical fibre communication systems.

Books Recommended

Text Books

Hecht, E	Optics
Jenkins, FA and White, HE	Principles of Optics
Ghatak, A	Optics
Brijlal, L	A Text Book of Optics

Reference Books

Meyer-Arendt, JR	Introduction to Classical & Modern Optics
Heavens, OS	Insight Into. Optics
Longhurst, RS	Geometrical & Physical Optics
Sladkova, J	Interference of Light
Arnold, RG	Electronic Devices
Hamam, S	Principles of Light
Svelto, O	Principles of Lasers
Ghatak, A and Thyagarajan, K	Optical Electronics
Ghatak, A and Thyagarajan, K	Introduction to Fibre Optics
Senior, JM	Optical Fibre Communications
Buck, JA	Fundamentals of Optics and Photonics

PH202 THERMAL PHYSICS (~ 75 *lectures*)

Course Type: Major — *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) — *Examination duration:* ***4*** *hours*

Prerequisite: HSC level physics.

Course Objective and Summary: This is a fundamental undergraduate course in physics designed to develop an in-depth knowledge of the laws of thermodynamics and to use this knowledge to explore various applications. Concepts of temperature, temperature measurement techniques, transport phenomena in the light of kinetic theory of gases, thermodynamic equilibrium, laws of thermodynamics, entropy, heat engines, thermodynamic potentials, phase transitions and various radiation laws are taught in this course. The elegance of thermodynamics is only surpassed by its importance as a core concept of physics, which is reflected throughout the course.

1. **Temperature:** Macroscopic and Microscopic Views; Thermal Equilibrium and Zeroth Law; Temperature Concept; Principles of Measurement and Establishment of Temperature Scales; Absolute Scale; International Scale; Gas Thermometer; Electrical Resistance Thermometer; Thermocouple.

   Learning outcomes: Enable the students to:
   - **(i)** Learn different temperature scales and their conversion.
   - **(ii)** Measure unknown temperatures with different types of thermometers.
   - **(iii)** Demonstrate the use of Thermocouple for different temperature measurements.

2. **Kinetic Theory of Gases and Transport Phenomenon:** Basic Assumptions; Equation of State of an Ideal Gas; Concept of Pressure and Temperature; Brownian Motion; Equipartition of Energy; Real Gases and Intermolecular Forces; Van der Waal's Equation of State; Collision Cross-Section; Mean Free Path; Thermal Conductivity; Diffusion.

   Learning outcomes: Enable the students to:
   - **(i)** Comprehend physical basis of the kinetic theory of gases.
   - **(ii)** Calculate the pressure exerted by a gas.
   - **(iii)** Apply equipartition theorem to derive the ideal gas law and Dulong-Petit law for the specific heat capacities of solid.
   - **(iv)** Learn physical basis of the Vander Waal's equation apply it to real gases.
   - **(v)** Calculate viscosity and thermal conductivity of gases using kinetic theory.

3. **Thermodynamic Fundamentals and First Law:** Thermodynamic Systems; Reservoirs, Walls and Surroundings; Thermodynamic Equilibrium and State of a System; Thermodynamic Processes and Cycles; Isothermal; Adiabatic; Quasi-Static; Reversible and Irreversible Processes; Heat and Work; Energy Equation; Internal Energy; Statement of First Law of Thermodynamics.

   Learning outcomes: Enable the students to:
   - **(i)** Explain the laws of thermodynamics and its place in Physics.
   - **(ii)** Gain the ability to use thermodynamic terminology appropriately.
   - **(iii)** Understand the concept of the systems, state variables and thermodynamic equilibrium.
   - **(iv)** Distinguish between various thermodynamic processes and calculate the work done in specific processes.
   - **(v)** Apply the concept of the first law of energy conversion.

4. **Second Law of Thermodynamics and Entropy:** Carnot's Cycle and Carnot's Theorem; Heat Engine and Refrigerators; Absolute Thermodynamic Temperature; Concept of Entropy, Entropy and Disorder; Principle of Increase of Entropy; Change of Entropy in Reversible and Irreversible Processes; Entropy Temperature Diagram; Theorem of Clausius; Clausius and Kelvin-Planck Statement of Second Law.

   Learning outcomes: Enable the students to:
   - **(i)** Explain the working mechanism of Carnot cycles.
   - **(ii)** Use the concept of entropy and the second law to solve thermodynamic problems.
   - **(iii)** Calculate the efficiency of various engines and explain why the efficiency cannot be 100%.

5. **General Thermodynamic Relations and Application to Simple Systems:** Thermodynamic Potential Functions; The Maxwell's Relations; Joule-Thomson Effect; Phase Transitions; Clausius-Clapeyron Equation; Chemical Potential; Phase Equation and Phase Rule; Heat Theorem and Third Law of Thermodynamics; Surface Corrections for a Finite System.

   Learning outcomes: Enable the students to:
   - **(i)** Use Maxwell's relations in various processes.
   - **(ii)** Explain the process of the liquefaction of gases and calculate the Joule-Thomson coefficient.
   - **(iii)** Explain basic features of phase transformations and calculate the temperature change with respect to pressure using the Clausius-Clapeyron equation.

6. **Radiation:** Theory of Exchange; Kirchhoff's Law; Nernst Black-Body Radiation; Stefan-Boltzmann's Law; Rayleigh-Jean's Law; Wien's Radiation Law; Planck's Quantum Law.

   Learning outcomes: Enable the students to:
   - **(i)** Understand the concept of blackbody radiation.
   - **(ii)** Explain some important astrophysical phenomena applying Kirchhoff's law.
   - **(iii)** Calculate the energy radiated by a body at a given temperature using Stefan-Boltzmann law.
   - **(iv)** Calculate the peak wavelength of radiation of a given body at a given temperature using Wien's law.
   - **(v)** Understand Planck's radiation law.

<u>Books Recommended</u>

Text Books

Sears, FW and Salinger, GL Thermodynamics: Kinetic Theory and

	Statistical Mechanics
Finn, CBP	Thermal Physics
Hossain, T	Text Book on Heat
Saha, MN and Srivastava, BK	A Treatise on Heat

Reference Books

Roberts, JK and Miller, AR	Heat and Thermodynamics
Zemansky, MW	Heat and Thermodynamics
Miah, W	Fundamentals of Thermodynamics
Reif, F	Fundamentals of Thermal Physics
Hoare, FE	Textbook of Thermodynamics
Schroeder	Introduction to Thermal Physics
Brijlal	Heat and Thermodynamics

PH203 CLASSICAL MECHANICS (~ 75 *lectures*)

Course Type: Major — *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) — *Examination duration:* ***4*** *hours*

Prerequisites: PH101, PH103, PH104, PH105R

Course Objectives and Summary: Classical mechanics describes constrained motion, generalized coordinates, variational principle, cyclic coordinates, Lagrangian formulation, Hamiltonian formulation, canonical transformations etc. Two-body central force problems are treated in the center of mass coordinate systems. Scattering problems and shapes of orbits are also discussed. Poisson bracket formulation, Hamilton-Jacobi theory and action angle are introduced for different specific problems and representations. Euler's theorem for the motion of rigid bodies are considered. The physics of small oscillations are also discussed.

1. **Lagrangian Formulation:** Motion of a System of Particles, Configuration Space, Degrees of Freedom, Constraints, and Generalized Coordinates; D'Alembert's Principle and Lagrange's Equations for Conservative and Holonomic Systems; Some Techniques of the Calculus of Variations; Hamilton's Principle for Conservative and Holonomic Systems and Lagrange's Equations; Extension of Hamilton's Principle to Non-Conservative and Non-Holonomic Systems and Lagrange's Equation; Conservation Theorems; Applications of Lagrange's Equations; Cyclic Coordinates.

   Learning outcomes: Enable the students to:

   (i) Understand different types of constraints and generalized coordinates.

- **(ii)** Use the generalized coordinates to model and solve a problem.
- **(iii)** Understand the principle of virtual work and evaluate the equilibrium(s) in basic structural engineering.
- **(iv)** Model and solve problems using Lagrangian formulation for both holonomic and non-holonomic systems.
- **(v)** Calculate the shortest distance between two points, minimum surface of revolution etc. using calculus of variation.
- **(vi)** Explain symmetry and its relation to the conservation laws.

2. **Two-Body Central Force Problem:** Definition and Characteristics of Central Force; Equations of Motion; Center of Mass and Laboratory Coordinate Systems; Reduction to One-Body Problem; Motion under Inverse-Square Law of Force Differential Equation and Shapes of Orbits; Elastic Scattering Problem in Laboratory and Center of Mass Systems.

   Learning outcomes: Enable the students to:
   - **(i)** Explain central force, center of mass and laboratory coordinate systems.
   - **(ii)** Reduce to equivalent one body problem.
   - **(iii)** Explain the details of orbits and evaluate the eccentricity, and stability of orbits.
   - **(iv)** Explain elastic scattering both in laboratory and center of mass systems and calculate the scattering cross-section.

3. **Rigid Bodies:** Kinematics of Rigid Body Motion; Independent Coordinates of a Rigid Body; Orthogonal Transformations; Formal Properties of Transformation Matrix; Euler's Angles; Infinitesimal Rotations; Rate of Change of a Vector; Coriolis Force and its Effects; Euler Equations of Motion; Force Free Motion; Gyroscopic Motion; Motion of Symmetric Tops.

   Learning outcomes: Enable the students to:
   - **(i)** Evaluate independent coordinates of a rigid body.
   - **(ii)** Find direction cosines and the Euler's angles.
   - **(iii)** Evaluate the properties of infinitesimal rotations.
   - **(iv)** Explain Coriolis force and its uses in meteorology, oceanography and other basic problems.

4. **Hamiltonian Formulation:** Phase Space and Motion of the System; Significance of Hamiltonian; Hamilton's Canonical Equations; Hamilton's Equations from Hamilton's Principle; Principle of Least Action; Cyclic Coordinates; Canonical Transformations; Legendre Transformations; Canonical Transformation Equations; Poisson and Lagrange Brackets and their Properties; Invariance of Poisson Brackets with Respect to Canonical Transformations; Hamilton's Equations of Motion in Poisson Bracket Form; Jacobi's Identity; Relation between Poisson Bracket and Lagrange Bracket .

Learning outcomes: Enable the students to:

(i) Explain the Hamilton's principle and principle of stationary action.
(ii) Explain cyclic coordinates and symmetry.
(iii) Derive the canonical transformation equations and use it in harmonic oscillator,
(iv) Find the Poisson and Lagrange brackets and evaluate their properties.

5. **Hamilton-Jacobi Theory:** Hamilton-Jacobi Equations for Hamilton's Principal and Characteristic Functions; Separation of Variables in Hamilton-Jacobi Equation; Action-Angle Variables; Applications.

Learning outcomes: Enable the students to:

(i) Derive Hamilton-Jacobi equation and use it in harmonic oscillator problem.
(ii) Use action-angle variables in one degree of freedom, completely separate systems, Kepler problems.

6. **Small Oscillations:** Formulation of Problem; Eigenvalue Equation and Introduction to Principal Axis Transformation; Frequencies of Free Vibration; Normal Coordinates and Normal Modes; Forced Vibrations and Effect of Dissipative Forces.

Learning outcomes: Enable the students to:

(i) Explain stable, unstable and metastable equilibrium.
(ii) Formulation of free vibration using energy consideration.
(iii) Evaluate the normal modes and frequencies.
(iv) Explain the effect of dissipative force and the need of forced oscillation.

Books Recommended

Text Books

Goldstein, G	Classical Mechanics
Spiegel, MR	Theoretical Mechanics
Rana, NC and Joag , PS	Classical Mechanics
Taylor, JR	Classical Mechanics

Reference Books

Gupta, Sl et al	Classical Mechanics
Constant, FW	Theoretical Physics
Gupta, KC	Mechanics of Particle & Rigid Bodies
Leech, JW	Classical Mechanics
Louis, NH and Janet, DF	Analytical Mechanics
Harun-or Rashid, AM	Chirayata Balavidya *(in Bangla)*
Biswas, SN	Classical Mechanics
Gregory, RD	Classical Mechanics
Hund and Finch	Analytical Mechanics

PH204 MATHEMATICAL METHODS IN PHYSICS-II (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: Factorial function, exponential and Gaussian functions, differentiation and integration, complex algebra of intermediate level.

Course Objectives and Summary: This is a basic course in mathematical physics to describe mathematical methods and functions useful for solving problems in physics. This course also covers matrix methods and tensor algebra that are widely used to explain various physical phenomena.

1. **Functions:** Gamma and Beta Functions; Bessel's Functions; Legendre Function-Legendre and Associated Legendre Polynomials; Hermite Polynomials; Laguerre Polynomials; Dirac Delta Function; Fourier transforms and its applications, Fourier series and analysis of various waveforms. Laplace transforms and its applications, Laplace transforms in a conducting cylinder within uniform field. Laplace transform in the potential about a spherical surface.

   Learning outcomes: Enable the students to:
   - **(i)** Solve problems using gamma and beta functions and.
   - **(ii)** Solve problems using Legendre polynomial, Hermite polynomials and Laguerre polynomials.
   - **(iii)** Solve problems of differential equation, quantum mechanics, wave analysis etc using Fourier and Laplace transformations.
   - **(iv)** Learn conversion of time domain signal into frequency domain.

2. **Complex Variables:** Complex Differentiation and Derivatives; Analytic Functions; Cauchy-Riemann Equations; Cauchy's Integral Formula and its Extension; Cauchy's Theorem; Residues at a Pole and at Infinity; Residue Theorems; Definite Integrals.

   Learning outcomes: Enable the students to:
   - **(i)** Calculate the modulus of a complex number.
   - **(ii)** Plot real and imaginary number to show the effect of them.
   - **(iii)** Apply this knowledge to analyze ac circuits and other physical problems.

3. **Matrices:** Types of Matrices; Matrix Equivalence; Adjoint and Inverse of a Square Matrix; Orthogonal and Unitary Matrices; Vector Spaces; Linear Equations; Characteristic Roots and Vectors; Diagonalization of Matrices.

   Learning outcomes: Enable the students to:
   - **(i)** Solve linear equations.

(ii) Construct angular momentum matrices and spin matrices.
(iii) Have basic knowledge of operator.

4. **Elements of Tensor Algebra:** Covariant and Contravariant Tensors; Metric Tensor; Christoffel Symbols.

Learning outcomes: Enable the students to:
(i) Explain covariant and contravariant tensors and its basic uses in relativistics mechanics.
(ii) Explain the properties of Christoffel symbols and use it in physical problems.
(iii) Explain the basic use of metric tensor in relativity.

Books Recommended

Text Books

Spiegel, MR	Vector Analysis and an Introduction to Tensor Analysis
Farid, SM	Introduction to Vectors and Special Functions
Pipes, L and Harvill, LR	Applied Mathematics for Engineers and
Physicists	
Ayres, F	Theory and Problems of Matrices
Spiegel, MR	Complex Variables

Reference Books

Sokolnikoff, IS and Redheffer, RM	Mathematics for Physics and Modern Physics
Churchill,RV et al	Complex Variables and Applications
Margenau, H and Murphy, GM	Mathematics of Physics and Chemistry
Wong, CW	Introduction to Mathematical Physics
Joshi, AW	Matrices and Tensors in Physics
Ali, MI	Matrices and Linear Transformations
Andrews, LC	Special Functions of Mathematics for Engineers

PH205R NUMERICAL METHODS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: Algebra, differential and integral calculus, matrices and basic FORTRAN programming.

Course Objectives and Summary: This course is designed to provide knowledge of some numerical techniques applicable to solve various mathematical problems, and also to develop simple, well-structured computer programing skills using standard language like Fortran and C/C^{++}.

1. **Transcendental Equations:** Numbers and their Accuracy; Error Analysis; Intermediate Value Theorem; Iteration Methods: Bisection Method, Iterative Method, False-Position Method, Newton-Raphson Method; Rate of Convergence; Acceleration of Convergence: Aitken's Δ^2-method; Efficiency of a Method.

   Learning outcomes: Enable the students to:
   - **(i)** Differentiate (a) iterative and direct methods and (b) transcendental and polynomial equations.
   - **(ii)** Apply iterative methods (bisection, Newton-Raphson, iterative, false-position) to solve transcendental and linear equations.

2. **System of Linear Equations:** Matrix Representation; Basic Matrix Operations; Direct Methods- Matrix Inversion; Gauss Elimination Methods; Gauss-Jordon Method; Triangularization Method; Iterative Methods: Jacobi Method, Gauss-Seidel Method.

   Learning outcomes: Enable the students to:
   - **(i)** Apply the above direct and iterative methods to solve a system of linear equations.

3. **Eigenvalues and Eigenvectors:** Eigenvalue Equation; Power Method; Jacobi Method; Givens Method; Householder Method.

   Learning outcomes: Enable the students to:
   - **(i)** Apply the above methods to find out eigenvalues and eigenvectors of square matrices.

4. **Interpolation and Curve Fitting:** Newton's Forward and Backward Difference Interpolation Formula; Hermite and Lagrange's Interpolation Formula; Spline Interpolation; Linear and Polynomial Least Squares Curve Fitting.

   Learning outcomes: Enable the students to:
   - **(i)** Explain finite divided differences.
   - **(ii)** Derive Newton's divided difference formula and use it to find missing data, such as population, laboratory data, and predict the behavior of a graph of no data region.
   - **(iii)** Construct a simple model of desired accuracy for a particular limit for engineering or research purpose from a sophisticated data.

5. **Numerical Differentiation and Integration:** Numerical Differentiation using Interpolation; Cubic Spline Method; Numerical Integration: Trapezoidal Method; Simpson's Method; Errors in these Methods; Romberg Method.

   Learning outcomes: Enable the students to:

(i) Find derivatives using interpolation.
(ii) Do integration using Trapezoidal rule, Simpson's rules.
(iii) Find the cross-section of a river, force due to non-uniform wind flow, heat flux etc.

6. **Ordinary Differential Equations:** Solution by Taylor Series; Euler's Method; Runge-Kutta Methods; Predictor-Corrector Methods: Adams-Moulton; Milne-Simpson.

Learning outcomes: Enable the students to:
(i) Solve ordinary differential equation by Taylor series, Euler's method, Runge-Kutta methods.

7. **Programming Examples in FORTRAN:** Interpolation using Lagrange's Polynomial; Integration by Trapezoidal and Simpson's Methods; Romberg Improvement; Solution of Differential Equations by Modified Euler's Method.

Learning outcomes: Enable the students to:
(i) Write a program to solve problems of Lagrange's Polynomial, Trapezoidal and Simpson's integration, modified Euler's method.
(ii) To use these programs for research purpose.

<u>**Books Recommended**</u>

Text Books

Sastry, SS	Introductory Methods of Numerical Analysis
Jain, MK, Iyengar and Jain	Numerical Methods for Science & Engineering Computation

Reference Books

Hamming, RW	Numer. Methods for Scientists and Engineers
Krishnamurthy, EVandSen, SK	Numerical Algorithms
Scheid, F	Introduction to Numerical Analysis.
Scarborough, JB	Numerical Mathematical Analysis
Carnahan, B, et al	Applied Numerical Methods
Ralston, A and Robinowitz, P	First Course in Numerical Analysis
Rajagopalan, R	Understanding Computer
Rajaraman, V	Numerical Analysis
Chapra, S and Canal, R	Numerical Methods for Engineering

PH206R PHYSICAL CHEMISTRY (~75 *lectures*)

Course Type: Minor/Related *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: Introductory idea about heat and physical chemistry of HSC level.

Course Objective and Summary: Chemistry is a closely connected discipline to physics. There are significant areas of overlap and useful applications of chemistry concepts in the study of synthesis and properties of materials. This is a basic undergraduate course covering key concepts in physical chemistry and is taught by teachers from the Chemistry department.

1. **Elements of Thermodynamics:** Thermodynamic Variables; Functions and their Relations; Gibbs-Helmholtz Equation; Spontaneity of a Chemical Reaction; Clapeyron-Claussius Equation.

   Learning outcomes: Enable the successful students to:
   - **(i)** Know what are thermodynamic variables and functions and establish their relation.
   - **(ii)** Calculate of the Gibbs free energy change for a chemical reaction at any temperature and predict the utility of Gibbs and Helmholtz free energy in practical purposes.
   - **(iii)** Calculate the temperature change with respect to pressure using the Clausius-Clapeyron equation.
   - **(iv)** Evaluate the spontaneity of chemical reaction.

2. **Chemical Equilibria:** Law of Mass Action; Thermodynamic Derivation of Law of Mass Action; Effects of Temperature; Pressure and Concentration on Chemical Equilibria; Relationship between K_P, K_C and K_X; Temperature Dependence of Equilibrium Constant.

   Learning outcomes: Enable the successful students to:
   - **(i)** Predict the dependency of chemical reaction on mass of reactants derive the law of mass action.
   - **(ii)** Know how do the pressure, temperature and concentration shift the chemical equilibria toward reactants or products and write specific chemical reactions as examples.
   - **(iii)** Determine exothermic and endothermic reactions.
   - **(iv)** Relate the affinity constants.

3. **Chemical Kinetics:** Order and Molecularity; Rate Equations for First and Second Order Reactions; Determination of Order of Reactions; Arrhenius Equation and Energy of Activation; Collision Theory; Catalysis: Definition, Characteristics, Promoter and Poisoning, Classification; Theory of Catalysis; Industrial Examples of Catalysis.

Learning outcomes: Enable the successful students to:

(i) Link the reaction rate with concentrations or pressures of reactants and constant parameters

(ii) Demonstrate the raise of concentration term in rate equation.

(iii) Explain the temperature dependence of reaction rate calculate the energy of activation.

(iv) Demonstrate the increase in the rate of a chemical reaction due to the participation of catalysis.

4. **Surface Chemistry and Colloids:** Adsorption; Langmuir Adsorption Isotherm; Determination of Surface Area; Colloids – Classification; Preparation; Purification; Properties and Importance; Elementary Ideas about Emulsion and Gels.

Learning outcomes: Enable the successful students to:

(i) Explain the adhesion of atoms, ions, or molecules from a gas, liquid, or dissolved solid to a surface.

(ii) Demonstrate the use of emulsion in food, health, synthesis.

(iii) Demonstrate the preparation and use of colloids.

5. **Colligative Properties:** Roult's Law; Elevation of Boiling Point; Depression of Freezing Point; Osmotic Pressure; Determination of Molecular Weight of Non-Volatile Substances.

Learning outcomes: Enable the successful students to:

(i) Demonstrate ideal and non-ideal mixing.

(ii) Find out negative and positive deviations.

(iii) Explain why the boiling point of a liquid (a solvent) will be higher when another compound is added

(iv) Describe the process in which adding a solute to a solvent decreases the freezing point of the solvent.

(v) Calculate the minimum pressure which needs to be applied to a solution to prevent the inward flow of water across a semipermeable membrane.

6. **Electrolytic Dissociation:** Arrhenius Theory of Electrolytic Dissociation; Electrolytes and their Classifications; Transport Number and its Determination; Ostwald's Dilution Law; Solubility and Solubility Products; Common Ion Effect.

Learning outcomes: Enable the successful students to:

(i) Demonstrate the separation of dissolved electrolytes into cations and anions.

(ii) Describe the degree of dissociation of weak electrolyte.

(iii) Explain the reduction in the solubility of an ionic precipitate when a soluble compound containing one of the ions of the precipitate is added to the solution in equilibrium with the precipitate.

7. **Electrolysis and Electrical Conductance**: Electrolysis; Faraday's Law of Electrolysis; Physical Significances of Chemical Equivalent and Electrochemical Equivalent; Conductance of Electrolytes: Specific Conductance and Equivalent Conductance, Variation of Electrical Conductance with Concentration and Temperature; Measurement of Equivalent Conductance: Conductance Cell, Cell constant Kohlrausch's Law of Independent Migration of Ions; Applications of Conductance Measurement.

   Learning outcomes: Enable the successful students to:
   - **(i)** Demonstrate the separation of elements from naturally occurring sources such as ores using an electrolytic cell.
   - **(ii)** Measure the ionic content in a solution by measuring conductivity of electrolyte.
   - **(iii)** Demonstrate the measurement of product conductivity is a typical way to monitor and continuously trend the performance of water purification systems.

8. **Acid and Bases:** Definitions of Acid and Bases According to Arrhenius, Browsted-Lowry, and Lewis; Frankline and Lux-flood Concepts; Neutralization Reactions; Strength of Acid and Bases: pH, pOH, pK_a, pK_b, pK_w; Measurement of pH of a Buffer Solution; Indicators and Acid-Base Titration Curves; Hydrolysis of Salts and pH of Salt Solutions.

   Learning outcomes: Enable the successful students to:
   - **(i)** Define acid and base according to Arrhenius.
   - **(ii)** Demonstrate the ability of acids to "donate" hydrogen ions (H^+) and ability of bases to "accept" them.
   - **(iii)** Describe the chemical reaction in which an acid and a base react quantitatively with each other.
   - **(iv)** Able to measure pH.

9. **Electrochemical Cells:** Definition; EMF; Presentation of an Electrochemical Cell; Measurement of EMF of a Cell; Standard Cell; Relation between EMF and Free Energy; Electrode Potential; Standard Hydrogen; Calomel and Ag-AgCl Electrodes; Nernst Equation; Quinhydrone Electrode; Glass Electrodes; Cell Reactions and EMF Calculations.

   Learning outcomes: Enable the successful students to:
   - **(i)** Define and measure EMF.
   - **(ii)** Demonstrate the relation between EMF and free energy.
   - **(iii)** Relate the reduction potential of an electrochemical reaction to the standard electrode potential, temperature, and activities of the chemical species undergoing reduction and oxidation.

Books Recommended

Text Books

Lewis, D and Glasstone, S	Elements of Physical Chemistry
Glasstone, S	Physical Chemistry
Rakshit, PC	Physical Chemistry
Haque, MM and Nawab, MA	Principles of Physical Chemistry
Palit, SR	Elementary Physical Chemistry
Barrow, GM	Physical Chemistry
Pal, SC and Chakraborty, PK	Snatak Vouta Rasayan *(in Bangla)*
Bahl, BS, Tuli, GD and Bahl, A	Essential of Physical Chemistry

PH207R BASIC ELECTRONICS, COMPUTER FUNDAMENTALS AND PROGRAMMING (~ 75 *lectures*)

Course Type: Minor/Related *Credit Point: 04*

Full Marks: **100** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* **4** *hours*

Prerequisites: PH102, basics of computer.

Course Objectives and Summary: This course aims to provide a brief introduction to electronics, computer hardware and software, and equip the students to be able to use office software to produce scientific documents, Fortran/C++/Python to address simple scientific problems. It also introduces symbolic scientific computation with Mathematica/Matlab/Maple and the basics of scientific plotting with a suitable scientific plotting software such as Sigmaplot/Origin/Kaleidagraph. Thus this course intends to provide a foundation of a range of computational tools that a student may require at more advanced levels of study and research.

1. **Fundamental Electronics:** Semiconducting Materials: Intrinsic and Extrinsic Semiconductors; p-type and n-type Materials; Semiconductor Diodes: Volt-Ampere Characteristics, Junction Capacitances; Special Diodes.

   Learning outcomes: Enable the successful students to:
   - **(i)** Differentiate between *p*-type and *n*-type materials.
   - **(ii)** Explain the formation of depletion layer consisting of negative and positive ions.
   - **(iii)** Know the mechanism of charge transfer through depletion region during the forward and reverse bias condition.
   - **(iv)** Calculate the forward and reverse resistances.

2. **Computer Fundamentals:** Binary, Hexadecimal and Alphanumeric Codes: ASCII, Unicode; Basic logic gates and their applications; Elements of a Computer System; Basic Computer Architecture; Hardware: Processor, Main memory, Input and Output Devices, Storage Devices, Modem.

Learning outcomes: Enable the students to:

- **(i)** Convert decimal number system into binary and hexadecimal systems.
- **(ii)** Connect fundamental logic gates with series and parallel circuits.
- **(iii)** Know the operation of logic gates and their practical applications.
- **(iv)** Know the operation of processor and its speed.
- **(v)** Know the functions of RAM and ROM.
- **(vi)** Describe the working process of input (mouse, keyboard) and output devices (printer, monitor).
- **(vii)** Know the working principle of modem.

3. **Software Fundamentals:** Categories of Software; System Software: Functions of an Operating System (OS); Types of Processing, Language Translators, Utility Software; PC Operating Environments: Comparison of OS: Windows, Macintosh OS, Linux; Malware; Application Software: Office software; Word-processing: Spreadsheet; Multimedia Presentations; Computer Viruses and Preventions.

Learning outcomes: Enable the students to:

- **(i)** Know the necessity of software.
- **(ii)** Compare Windows, Linux, Macintosh OS.
- **(iii)** Differentiate between system software and application software.
- **(iv)** Use office software to prepare documents with images and tables, spreadsheets with graphs and presentations with animation effects
- **(v)** Fight with computer viruses for running his/her computer efficiently.

4. **Computer Programming:** Introduction to High-Level Languages; Steps in Programming: Algorithm and Flowchart, Sequential Executions, Branching Operations, Looping Operations, Procedures, Comments and Debugging. FORTRAN Programming: Data Types, Arithmetic Statements, Formatted Input/Output, Loops and Logical Expressions, Arrays, Functions and Subroutines, File Processing, Applications to Various Statistical and Physical Problems; Basics of C++ Programming; Introduction to Python.

Learning outcomes: Enable the students to:

- **(i)** Write algorithms and flowcharts to solve relevant problems
- **(ii)** Write the corresponding programs in FORTRAN / C++ / python.
- **(iii)** Sort out the problems in the software.

5. **Symbolic Scientific Computing:** Data Input/Import, Data Manipulation, Solution of Equations, Integrations, Matrix Operations, Visualization [Suitable software from options such as Matlab, Mathematica, Octave etc.].

Learning outcomes: Enable the students to:

- **(i)** Manipulate data.
- **(ii)** Do differentiation, integration, and matrix operations using computer program.

(iii) Solve mathematical problems using suitable software.

6. **Scientific Plotting:** Data Input/Import, Plot types, Curve Fitting, Formatting, Output [Suitable software from options such as Gnuplot, Origin, KaleidaGraph, SigmaPlot, Grace etc.].

   Learning outcomes: Enable the students to:
   (i) Import data and draw graphs using aforesaid software.

Books Recommended

Text Books

Grob, B	Basic Electronics
Malvino, AP	Electronic Principles
Norton, P	Peter Norton's Introduction to Computers
Rajaraman, V	Computer Programming in Fortran 90 and 95
Chapman, SJ	Introduction to Fortran 90/95
Hubbard	Programming with C++

Reference Books

Gupta, SL and Kumar, V	Hand Book of Electronics
Hutchinson, SE & Sawyer, SE	Computer and Information System
Schildt, H	Turbo C/C++
Rajaraman, V	Computer Programming in Fortran 90 and 95
Metcalf, M, Reid, J and Cohen, M	Modern Fortran Explained
Nyhoff, L and Leestma, S	Fortran 90 for Scientists and Engineers

PH209 PRACTICAL (Thermal Physics, Optics, Electricity and Computation)

Course Type: Major *Credit Point: 08*

Full Marks: **200** (*Continuous Assessment 60 marks, Practical Examination 140 marks*)

(*3 days for Experiments and 1 day for Defense on Experiments*)

Examination duration: (**6**+**6**+**6**+**6**) *hours*

Prerequisites: PH102, PH109

List of Experiments

1. Practicing of Programming (FORTRAN/MATLAB/C++).

   Learning outcomes: Successful students should be able to:
   (i) Compile and run computer programme.

2. Practicing (Operations on PC) of Applications Software (MS-Office Word, MS-Excel and MS-Power Point).

Learning outcomes: Successful students should be able to:
- **(i)** Write with MS-Word.
- **(ii)** Analyses data (performing calculation and drawing graph) with MS-Excel.
- **(iii)** Present a report with MS-Power Point.

3. Determination of Specific Heat of Solid with Radiation Correction.

Learning outcomes: Successful students should be able to:
- **(i)** Define specific heat, thermal capacity and water equivalent.
- **(ii)** Use calorimeter.
- **(iii)** Understand Newton's law of cooling.
- **(iv)** Name the factors on which the radiation of heat depends.

4. Determination of Thermal Conductivity of a Bad Conductor.

Learning outcomes: Successful students should be able to:
- **(i)** Define thermal conductivity, temperature gradient, area of cross section.
- **(ii)** Explain Newton's law of cooling.
- **(iii)** Name the processes by which heat can flow.
- **(iv)** Name the factors on which the radiation of heat depends.

5. Calibration of a Thermocouple and Determination of Unknown Temperature.

Learning outcomes: Successful students should be able to:
- **(i)** Use the potentiometer, draw the calibration cure, and measure an unknown temperature using the curve.

6. Determination of the Ratio of the Specific Heats of a Gas by Clement and Desorme's Apparatus.

Learning outcomes: Successful students should be able to:
- **(i)** Use the Clement and Desorme's apparatus.
- **(ii)** Relate the specific heats with the barometric height.

7. Determination of J by Callendar and Barnes Apparatus (with radiation correction).

Learning outcomes: Successful students should be able to:
- **(i)** Use Callendar and Barnes apparatus.
- **(ii)** Calculate electric energy transformed in the heating element.
- **(iii)** Explain the meaning of J.

8. Determination of Mutual Inductance of two Coils.

Learning outcomes: Successful students should be able to:
- **(i)** Explain electro-magnetic induction.
- **(ii)** Define self and mutual inductance.
- **(iii)** Name the factors on which self and mutual inductances depend.

9. To Study the Variation of Reactances due to L and C with Frequencies and Hence Find the Condition of Resonance from the (X-f) Curves.

Learning outcomes: Successful students should be able to:
- **(i)** Show the relation between frequency and reactance mathematically as well as graphically.
- **(ii)** Find out the resonance condition.
- **(iii)** Differentiate between ohmic and reactive resistances.

10. Determination of Resonant Frequency in LCR Circuits with: a) L and C in Series, b) L and C in Parallel.

Learning outcomes: Successful students should be able to:
- **(i)** Show the relation between voltage/current/impedance and frequency.
- **(ii)** Find out the resonance frequency.
- **(iii)** Find out the Q-factor of a curve.

11. Phasor Diagram of Voltages in an AC Circuit Containing L, C and R and Study of the Variation of Phases with Frequency.

Learning outcomes: Successful students should be able to:
- **(i)** Represent graphically the directions of V_L, V_C and V_R in an AC circuit.

12. Determination of Refractive Indices of Thick and Thin Prisms.

Learning outcomes: Successful students should be able to:
- **(i)** Describe the characteristics of thin and thick prisms.
- **(ii)** Show ray trace through them.
- **(iii)** Define refractive index and relate it to the velocity of light.

13. Determination of Radius of Curvature of a Given Lens by Newton's Ring Method and Verification of the Result by Spherometer.

Learning outcomes: Successful students should be able to:
- **(i)** Explain the formation of Newton's ring
- **(ii)** Use spectrometer.
- **(iii)** Establish a relationship between radius of curvature and wavelength of light.

14. Determination of Wavelength of Light by Diffraction through a Single Slit.

Learning outcomes: Successful students should be able to:
- **(i)** Show the diffraction pattern.
- **(ii)** Measure the width of the principal maximum.
- **(iii)** Measure the width of the slit.

15. Determination of Wavelength of Light by Bi-prism.

Learning outcomes: Successful students should be able to:
- **(i)** Show diffraction pattern through bi-prism.

(ii) Establish a relationship between wavelength and the slid width.

16. Calibration of a Spectrometer and Determination of Unknown Wavelength.

Learning outcomes: Successful students should be able to:

(i) Name and describe the functions of the essential parts of a spectrometer.
(ii) Adjust the spectrometer and source including focusing for parallel rays.
(iii) Find out the position of minimum deviation.
(iv) Show graphically the relation of wavelength and angle of minimum deviation.

17. Determination of Wavelength by Plane Diffraction Grating.

Learning outcomes: Successful students should be able to:

(i) Understand the mechanism of discharge tube.
(ii) Establish a relationship between wavelength and grating element.
(iii) Explain how a grating forms a spectrum.

18. Determination of Resolving Power of a Grating.

Learning outcomes: Successful students should be able to:

(i) Define resolving power of an optical instrument.
(ii) Explain how a grating forms a spectrum.

19. Determination of Dispersive Power of a Prism.

Learning outcomes: Successful students should be able to:

(i) Differentiate dispersion from diffraction.
(ii) Understand and calculate the dispersive power of a prism.

20. To Study the Values of Basic Parameters for the Ray Transmission through the Optical Fibre Using a Computer Software.

Learning outcomes: Successful students should be able to:

(i) Use the software and show the ray transmission characteristics.

21. To Study the Characteristics of a *p-n* Junction Diode and hence to Determine its Dynamic Resistance.

Learning outcomes: Successful students should be able to:

(i) Draw the characteristic curve of a p-n junction.
(ii) Show the knee voltage.
(iii) Calculate dynamic resistance.

22. To Study the Characteristics of a Zener Diode and Its Use in a Voltage Regulator.

Learning outcomes: Successful students should be able to:

(i) Regulate voltage.
(ii) Explain the Zener characteristics.

23. Calibration of a Polarimeter and hence Determination of Specific Rotation of a Sugar Solution.

Learning outcomes: Successful students should be able to:

(i) Understand the function of polarizer and analyzer.
(ii) Define polarization of light.
(iii) Show graphically the relation between concentration and angular rotation.

Books Recommended

Text Books

Chawdhury, SA and Basak, AK	Byaboharik Padarthvidya*(in Bangla)*
Ahmed, G and Uddin, MS	Practical Physics
Nelkon, M and Ogborn, JM	Advanced Level Practical Physics
Tyler, F	Laboratory Manual of Physics
Worsnop, BL and Flint, HT	Advanced Practical Physics
Din, K and Motin, A	Advanced Practical Physics
Schildt, H	Turbo C/C++
Rajaraman, V	Computer Programming in Fortran 90 and 95
Chapman, SJ	Introduction to Fortran 90/95

PH301 ELECTRODYNAMICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: PH102, PH104.

Course Objective and Summary: The course deals with Maxwell's equations, wave equations in different media and their solutions, boundary conditions of wave propagation at an interface and their applications, waveguides, radiation from an accelerated charge, scattering and dispersion of electromagnetic waves. This is one of the foundation undergraduate courses designed to make the students well-versed in the physics associated with electromagnetic wave propagation.

1. **Maxwell's Field Equations:** Maxwell's Equations; Electromagnetic Energy-Poynting Vector; Scalar and Vector Potentials; Wave Equations and their solutions.

   Intended learning outcomes: Enable the successful students to:
   - **(i)** Set up Maxwell's wave equation and solve it.
   - **(ii)** Derive expression for Poynting vector.
   - **(iii)** Understand and apply the concepts of scalar and vector potentials.

2. **Propagation of Electromagnetic Waves:** Plane Waves in Infinite Medium.
   - **a)** Waves in Non-Conducting Media; Waves in Conducting Media.
   - **b)** Waves in Plasma; Concepts of Plasma; Conductivity; Plasma Frequency; Wave Propagation at High and Low Frequencies.
   - **c)** Waves in Crystalline Medium; Isotropic and Anisotropic Crystals; Optic Axis; Double Refraction; Propagation of Plane Waves in Anisotropic Crystals.

   Intended learning outcomes: Enable the successful students to:
   - **(i)** Solve wave equation in non-conducting and conducting media.
   - **(ii)** Explain wave propagation in plasma medium quantitatively.
   - **(iii)** Explain waves in crystalline medium quantitatively.

3. **Reflection and Refraction of EM Waves:** Boundary Conditions; Reflection and Refraction at Boundaries of two Non-Conducting Media; Metallic Reflection; Total Internal Reflection.

   Intended learning outcomes: Enable the successful students to:
   - **(i)** Differentiate between kinematics and dynamic properties of light.
   - **(ii)** Relate angle of incidence, reflection and refraction.

(iii) Calculate phase change and propagation energy of electromagnetic waves.

4. **Waves in Bounded Region:** Wave Propagation between two Parallel Conducting Plates; Wave Guides (rectangular).

   Intended learning outcomes: Enable the successful students to:
   (i) Derive field equations for plane waves propagating in a particular direction between the infinite conducting parallel planes.
   (ii) Grasp the idea of wave propagation through optical fibre.

5. **Radiation from an Accelerated Charge:** Liénard and Wiechert Potentials; Field of a Charge in Uniform Motion; Fields of an Accelerated Charge; Radiation at Low Velocities.

   Intended learning outcomes: Enable the successful students to:
   (i) Know what Lienard-Wiechert potentials do.
   (ii) Calculate the electric field and magnetic field from the potentials.
   (iii) Know the implications of Lienard-Wiechert potentials.
   (iv) Know how the field varies due to accelerated point charge.

6. **Scattering and Dispersion:** Forced Vibration; Scattering by Free and Bound Electrons; Thomson, Rayleigh and Resonance Scattering; Normal and Anomalous Dispersions.

   Intended learning outcomes: Enable the successful students to:
   (i) Learn how electrons become bound in a material.
   (ii) Relate Compton scattering with the Thompson scattering.
   (iii) Explain how Thompson scattering takes place and calculate the cross section of this scattering.
   (iv) Know how the knowledge of Thompson scattering can be applied to cosmic microwave background, x-ray crystallography and inverse Compton scattering.
   (v) Explain the reason of blue hue of the daytime sky and reddening of the sun during sunset.
   (vi) Calculate the energy loss in optical fiber using Rayleigh scattering.

<u>Books Recommended</u>

Text Books

Reitz, JR et al	Foundations of Electromagnetic Theory
Griffiths, DJ	Introduction to Electrodynamics
Gupta, SL et al	Electrodynamics

Reference Books

Islam, AKMA & Islam, S	Tarit Gativijnan (*in Bangla*)
Huq, MS et al	Concept of Electricity and Magnetism

Tralli, N	Classical Electromagnetic Theory
Panofsky, WKH and Philip, M	Classical Electricity
Jackson, JD	Electrodynamics
Duffin, WJ	Advanced Electricity and Magnetism
Lim, YK	Introduction to Classical Electrodynamics
Slate, JC and Frank, NH	Electromagnetism
Chen, FF	Introduction to Plasma Physics
Sen, SN	Plasma Physics
Wangsness,	Electromagnetic Fields
Heald and Marrion	Classical Electromagnetic Radiation

PH302 BASIC QUANTUM MECHANICS (~ 75 *lectures*)

Course Type: Major — *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) — *Examination duration:* ***4*** *hours*

Prerequisites: PH101, PH107R, PH203.

Course Objectives and Summary: This course explains the nature and behavior of matter and energy on the atomic and subatomic levels. The course will allow students to perform calculations on simple systems using the Schrödinger equation. Applications, such as stationary states of the hydrogen atom, harmonic oscillator, etc. are discussed.

1. **Physical Basis of Quantum Mechanics:** Shortcomings of Classical Theory; Two-slit Experiment; Wave Aspects of Matter; Wave Function and its Interpretation; Wave Packets and Uncertainty Principle.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Identify and understand the kinds of experimental results which are incompatible with classical physics and which required the development of a quantum theory of matter and light.
   - **(ii)** Interpret the wave function and apply operators to it to obtain information about physical systems.
   - **(iii)** Understand the role of uncertainty principle, and use the commutation relations of operators to determine whether or not two physical properties can be simultaneously measured.

2. **Formalism of Quantum Mechanics:** Postulates of Quantum Mechanics; Correspondence Principle; Complementarity Principle, Measurements and Observable; Commutation of Observations; Linear Operators; Hermitian Operators; Eigenvalue Equations; Eigenvalues and Eigenfunctions; Eigenstates; Orthonormality of Eigenstates; Degeneracy; Principle of Superposition; Probability Amplitudes; Probability Current Density; Overlap

Integrals; Completeness; Change of Basis; Wave Function in Position and Momentum Space.

Intended learning outcomes: Enables successful students to:

- **(i)** Describe the formal structure of quantum mechanics.
- **(ii)** Comprehend how measurements are interpreted in quantum mechanics.
- **(iii)** Calculate the expectation value of various physical quantities and how the measurement process works in quantum mechanics.
- **(iv)** Identify and relate the Eigen-value problems for energy, momentum and angular momentum.

3. **Problems in One Dimension:** Schrödinger Wave Equation; Particle in a Potential Box; Potential Step; Tunneling through a Potential Barrier; Rectangular Potential Well; Linear Harmonic Oscillators.

Intended learning outcomes: Enables successful students to:

- **(i)** Solve the Schrödinger equation to obtain wave functions and eigenvalues for some basic, physically important types of potential in one dimension.
- **(ii)** Calculate the energy eigenvalues of linear harmonic oscillator.

4. **Spherically Symmetric Systems:** Three-dimensional Schrödinger Equation for Spherically Symmetric Potentials; Spherical Harmonics; Three Dimensional Potential Wells-degenerate States; Two-body Problems- Hydrogen Atom; Rigid Rotor; Rotational Energy Levels of Diatomic Molecules.

Intended learning outcomes: Enables successful students to:

- **(i)** Apply the technique of separation of variables to solve problems in three dimensions and understand the role of degeneracy in the occurrence of electron shell structure in atoms.

<u>Books Recommended</u>

Text Books

Matthews, PT	Introduction to Quantum Mechanics
Griffiths, D	Introduction to Quantum Mechanics
Bransden, and Joachain, C	Quantum Mechanics

Reference Books

Greiner, W	Quantum Mechanics
Powell, JL and Crasemann, B	Quantum Mechanics
Fong, P	Elementary Quantum Mechanics
Golder, SK	Quantum Balovidya (*in Bangla*)
Sherwin, CW	Introduction to Quantum Mechanics
Shankar, R	Principles of Quantum Mechanics

Agarwal, BK and Prakash, H	Quantum Mechanics
Gupta, Kumar and Sharma	Quantum Mechanics
Ziock, C	Basic Quantum Mechanics
Pauling, L and Wilson, EB	Quantum Mechanics

PH303 ATOMIC AND MOLECULAR PHYSICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: PH103, PH105R.

Course Objectives and Summary: This course aims to study the physical properties of atoms and molecules focusing on the role of atoms as the building blocks of matter based on the atomic models. It mainly deals with the interactions between matters and light-matter on the scale of one or a few atoms and energy scales around several electron volts. Atomic and molecular theory includes classical, semi-classical and quantum treatments of emission, absorption, scattering of electromagnetic radiation (light) from excited atoms and molecules.

1. **Atomic Models:** Rutherford's Nuclear Atom; Atomic Spectra; Bohr Model and Structure of Atoms; Vector Atom Model; Atomic Excitation; Franck-Hertz Experiment; Correspondence Principle; Correction for Nuclear Motion; Hydrogen-Like Atoms.

   Intended learning outcomes: Enable the successful students to:
   - **(i)** Explain Rutherford's nuclear atom.
   - **(ii)** Describe the Bohr model and calculate electron energy levels.
   - **(iii)** Describe the Franck-Hertz experiment to show the quantum nature of atoms.
   - **(iv)** Explain Correspondence Principle.

2. **Quantum Mechanical Theory of Hydrogen Atom:** Schrödinger Equation for Hydrogen Atom; Electron Probability Density; Spectrum of Hydrogen.

   Intended learning outcomes: Enable the successful students to:
   - **(i)** Solve Schrodinger equation for Hydrogen atom and explain the symmetry nature of coulomb potential produced by the nucleus, calculate energy levels, visualize electron orbitals.
   - **(ii)** Demonstrate the quantum numbers.
   - **(iii)** Describe Rydberg formula and demonstrate different spectral lines.

3. **Wave-Particle Duality:** Photoelectric Effect; Einstein's Photoelectric Equation and its Experimental Verification; Photoelectric Cells and their Applications; de Broglie Waves; Experimental Verification of Particle Waves; Wave and Group Velocities; Uncertainty Principle.

Intended learning outcomes: Enable the successful students to:

- **(i)** Illustrate the wave-particle duality.
- **(ii)** Explain the emission of electrons or other free carriers when light is impinged onto a material.
- **(iii)** Calculate de Broglie wavelength.

4. **X-Rays:** Production and Properties of X-Rays; Continuous and Characteristic X-Rays; X-Ray Spectra; X-Ray Absorption; Moseley's Law; Compton Effect.

Intended learning outcomes: Enable the successful students to:

- **(i)** Demonstrate the production of X-rays.
- **(ii)** Differentiate between continuous and characteristic X-rays.
- **(iii)** Demonstrate the inelastic scattering of a photon by a charged particle, usually an electron in Compton effect.

5. **Electron Spin and Complex Atoms:** Spin Angular Momentum; Exclusion Principle; Stern-Gerlach Experiment; Spin-Orbit Interaction-Fine Structure; Total Angular Momentum of Atoms; Atomic Spectra (Helium, Sodium and Mercury); Zeeman Effect, Stark Effect.

Intended learning outcomes: Enable the successful students to:

- **(i)** Explain the intrinsic angular momentum.
- **(ii)** Demonstrate the Pauli exclusion principle.
- **(iii)** Demonstrate the interaction of a particle's spin with its motion.
- **(iv)** Explain the splitting a spectral line into several components in the presence of a static magnetic field.
- **(v)** Explain the shifting and splitting of spectral lines of atoms and molecules due to presence of an external electric field.
- **(vi)** Describe the splitting of the spectral lines of atoms due to electron spin and relativistic corrections to the non-relativistic Schrödinger equation.

6. **Molecular Spectra:** Molecular Spectra of Diatomic Molecules; Rotational Spectra; Vibrational-Rotational Spectra; Molecular Quantum States; Dissociation of Molecules; Heat of Dissociation; UV- Spectra; Raman Spectra.

Intended learning outcomes: Enable the successful students to:

- **(i)** Characterize materials using X-ray spectroscopy.
- **(ii)** Measure of the energies of transitions between quantized rotational states of molecules in the gas phase.
- **(iii)** Demonstrate the vibrational, rotational and other low-frequency modes in a system.

Books Recommended

Text Books

Beiser, A Concepts of Modern Physics

Rajam, JB	Atomic Physics
Krane, K	Modern Physics

Reference Books

Enge, HA et al	Introduction to Atomic Physics
Husain, A and Islam, GS	Paramanabik Vijnan (*in Bangla*)
Islam, GS	Paramanbik Ebong Nucleo Padarthavijnan, Vol.1
Semat, H & Albright Jr	Introd. to Atomic and Nuclear Physics
Brehm and Mullen	Introduction to the Structure of Matter
Richtmeyer,FK	Introduction to Modern Physics
Acosta, V and Cowan, GL	Essentials of Modern Physics
Kiruthiga, S and Murughesan, R	Modern Physics

PH304 NUCLEAR PHYSICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: PH105R, PH101, PH102.

Course Objective and Summary: This course deals with nuclear properties, nuclear force and nuclear reactions. It covers the area of study on radioactive nuclides and their decay modes along with the detection of nuclear particles. The mechanism of interactions of charged particles and radiations with matter, and different methods of acceleration of charged particles are also included in this course.

1. **The Nucleus:** Constituent of Nuclei; Nuclear Mass; Charge and Density; Nuclear Size; Mass Defect; Binding Energy; Nucleon Separation Energy; Nuclear Force; Meson Theory of Nuclear Forces; Stability Conditions and Semi-Empirical Mass Formula: Liquid Drop Model.

   Intended learning outcomes: Enable the successful students to:
   - **(i)** Understand nucleon.
   - **(ii)** Calculate the nuclear as well as atomic mass.
   - **(iii)** Calculate the nuclear mass defect using the mass and number of nucleon.
   - **(iv)** Understand about nuclear stability.
   - **(v)** Learn nature and properties of nuclear force.

2. **Radioactivity:** Radioactive Decay Laws; Half-Life and Mean-Life; Secular and Transient Equilibrium; Radioactive Series; Artificial Radioactivity; Uses of Radioisotopes; Units of Radioactivity.

Intended learning outcomes: Enable the successful students to:

(i) Learn about natural and artificial radioactive material.
(ii) Calculate half life and mean life of a radioactive material.
(iii) Realize the use of radioisotopes in nuclear medicine, radiation therapy treatment, agriculture and industrial purposes.
(iv) Understand the physical meaning of unit of radioactivity.

3. **Alpha, Beta, and Gamma Emissions:** Alpha Instability; Fine Structure; Long Range Alpha Particles; Theory of Alpha-Decay; Beta Decay and its Energy Measurement; Conservation of Energy and Momentum in Beta Decay; Neutrino Hypothesis; Orbital Electron Capture; Positron Emission; Mass Conditions for Beta Decay; Gamma Decay; Mean Lives for Gamma Emission; Internal Conversion.

Intended learning outcomes: Enable the successful students to:

(i) Get idea about conversion of parent nucleus into daughter nucleus and draw the transitions for different excited states.
(ii) Calculate and draw decay energy for different emissions.
(iii) Learn about neutrino and the conditions for different types of beta decay.
(iv) Understand about gamma emission and internal conversion of an excited nucleus.

4. **Interaction of Charged Particles and Radiation with Matter:** Ionization; Multiple Scattering; Stopping Power; Range Determination; Energy Loss of Electrons and other Charged Particles; Straggling; Positronium, Pair Production and Annihilation, Radiation Length.

Intended learning outcomes: Enable the successful students to:

(i) Calculation of stopping power and range of light and heavy charge particle.
(ii) Learn about the interaction of charge particle and radiation with matter.

5. **Nuclear Reactions:** Different Types of Reactions; Conservation of Physical Quantities; Energetics of Nuclear Reactions; Cross-Section; Compound Nucleus Hypothesis; Production and Properties of Neutrons.

Intended learning outcomes: Enable the successful students to:

(i) Learn about different types of nuclear reaction mechanism and conservation condition for the same.
(ii) Calculation of energy and cross section of a nuclear reaction.

6. **Nuclear Detectors:** Ionization Chambers; Proportional Counter; Geiger-Muller Counters.

Intended learning outcomes: Enable the successful students to:

(i) Development of idea about the detection mechanism for different types of radiation with various detector systems.
(ii) Calculation of the intensity and energy of a radiation.

7. **Particle Accelerators:** Linear Accelerator; Betatron; Cyclotron; Synchrotron; Introduction to LHC.

Intended learning outcomes: Enable the successful students to:
(i) Learn about the charge particle acceleration mechanism and the calculation of the energy of the charge particle.

8. **Nuclear Fission and Fusion:** Fission Process; Energy Release in Fission; Chain Reaction; Nuclear Fusion; Thermonuclear Reaction in Stars.

Intended learning outcomes: Enable the successful students to:
(i) Learn about fission and fusion reaction mechanism and their practical applications.
(ii) Calculation of fission and fusion energy.

Books Recommended

Text Books

Beiser, A	Concepts of Modern Physics
Islam, AKMA & Islam, MA	Nucleo Padarthavijnan *(in Bangla)*
Islam, GS	Paramanbik ebong Nucleo Padarthavijan, Vol. 2
Kaplan, I	Nuclear Physics
Cohen, BL	Concepts of Nuclear Physics

Reference Books

Burcham,WE	Nuclear Physics
Enge, HA	Introduction to Nuclear Physics
Krane, K	Introductory Nuclear Physics
Wong, SSM	Introduction to Nuclear Physics
Evans, AD	Atomic Nucleus
Meyerhof, WE	Elementary Nuclear Physics
Smith, CMH	Text Book of Nuclear Physics
Heyde, K	Basic Ideas and Concepts in Nuclear Physics

PH305 BASIC SOLID STATE PHYSICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: Knowledge about coordinate system, vector addition and subtraction, dot and cross product, diffraction in real space, mass-spring concept, electronic configuration of atoms, Ohm's law, direct and indirect band gap.

Course Objectives and Summary: Difference between crystalline and non-crystalline materials along with their formation mechanism are explained. Electronic energy bands, lattice dynamics, mechanism of conduction and effects of various defects in semiconducting and conducting materials are also discussed.

1. **Crystal Systems:** Crystalline and Non-crystalline States; Unit Cell; Bravais Lattice; Symmetry Operations; Miller Indices; Simple Crystal Structures; Packing Factor; Inter-planar Spacing; Concept of Reciprocal Lattice; Bragg Diffraction in Reciprocal Lattice; Brillouin Zones.

   Intended learning outcomes: Successful students should be able to:
   - **(i)** Locate atoms in a crystal using lattice translation vector.
   - **(ii)** Calculate distance between two planes.
   - **(iii)** Calculate the position of atoms in Cartesian coordinates
   - **(iv)** Draw primitive cell in a crystal.
   - **(v)** Demonstrate the conversion of Bragg diffraction law in real space into that in reciprocal space and vice versa.
   - **(vi)** Explain the limitation of crystal diffraction both in real and reciprocal space.

2. **Crystal Bindings:** Crystals of Inert Gas; Ionic Crystals; Binding Energy and Bulk Modulus; Covalent; Metal and Hydrogen Bonded Crystals.

   Intended learning outcomes: Successful students should be able to:
   - **(i)** Understand the mechanism of various bondings.
   - **(ii)** Calculate the bond energy associated with different bonds.
   - **(iii)** Calculate bond strength that holds the atoms together to from the crystal structure.
   - **(iv)** Explain the electronegativity of elements and formation of various compounds.

3. **Dynamics of Crystal Lattice:** Concept of Phonon; Elastic Vibration of a Continuous Medium; One-dimensional Monatomic and Diatomic Lattices; Theories of Lattice Specific Heat - Einstein Model and Debye Model.

   Intended learning outcomes: Successful students should be able to:
   - **(i)** Calculate vibrational frequencies of atoms in different types of crystals.

(ii) Demonstrate the stability of crystal structure.

4. **Free Electron Theory of Metals:** Drude Model and Sommerfeld Model; Energy Levels and Density of Orbitals in One-dimension and Three-dimensions; Effect of Temperature on F-D Distribution; Electrical Conductivity and Ohm's Law; Thermal Conductivity of Metals; Electronic Heat Capacity; Wiedemann-Franz Law.

   Intended learning outcomes: Successful students should be able to:
   (i) Calculate and plot free electron energy band in solids.
   (ii) Demonstrate inefficiency of the free electron model to explain band gap.
   (iii) Show the effect of electrons in conductivity in crystalline solids.
   (iv) Relate Fermi energy with free electron energy.

5. **Band Theory and Semiconductors:** Energy Bands in Crystals; Nearly Free Electron Model and Energy Gaps; Motion of Electrons in One and Three Dimensions in a Periodic Potential; Band Theory; Effective Mass of Electrons; Intrinsic and Extrinsic Semiconductors; Hall Effects for One and Two-carrier Systems.

   Intended learning outcomes: Successful students should be able to:
   (i) Calculate the amount of band gap in crystals.
   (ii) Distinguish metal, semiconductor and insulator in terms of band gap.
   (iii) Predict the effect of crystal potential on energy band as well as the difference between free electron model and nearly free electron model.
   (iv) Calculate the effective mass of electron.
   (v) Calculate the amount of charge carriers and determine the type of semiconducting specimen.

6. **Imperfections in Crystals:** Classification of Defects; Point Defects; Dislocations: Screw and Edge Dislocations; Diffusion in Metals; Plane Defects; Crystal Grains and Grain Boundaries; Energy of Grain Boundaries.

   Intended learning outcomes: Successful students should be able to:
   (i) Explain the formation and mechanism of defects produced in a crystal.
   (ii) Calculate the amounts of various defects as a function of temperance.
   (iii) Calculate the energy associated with grain boundary.
   (iv) Demonstrate and calculate the energy required to form various dislocations in crystals.

7. **Optical Phenomena in Solids:** Color of Crystals; Weakly and Tightly Bound Excitons; Photoconductivity; Traps; Crystal Counters.

   Intended learning outcomes: Successful students should be able to:
   (i) Demonstrate the formation of colors in crystals.
   (ii) Calculate exciton energy while it propagates through a crystal.

Books Recommended

Text Books

Kittel, C	Introduction to Solid State Physics
Omar, MA	Elementary Solid State Physics
Dekker, AJ	Solid State Physics
Puri and Babar	Solid State Physics

Reference Books

Mckelvey, JP	Solid State and Semiconductor Physics
Ashcroft and Mermin, A	Solid State Physics
Azaroff, LV and Brophy, JJ	Electronic Processes in Materials
Singhal, RL	Solid State Physics
Sze, SM	Physics of Semiconductor Devices
Wert, CA and Thomson, RM	Physics of Solids
Wahab, MA	Solid State Physics
Islam, MS	Kathin Abasthar Padartha Vijnan (*in Bangla*)

PH306 ELECTRONICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisite: PH102.

Course Objectives and Summary: This course describes network circuit analysis, filters, electronic devices and their characteristics. This course also includes transistor amplifier, feedback and oscillator circuits, radio-wave propagation and the related devices.

1. **Circuit Analysis:** Superposition Theorem; Constant Voltage and Current Sources; their Conversions; Reduction of Complicated Networks-Equivalent Star and Delta Circuits, their Conversions; Thevenin's Theorem; Maximum Power Transfer Theorem; Norton's Theorem.

   Intended learning outcomes: Successful students should be able to:
   - **(i)** Demonstrate superposition theorem, Thevenin's Theorem, Maximum Power Transfer Theorem and Norton's Theorem.
   - **(ii)** Reduce Complicated Networks to equivalent star and delta Circuits.

2. **Wave Filters:** Symmetrical Networks; Characteristic Impedance, Propagation Constants; Filter Fundamentals: Pass and Stop Band; Constant-k Low Pass, High Pass, Band Pass and Band Elimination Filters; Introduction to m-derived Filters; Filter Design.

   Intended learning outcomes: Successful students should be able to:
   - **(i)** Design and construct filter.

- **(ii)** Demonstrate the function of high pass, band pass and band elimination filters.

3. **Electronic Devices:** Diode Applications: Rectifier and Power Supplies; Special Diodes: Zener, Photo, LED and LCD; Transistors: Transistor DC and AC Characteristics; Equivalent Circuits in h-Parameters; Special Transistors: UJT, SCR, Phototransistor; FET: Construction and Characteristics of JFET and MOSFET.

   Intended learning outcomes: Successful students should be able to:
   - **(i)** Demonstrate the operation and applications of Zener, Photo, LED and LCD diodes.
   - **(ii)** Describe the operation of transistor and its characteristics.
   - **(iii)** Demonstrate the Construction and Characteristics of JFET and MOSFET.

4. **Transistor Biasing and Thermal Stabilization:** Factors Contributing to Thermal Instability; Stability Factors; Fixed Bias; Collector-Base Bias; Self-Bias; Bias Compensations.

   Intended learning outcomes: Successful students should be able to:
   - **(i)** Establish the predetermined voltages or currents at various points of an electronic circuit for the purpose of establishing proper operating conditions in electronic components.
   - **(ii)** Construct the biasing circuits and describe their merits and demerits.

5. **Transistor Amplifiers:** Transistor CE, CB and CC Amplifiers; Cascading and Coupling; Class A, Class B, Class C and Push-Pull Amplifiers.

   Intended learning outcomes: Successful students should be able to:
   - **(i)** Demonstrate the use of a common emitter amplifier as a voltage amplifier.
   - **(ii)** Demonstrate the use of a common base (grounded-base) amplifier as a current buffer or voltage amplifier.
   - **(iii)** Demonstrate the use of a common collector amplifier as a voltage buffer.

6. **Feedback and Oscillator Circuits:** Feedback: Principles, Characteristics, Current and Voltage Feedback Amplifiers; Oscillator: Positive Feedback; Condition for Sustained Oscillation; Phase-Shift, Wein-Bridge, Hartley, Colpitt's and Crystal Oscillators.

   Intended learning outcomes: Successful students should be able to:
   - **(i)** Demonstrate the operation of feedback circuits.
   - **(ii)** Explain positive and negative feedback.
   - **(iii)** Describe the production of a periodic, oscillating electronic signal, often a sine wave or a square wave using oscillator.
   - **(iv)** Demonstrate the generation of sine waves of large range of frequencies.

(v) Describe the operation of a Colpitt's oscillator that use a combination of inductors and capacitors to produce an oscillation at a certain frequency.

7. **Radio Wave Propagation:** Modulation; Demodulation; Transmitter Circuits; A.M. Radio Receiver, Wave Propagation through Ionosphere; Antenna: Fundamentals, Types of Antenna and Arrays.

Intended learning outcomes: Successful students should be able to:

(i) Demonstrate the process of varying one or more properties of a periodic waveform, called the carrier signal.
(ii) Demonstrate the operation of AM radio receiver.
(iii) Describe Wave Propagation through Ionosphere.

<u>Books Recommended</u>

Text Books

Millman, J and Halkias, CC	Electronic Devices and Circuits
Boylestad, RL and Nashelsky, L	Electronic Devices and Circuit Theory
Ryder, J	Networks, Lines and Fields
Bhargav, NN et al	Basic Electronics and Linear Circuits
Theraja BL	Basic Electronics (Solid State)

Reference Books

Gupta, SL and Kumar, V	Hand Book of Electronics
Malvino, AP	Electronic Principles
Singh, A	Principles of Communications
Sharma, SP	Basic Radio and Television
Choudhury, GM	Electronics (*in Bangla*)
Mottershead, A	Electronic Devices and Circuits
Brophy, JJ	Basic Electronics for Scientists
Terman, R	Radio Electronics
Theraj, BL	Basic Electronics Solid State
MIT Staff	Transistors
Siskind, CS	Electrical Circuits
Arokh Singh	Electronic Communications
Theraja BL and Theraja AK	A Text Book of Electrical Technology

PH307 STATISTICAL MECHANICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: PH202, PH203, elementary statistics and probability theory, postulates of quantum mechanics.

Course Objectives and Summary: The course gives an introduction to statistical mechanics with an emphasis on applications. It discusses how probability theory can be used to derive relations between the microscopic and macroscopic properties of matter. The course is designed to enable the students to comprehend the important concepts of phase space, energy distributions in phase space, different ensembles, Maxwell-Boltzmann distributions, quantum statistics and their applications under variety of conditions.

1. **Classical Statistical Mechanics:** Statistical Mechanics: an Outline; Phase Space and Phase Trajectory; Volume in Phase Space; Specification of States of a System; Density of States and its General Behaviour; Liouville's Theorem and its Consequence; Postulates of Classical Statistical Mechanics; Stirling's Approximation; Thermodynamic Probability; Statistical Equilibrium; Macrostates and Microstates; Ensembles; Its Classification and Usage, Statistics and Thermodynamics; Entropy; Maxwell Velocity Distribution; Boltzmann Energy Distribution Function; Maxwell-Boltzmann Statistics and its Applications; Partition Functions and Thermodynamical Potentials; Principle of Equipartition of Energy.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Specify macroscopic systems in phase space.
   - **(ii)** Derive the Liouville's equation and explain its consequences.
   - **(iii)** Comprehend the postulates of statistical mechanics.
   - **(iv)** Calculate thermodynamical probability for classical particles.
   - **(v)** Relate thermodynamical probability to entropy.
   - **(vi)** Derive and apply Boltzmann distribution function.
   - **(vii)** Apply Maxwell-Boltzmann statistics to calculate velocities of the particles.
   - **(viii)** Classify different classical ensembles.
   - **(ix)** Apply partition function to obtain different thermodynamical parameters.

2. **Quantum Statistical Mechanics:** Pure and Mixed Quantum States; Postulates of Quantum Statistical Mechanics; Transition from Classical to Quantum Statistical Mechanics; Indistinguishability and Quantum Statistics; Exchange Symmetry of Wave Functions; Exchange Degeneracy; Average Value and Quantum Statistics; Statistics of various Quantum Mechanical Ensembles.

Intended learning outcomes: Enables successful students to:

(i) Understand and explain the postulates of quantum statistical mechanics.
(ii) Apply the concept of distinguishability on various systems of interest.
(iii) Explain the transition from classical to quantum statistical mechanics and vice versa.
(iv) Calculate ensemble average of a dynamical variable (operator).
(v) Construct symmetric and anti-symmetric wave functions.
(vi) Distinguish among various quantum mechanical ensembles and derive appropriate density operator.

3. **Fermi Systems:** Fermi-Dirac Distribution Function; Fermi Energy; Fermi Temperature; Fermi Velocity and Mean Velocity of a Free Electron in a Metal; Degenerate Fermi System; Landau Diamagnetism; Pauli Paramagnetism; Electronic Heat Capacity of Metals; Thermionic Emission; Photoelectric Current Density; Statistical Equilibrium in White Dwarfs.

Intended learning outcomes: Enables successful students to:

(i) Calculate thermodynamical probability for a system of fermions.
(ii) Derive Fermi-Dirac statistics (FDS).
(iii) Apply FDS to calculate average energy and total energy of system of fermions.
(iv) Determine Pauli spin susceptibility.
(v) Explain stability of compact stars.
(vi) Calculate thermionic and photoelectric current densities.

4. **Bose Systems:** Bose-Einstein Distribution Function; Applications: Photon Gas; Phonon Gas; Bose-Einstein Condensation; Superfluidity in Liquid He, Thermodynamics of Bose Systems. Thermodynamic Properties of Diatomic Molecules; Nuclear Spin Effects in Diatomic Molecules.

Intended learning outcomes: Enables successful students to:

(i) Calculate thermodynamical probability for a system of bosons.
(ii) Derive Bose-Einstein statistics (BES).
(iii) Apply BES to calculate energy densities for photons and phonons.
(iv) Calculate lattice specific of solids.
(v) Explain Bose-Einstein condensation (BEC) at qualitative and quantitative level.
(vi) Estimate BEC temperature.
(vii) Explain the basic features of diatomic molecules due to nuclear spin configuration.
(viii) Explain the origin of superfluidity.
(ix)

Books Recommended

Text Books

Pathria, RK	Statistical Physics
Huang, K	Statistical Mechanics
Reif, B	Fund. of Statistical and Thermal Physics
Gupta, SL et al.	Elementary Statistical Mechanics
Brijlal, L et al.	Thermal and Statistical Physics
Kardar, M	Statistical Mechanics of Particles

Reference Books

Berkeley Physics Course, V	Statistical Physics
Kittel, C and Kroemer, H	Thermal Physics
Stowe,K	Introduction to Statistical Mechanics
Pointon, AJ	Introduction to Statistical Physics
Singh, K et al.	Elements of Statistical Mechanics
Allis, WP and Herlin, MA	Thermodynamics and Statistical Mechanics
Riedl, PC	Thermal Physics
Saha, MN and Srivastava, BN	Treatise on Heat
Beiser, A	Concept of Modern Physics
Constant, FW	Theoretical Physics 2
Sears FW and Salinger, GL	Thermodynamics, Kinetic Theory & Statistical Mechanics
Agarwal, BK and Eisner, M	Statistical Mechanics

PH308 RELATIVITY (~ 40 *lectures*)

Course Type: Major *Credit Point: 02*

Full Marks: ***50*** (*Written Examination 40, In-course evaluation 7.5 and Attendance 2.5*)

(*4 questions to be answered out of 6 questions*) *Examination duration:* ***3*** *hours*

Prerequisites: PH101, PH105R, PH203.

Course Objectives and Summary: This course describes the relativistic coordinate transformations, mass-energy equivalence, relativistic kinematics, relativistic dynamics with applications to relativistic phenomena in mechanics and electromagnetism. The effects of gravity on space-time and gravitational waves are also described here.

1. **Background:** Space and Time in Newtonian Relativity; Inertial and Non-inertial Frames; Galilean Transformations; Electromagnetism and Newtonian Relativity; Absolute Frame; Michelson and Morley Experiment; Implication of Negative Result.

   Intended learning outcomes: Enables successful students to:

- **(i)** Differentiate between inertial and non-inertial frames.
- **(ii)** Demonstrate the Michelson and Morley Experiment and interpret its negative result.

2. **Relativistic Kinematics:** Postulates of Special Theory of Relativity; Relativity of Simultaneity; Synchronization of Clocks; Lorentz Transformations; Proper Frame, Proper Length and Proper Time; Twin Paradox; Relativistic Addition of Velocities; Some Applications of Special Theory of Relativity.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Explain the Postulates of Special Theory of Relativity.
   - **(ii)** Explain the Synchronization of Clocks.
   - **(iii)** Demonstrate Lorentz Transformations and explain time dilation, length contraction and twin paradox.

3. **Relativistic Dynamics:** Mechanics and Relativity; Relativistic Momentum and Force; Equivalence of Mass and Energy; Four Vectors; Transformation Properties of Momentum; Energy, Mass and Force; Relativistic Lagrangian and Hamiltonian.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Explain the Equivalence of Mass and Energy.
   - **(ii)** Use four vectors.
   - **(iii)** Study relativistic Lagrangian and Hamiltonian.

4. **Geometric Representation of Space-Time:** Minkowski Space; World Line; Space Time Interval; Geometrical Interpretation of Lorentz Transformation; Time Order and Space Separation of Events.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Demonstrate the Minkowski Space.
   - **(ii)** Explain the world line, space-time interval and causality.

5. **Relativity and Electromagnetism:** Magnetism as a Relativistic Phenomenon; Transformation of **E** and **B** Field Tensors; Invariance of Maxwell's Field Equations.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Describe magnetism as a relativistic phenomenon.
   - **(ii)** Show the invariance of Maxwell's field equations.

6. **General Relativity:** Principle of General Covariance; Principle of Equivalence; Inertial and Gravitational Mass; Bending of Light in Gravitational Field; Gravitational Red Shift; Mach's Principle; Correspondence Principle; Geodesic Equation; Einstein Field Equation; Gravitational Interferometry and Gravitational Wave Detection.

   Intended learning outcomes: Enables successful students to:

(i) Demonstrate the principle of covariance and equivalence.
(ii) Explain the bending of light in gravitational field.
(iii) Demonstrate gravitational red shift.
(iv) Derive Einstein's field equation.

Books Recommended

Text Books

d'Inverno, R	Introducing Einstein's Relativity
Resnick, R	Introduction to Special Relativity
Prakash, S	Relativistic Mechanics
Beiser, A	Concepts of Modern Physics
Hartle, JB	Gravity: An Introduction to Einstein's General Relativity

Reference Books

Einstein, A	Relativity- The Special and General Theory
Bergmann, PG	Introduction to the Theory of Relativity
Griffiths, DJ	Introduction to Electrodynamics
Islam, JN	Introduction to Mathematical Cosmology
Fock, V	The Theory of Space, Time and Gravitation
Gamow, G	Gravitation
Rindler, W	Relativity: Special, General and Cosmological
Taylor, EF and Wheeler, JA	Spacetime Physics: Introduction to Special Relativity

PH310 PHYSICS PRACTICAL

Course Type: Major *Credit Point: 10*

Full Marks: **250** (*Continuous Assessment 75 marks, Practical Examination 175 marks*)
(*4 days for Experiments and 1 day for Defense on Experiments*)

Examination duration: (**6+6+6+6+6**) *hours*

Prerequisites: PH109, PH209

List of Experiments

1. Study of Photoelectric Effect.

Learning outcomes: Successful students should be able to:
(i) Explain the phenomenon of photoelectric effect in detail.
(ii) Calculate the stopping potential for a given frequency.
(iii) Understand the effect of intensity of the incident radiation on the photocurrent.

2. Determination of e/m of an Electron.

Learning outcomes: Successful students should be able to:
- **(i)** Explain the trajectory of electrons under applied magnetic field.
- **(ii)** Calculate the specific charge of an electron.

3. Determination of the Plateau and Operating Voltage of a Geiger-Muller Counter.

Learning outcomes: Successful students should be able to:
- **(i)** Characterize any Geiger-Müller Counter in terms of its plateau length, plateau slope and operating voltage.

4. Absorption of Gamma Rays in Lead.

Learning outcomes: Successful students should be able to:
- **(i)** Investigate the absorption of gamma rays in matter, calculate the half-value thickness and absorption coefficient.

5. Calibration of an Electromagnet by an Exploring Coil.

Learning outcomes: Successful students should be able to:
- **(i)** Calibrate an electromagnet with the help of a ballistic galvanometer.
- **(ii)** Understand the factors affecting the magnetic field intensity at a point within the poles.
- **(iii)** Narrate how the law of electromagnetic induction and Lenz's law work in this experiment.

6. Construction and Study of a Low-pass Filter.

Learning outcomes: Successful students should be able to:
- **(i)** Design and construct a low-pass filter.
- **(ii)** Calculate the filter parameters.

7. Construction and Study of a High-pass Filter.

Learning outcomes: Successful students should be able to:
- **(i)** Design and construct a high-pass filter.
- **(ii)** Calculate the filter parameters.

8. Construction of Full-wave Bridge Rectifier using Semiconductor Diodes and Study the Effect of Filters.

Learning outcomes: Successful students should be able to:
- **(i)** Understand the concept of rectification.
- **(ii)** Construct a low voltage power-supply unit.

9. To draw the Characteristic Curves and DC Load Line for a CE Transistor and Determination of Hybrid Parameters.

Learning outcomes: Successful students should be able to:

(i) Identify the terminals and type of a transistor.
(ii) Determine the input and output characteristics of a CE transistor.
(iii) Draw the theoretical dc load line from the output characteristic curve.
(iv) Calculate the hybrid parameters.
(v) Understand the theoretical and experimental load lines.
(vi) Determine the operating points.

10. Characteristics of a FET and Determination of its Parameters.

Learning outcomes: Successful students should be able to:
(i) Study the characteristics of FET ($I_D \sim V_{DS}$ and $I_D \sim V_{GS}$ curves).
(ii) Calculate the FET parameters (amplification factor, drain resistance and mutual conductance).

11. Construction and Study of the Frequency Response Curves of a Single-Stage AF Amplifier with and without Feedback.

Learning outcomes: Successful students should be able to:
(i) Design and Construct a single stage AF amplifier with and without feedback.
(ii) Know the potential divider biasing method.
(iii) Know how to plot wide range of data on a semi-log graph paper and observe frequency responses of amplification circuits.
(iv) Calculate cut-off frequency and band-width of the designed amplifier.
(v) Effect of negative feedback on gain and bandwidth.

12. Construction and Study of a Phase Shift Oscillator.

Learning outcomes: Successful students should be able to:
(i) Understand the operation of a Phase Shift Oscillator.
(ii) Discuss how oscillations are initiated at first.
(iii) Explain necessary and sufficient conditions required to generate the sustainable oscillations.
(iv) Describe how to select frequency component of oscillator.
(v) Know relevant formula for the frequency of oscillation.
(vi) Compute the frequency of oscillation from component values.

13. Construction of a Transistor Radio Receiver.

Learning outcomes: Successful students should be able to:
(i) Understand the basic function and characteristics of a radio receiver.
(ii) Draw a block diagram of a simple Radio receiver and explain the function of each block.
(iii) Draw the circuit diagram and analyze the function of each component.
(iv) Construct the circuit and test receiving signals transmitted by the local radio broadcasting center.

14. Construction of a Transistor Radio Transmitter.

Learning outcomes: Successful students should be able to:

(i) Understand AM and FM signals.
(ii) Draw the circuit and analyze the function of each component.
(iii) Construct the circuit and test its performance using a commercial radio receiver set.

Computational Physics Lab

1. Solution of Polynomial Equations (Newton-Raphson method)
2. Linear Least Squares Fitting
3. Polynomial Interpolation (Newton's forward difference formula)
4. Numerical Integration (Trapezoidal and Simpson's methods)
5. Numerical Differentiation

Books Recommended

Text Books

Chowdhury, SA and Basak, AK	Byaboharik Padarthavidya (*in Bangla*)
Tyler, F	Laboratory Manual of Physics
Worsnop, BL and Flint, HT	Advanced Practical Physics
Bar, Z and Malvino, AP	A Text Lab. Manual: Basic Electronics
Tout, E & Jansen, GJ	Practical Structure Determination

PH401 QUANTUM MECHANICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: PH302, PH307, PH308, Basic matrix algebra.

Course Objectives and Summary: This is an advanced quantum mechanics course. This course will equip the students with the tools of matrix formulation of quantum mechanics and a thorough understanding of the role of operators in the Hilbert space for problem solving. The importance of the transformation theory has been highlighted. It also contains an extended section on applications to quantum mechanical problems in terms of various approximation methods, and another section on scattering theory. An introduction to relativistic quantum mechanics is also included.

1. **Matrix Formulation of Quantum Mechanics:** State Vectors in Hilbert Space; Bra and Ket Notations; Operators and their Representation; Unitary Transformations; Schrödinger, Heisenberg and Dirac Representations; Parity Operators and Conservation of Parity, Harmonic Oscillator.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Explain the concept of state vectors in Hilbert space.
   - **(ii)** Construct matrix elements of an operator.
   - **(iii)** Transform different representations by using unitary operators.
   - **(iv)** Calculate the density matrix of a system.
   - **(v)** Solve one-dimensional harmonic oscillator problem using matrix formalism.
   - **(vi)** Derive equation of motion for various operators.
   - **(vii)** Explain parity and its conservation.

2. **Theory of Angular Momentum:** Eigenvalues of Angular Momentum; Addition of Angular Momenta; Clebsch-Gordon Coefficients; Pauli's Exclusion Principle and Spin Matrices.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Calculate commutator brackets for different angular momenta operators.
   - **(ii)** Employ ladder operators to obtain off-diagonal angular momenta matrices.
   - **(iii)** Obtain Pauli spin matrices.
   - **(iv)** Understand the necessity of Clebsch-Gordon coefficients and their selection rules.
   - **(v)** Visualize the coupling of spin system using Clebsch-Gordon coefficients.

3. **Theory of Scattering:** Scattering Cross-section; Partial Wave Analysis; Applications to Scattering by Square Well Hard Sphere and Coulomb Potential;

Resonance Scattering; Optical Theorem; Born Approximation; Validity Criterion; Applications of Green's Function Technique; Examples.

Intended learning outcomes: Enables successful students to:

- **(i)** Calculate scattering cross-sections for simple potentials.
- **(ii)** Derive and apply the Born formula for the scattering amplitude.
- **(iii)** Identify cases where the partial wave and Born approximation are applicable.

4. Approximate Methods:

- **a)** Stationary Perturbation Theory: Nondegenerate Case; First-Order Perturbation; Second-Order Perturbation; Degenerate Case.
- **b)** Variational Method: Expectation Value of Energy; Application to Excited States; Linear Variation Function; Applications to Harmonic Oscillator; Hydrogen Atom and Helium Atom.
- **c)** WKB Approximation: Classical Limit; Approximate Solutions and Asymptotic Nature of Solutions; Validity Criterion; Solutions near a Turning Point; Connection Formulae; Application to Bound States.
- d) Time-dependent Perturbation Theory: Principle of the Method; Constant and Harmonic Perturbations; Fermi's Golden Rule; Radiative and Dipole Transitions; Selection Rules.

Intended learning outcomes: Enables successful students to:

- **(i)** Choose an appropriate method from perturbation theory, variational method and WKB approximation for a problem.
- **(ii)** Solve problems for energies and wave functions up to first order (second order for energies) in perturbation theory.
- **(iii)** Choose suitable trial functions and obtain ground state energies using the variational method.
- **(iv)** Use the WKB approximation and obtain quantization condition on energy/momentum for bound systems.
- **(v)** Calculate transition rates up to first (or second) order.

5. Relativistic Wave Equations: Klein-Gordon and Dirac's Relativistic Wave Equation; Solution of Free Particle Equations; Equation of Continuity and its Consequences; Negative Energy States and Hole Theory; Spin-Orbit Interaction.

Intended learning outcomes: Enables successful students to:

- **(i)** Solve Klein-Gordon equation.
- **(ii)** Solve Dirac free particle equation.
- **(iii)** Obtain Dirac matrices.
- **(iv)** Understand Dirac's hole theory and the concept of antiparticles.

Books Recommended

Text Books

Schiff, LI	Quantum Mechanics
Merzbacher, E	Quantum Mechanics
Griffiths, DJ	Introduction to Quantum Mechanics
Mathews, PM and Venkatesan, K	Text Book of Quantum Mechanics
Bransden, BH and Joachain, CJ	Quantum Mechanics

Reference Books

Blokhintsev, DI	Fundamentals of Quantum Mechanics
Brink, DM and Satchler, GR	Angular Momentum
Bhuiyan, GM	Quantum Mechanics
Dirac, PAM	Principles of Quantum Mechanic
Edmonds, AR	Angular Momentum in Quantum Mechanics
Goldberger, ML and Watson, KM	Collision Theory
Golder, S	Quantum Balobidya (Bengali)
Landau, LD and Lifshitz, EM	Quantum Mechanics
Messiah, A	Quantum Mechanics
Pauling, L and Wilson, EB	Introduction to Quantum Mechanics
Powell, JL and Crasemann, B	Quantum Mechanics
Rashid, AMH	Quantum Mechanics
Ziock, C	Basic Quantum Mechanics
Sakurai, JJ	Modern Quantum Mechanics
Shankar, R	Principles of Quantum Mechanics
Cohen-Tannoudji,C, et al.	Quantum Mechanics (Vols. I and II)

PH402 PULSE AND DIGITAL ELECTRONICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: PH207R, PH306.

Course Objectives and Summary: In-depth study of pulse processing especially needed in data conversions and storage in computing systems is presented in this course. The course provides the concepts, working principles and key applications of digital electronic circuits.

1. **Pulse Shaping:** Pulse Parameters; Linear Waveshaping: RC Integrator and RC Differentiator; Non-linear Waveshaping: Clipping and Clamping.

   Intended learning outcomes: Enables successful students to:

- **(i)** Characterize a given pulse using the concept of various pulse parameters, e.g. Pulse width, rise time, fall time etc.
- **(ii)** Design integrator and differentiator circuits for practical applications.
- **(iii)** Solve non-linear wave-shaping problems.
- **(iv)** Construct clipping and clamping circuits for specific needs.

2. **Pulse Generators:** Multivibrators: Astable, Monostable and Bistable, Schmitt Trigger, Blocking Oscillators and Time-Base Generators.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Explain the functioning and utility of various multivibrators.
   - **(ii)** Design and construct different multivibrators for specific needs.
   - **(iii)** Design and construct Schmitt trigger, blocking oscillators, and time-base generators.

3. **Fabrication of IC and Operational amplifiers:** Fabrication of Integrated Circuits; Basic Principles of Operational Amplifiers; Inverting and Non-inverting Amplifier; Operational Amplifier: Summer, Subtractor, Integrator, Differentiator and Active Filters.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Describe how ICs are fabricated.
   - **(ii)** Explain in detail the working principle of OP amps.
   - **(iii)** Design and construct summer, subtractor, integrator, differentiator, and active filter ckts.

4. **Combinational Logic Circuits:** OR, AND, NOT, NOR and NAND Operations; Laws of Boolean Algebra; De-Morgan's Theorems; Truth Tables and Maps.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Perform Boolean algebra.
   - **(ii)** Design and construct logic gate ckts.
   - **(iii)** Understand De-Morgan's theorem and construct truth-tables.

5. **Data Conversion:** Decoder, Encoder, Multiplexer, Demultiplexer, Code Converter, Analog-Digital Conversion (ADC) and Digital-Analog Conversion (DAC); Digital Multimeters.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Explain the functions and constructions of all these data conversion systems.
   - **(ii)** Explain the functions and constructions of digital multimeters.

6. **Sequential Logic Circuits:** Flip-flops: NAND Gate Latch; NOR Gate Latch; R-S Flip-flop; D Flip-flop; J-K Flip-flop; Master/Slave Flip-flop; T Flip-flop.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Explain the functions and constructions of NAND and NOR gate latches.
   - **(ii)** Explain the functions and constructions of all these flip-flops.

7. **Counters:** Synchronous and Asynchronous Counters; Up-Down Counters; Shift-Register and Frequency Counters; Digital Clock.

   Intended learning outcomes: Enables successful students to:
   (i) Explain the functions and constructions of various counters.
   (ii) Explain the functions and constructions digital clock.

8. **Memory Elements:** RAM, ROM, EPROM, Static and Dynamic Access Memories; Magnetic Disk; MRAM.

   Intended learning outcomes: Enables successful students to:
   (i) Explain the functions and constructions of various memory elements.
   (ii) Explain digital recording techniques.

<u>Books Recommended</u>

Text Books

Millman, J and Taub, H	Pulse, Digital and Switching Waveforms
Tocci, RJ	Digital System Principles & Applications
Mottershead, A	Electronic Devices and Circuits: An Introduction
Blitzer, R	Introduction to Pulse Shaping Circuits
Faulken, B	An Intro. To Op-Amplifiers with Linear Applications

Reference Books

Malvino, AP	Electronic Principles
Millman, J and Halkias, CC	Integrated Electronics: Analog. and Digital Circuits & Systems
Gothman, WH	Digital Electronics: an Intro. To Theory and Practice
Bartee, T	Digital Computer Fundamentals
Taub, H and Schilling, DL	Digital Integrated Circuits
Malvino, AP and Leach, R	Digital Principles and Applications

PH403 NUCLEAR AND PARTICLE PHYSICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered taking 3 from Section A and 2 from Section B*)

Examination duration: ***4*** *hours*

Prerequisites: PH303, PH304.

Course Objectives and Summary: This course aims to provide the concepts of nuclear physics focusing on characteristics of nuclear two-body interaction, nuclear models and nuclear reaction mechanisms. The course also includes introductory discussion on elementary particles, their fundamental interactions and an outline of the standard model of particle physics.

Section A: Nuclear Physics (5 questions to be set)

1. **Nuclear Two-body Systems and Nuclear Forces:** Ground State of Deuteron; Normalization of Deuteron Wave Function; Non-existence of Excited States of Deuteron; Tensor Force; Low-Energy n-p Scattering; Determination of Phase Shift; Spin Dependence; Scattering Length; Effective Range Theory.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Apply quantum mechanics to calculate properties of two-body bound nuclear system, namely deuteron.
   - **(ii)** Identify consequences of the non-central features of nuclear force.
   - **(iii)** Calculate phase-shifts and scattering cross-sections for low-energy n-p scattering.
   - **(iv)** Apply the concept of scattering length to n-p scattering.
   - **(v)** Describe n-p scattering in terms of the effective range theory.

2. **Nuclear Models:**
   - **a)** Fermi Gas Model: Fermi Momentum; Average Energy of Nucleons in Nuclear Matter.
   - **b)** Nuclear Shell Model: Single Particle Potentials; Spin-Orbit Potential; Magic Numbers; Shell Model Predictions; Ground Stare Spins; Spin and Magnetic Moments of Nuclei; Schmidt Curves.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Understand the salient features of different models to explain the basic nuclear properties.
   - **(ii)** Predict angular momentum, parity, and magnetic dipole moment of nuclei, on the basis of single-particle configurations.
   - **(iii)** Calculate average energy of nucleon in nuclear matter.

3. **Nuclear Scattering and Reactions:** Optical Model: Complex Potential; Energy Averaged Cross-sections; Phenomenological Optical Model Cross-sections by Method of Partial Waves; Compound Nuclear Reactions; Continuum Theory; Resonance; Breit-Wigner Dispersion Formula for $l = 0$.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Employ optical model to calculate nuclear reaction cross-sections.
   - **(ii)** Compare and contrast among different reaction mechanisms in relation to cross-sections, excitation functions, and angular-distributions.
   - **(iii)** Comprehend the compound nuclear reaction and calculate the Q-values of reactions.

Section B: Particle Physics (3 questions to be set)

4. **Elementary Particles I:** Fundamental Interactions; Electromagnetic, Weak and Strong Couplings; Classification of Elementary Particles; Conservation Laws; Quantum Numbers; CPT Theorem; CP Violation in Kaons; Parity Violation in β Decay.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Identify the basic features of different fundamental interactions.
   - **(ii)** Apply conservation principles to different interactions.
   - **(iii)** Describe parity and CP violation and their consequences.

5. **Elementary Particles II:** Spectrum and Interactions of Known Particles; Conservation or Violation of Isospin; Strangeness and Charm in Particle Interactions; Hadron Spectroscopy and Resonances; SU(3) Flavour Classification of Lightest Hadrons; Introduction to Standard Model and Ideas of Unification; Neutrino Masses.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Classify elementary particles by their possible interactions.
   - **(ii)** Apply conservation laws to different processes.
   - **(iii)** Understand basic features of standard model of particle physics.
   - **(iv)** Use the quark model in case of light hadrons.
   - **(v)** Explain the $SU(3)_{flavour}$ symmetry.

<u>Books Recommended</u>

Text Books

Enge, HA	Introduction to Nuclear Physics
Roy, RR and Nigam, BP	Nuclear Physics
Griffiths, D	Introduction to Elementary Particles
Burcham, WE and Jobes, M	Nuclear and Particle Physics

Reference Books

Sen Gupta, HM	Nucleo Padarthavidya (*in Bangla*)
Islam, GS	Paramanobik ebong Nucleo Padarthavijnan, Vol 1
Ghoshal, SN	Nuclear Physics
Segre, E	Nuclei and Particles
Cohen, BL	Concept of Nuclear Physics
Blatt, JM and Weiskopff, VF	Theoretical Nuclear Physics
Elton, LRB	Introductory Nuclear Theory
Heyde, K	Basic Ideas and Concepts in Nuclear Physics
Halzen, F and Martin, AD	Quarks and Leptons: An Introduction with Application
Perkins, DH	Introduction to High Energy Physics
Lichtenberg, DB	Unitary Symmetry and Elementary Particles

PH404 SOLID STATE PHYSICS AND MATERIALS SCIENCE (~75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisite: PH305.

Course Objectives and Summary: This course explains the concepts that are used to describe the structure and physical properties of solids and uses physical models to perform calculations of the application related physical phenomena. This course includes description of electronic structure, structural and physical properties of metals, semiconductors, dielectrics, magnetic materials and superconductors based on the classical and quantum physics principles. An overview of the engineering materials and their elastic properties are also discussed.

1. **Dielectric Properties:** Macroscopic Electric Field; Local Electric Field at an Atom; Dielectric Constants and Polarizabilities; Clausius-Mossotti Relation; Dielectric Phenomena in an AC Field; Debye Equations for Dielectric Constant and Dielectric Loss; Dielectric Response of an Electron Gas - Concept of Plasmon and Calculation of Plasma Frequency; Screened Coulomb Potential; Motion in Magnetic Fields; Ferroelectrics.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Calculate dielectric constants and polarizabilities.
   - **(ii)** Derive Debye equations for dielectric constants.
   - **(iii)** Derive expression for screened Coulomb potential.
   - **(iv)** Understand the concept of plasmon and calculate the plasma frequency.
   - **(v)** Describe the motion of charge particles in magnetic field and apply that for the case of Hall effect.
   - **(vi)** Explain the main features of ferroelectricity.

2. **Magnetism:** Types of Magnetism and their Origins; Langevin Equation for Dia- and Paramagnetism; Curie Law; Quantum Theory of Paramagnetism; Hund's Rules; Quenching of Orbital Angular Momentum; Ferromagnetism; Weiss Molecular Field and Exchange Integral; Magnetic Domain and Bloch Wall; Antiferromagnetism; Neel's Theory; Two Sublattice Model; Ferrimagnetism and Structure of Ferrites and Garnets; Uses of Various Magnetic Materials; Magnetic Anisotropy, Magnetic Resonance.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Explain the physical origins of different types of magnetism.
   - **(ii)** Calculate the diamagnetic susceptibility.
   - **(iii)** Apply Hund's rules to calculate effective number of Bohr magnetons.
   - **(iv)** Derive expressions for paramagnetic susceptibilities.
   - **(v)** Explain the magnetic domain dynamics.
   - **(vi)** Derive expression for Neel temperature.

(vii) Explain the magnetic properties of ferrites and garnets and identify their scope of applications.
(viii) Explain magnetic resonance, describe the arrangement for NMR measurement, and understand its utility.

3. **Superconductivity:** Basic Properties of Superconductors; Meissner Effect; Type I and Type II Materials; Thermal and Electromagnetic Properties of Superconductors; Elementary Idea of BCS Theory.

Intended learning outcomes: Enables successful students to:
(i) Understand the basic features of superconductivity.
(ii) Classify superconductors according to their magnetic response.
(iii) Explain thermal and electromagnetic properties of superconductors.
(iv) Explain the ideas behind BCS theory.

4. **Engineering Materials:** Classification of Engineering Materials; Structures and Properties of Non-metallic Materials; Portland Cement; Ceramics; Polymers; Refractories; Glassy-metals and Glass Ceramics; Cermet.

Intended learning outcomes: Enables successful students to:
(i) Classify different engineering materials.
(ii) Describe composition and structural features of engineering materials.
(iii) Design engineering material for specific needs.
(iv) Describe essential features of glass ceramics and identify their areas of application.

5. **Elastic Properties and Hardness of Materials:** Elastic Constants and Moduli of Elasticity; Elastic Waves; Elastic and Plastic Deformations; Creep; Fatigue; Hardness Testing; Hardness Scales.

Intended learning outcomes: Enables successful students to:
(i) Derive expressions for elastic constants and elastic moduli.
(ii) Solve equation for elastic wave.
(iii) Explain various forms of elastic and plastic deformations.
(iv) Describe the arrangement for hardness testing.
(v) Apply the understanding of elastic properties to practical situations.

6. **Liquid Crystals:** Structure and Classifications of Different Phases; Orientation Order; Electric and Magnetic Effects; Optical Properties; Introduction to Theories of Liquid Crystalline Phases; Practical Applications.

Intended learning outcomes: Enables successful students to:
(i) Classify different types of order in liquid crystals.
(ii) Comprehend the idea of order parameter.
(iii) Explain the magnetic and optical effects.
(iv) Learn how liquid crystals are used for display technology.

7. **Nanostructures and Nanomaterials:** Nanostructures- Physics of Nanostructure; Different forms of Nanostructures; Idea of 2D, 1D and 0D Nanostructures; Quantum Dots; 2D Electron Gas in Square Well; Density of States and Dimensionality; Surface Electron Density; Quantum Size Effect; Electron Confinement-Strong and Weak Limit; Electronic Properties of Graphene and Amorphous Silicon; Experimental Techniques for Nanostructure Characterization.

Intended learning outcomes: Enables successful students to:

- **(i)** Understand different degrees of confinement of nanostructures.
- **(ii)** Calculate energy density of states for one-, two- and three-dimensions.
- **(iii)** Explain quantum size effect.
- **(iv)** Explain surface effects.
- **(v)** Describe electronic properties of grapheme and amorphous silicon and their relevance to practical applications.
- **(vi)** Describe different methods of nanostructure characterization.

Books Recommended

Text Books

Kittel, C	Introduction to Solid State Physics
Dekker, AJ	Solid State Physics
Omar, MA	Elementary Solid State Physics
Rangawala, SC	Engineering Materials
Brailsford, F	Physical Principle of Magnetism
Chikazumi, S	Physics of Magnetism
Duart, M, Palma, M and Rueda, A	Nanotechnology for Microelectronics and Optoelectronics

Reference Books

Pascoe, KJ	Intro. To the Properties of Engineering Materials
Van Vleck, LH	Materials Science for Engineers
Smith, WH	Principles of Materials Science and Engineering
Kresin, VZ and Wolf, SA	Fundamentals of Superconductivity
Wahab, MA	Solid State Physics
Kochelap, M and Stroscio	Quantum Heterostructures: Microelectronics and Optoelectronics
Yariv, A	Quantum Electronics
Bhattacharyya, P	Semiconductor Optoelectronics Devices
Rogers, Pennathur, Adams	Nanotechnology: Understanding Small Systems
Wert, CA and Thomson, RM	Physics of Solids

PH405 MEDICAL AND RADIATION PHYSICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisites: PH 304, SSC/HSC level biology.

Course Objectives and Summary: This course is aimed to illustrate the applications of physics to the various techniques of medical imaging. This course also provides the fundamental concept of radiation dosimetry, nuclear medicine, biological effects of radiation, radiation protection and radiotherapy for cancer treatment.

1. **Physics of Cardiovascular and Nervous System:** Physics of Cardiovascular System: Work done by Heart, Blood Pressure, Bernoullis Principle Applied to Cardiovascular System; Electricity within Body; Electrical Potential of Nerves, Electromyogram, Electrocardiogram.

   Intended learning outcomes: Enables successful students to:
   (i) Identify and describe the structures and the functions of heart, brain, lungs, spinal cord, neuron etc.
   (ii) Explain the physiology of these physical systems.

2. **Introduction to Modern Imaging Techniques:** Gamma Cameras; Computed Tomography (CT); SPECT; PET; Magnetic Resonance Imaging (MRI); Ultrasonography.

   Intended learning outcomes: Enables successful students to:
   (i) Explain the working principles of modern imaging techniques.
   (ii) Have working knowledge about the scope of applications of these imaging devices.

3. **Nuclear Medicine & Radiation Therapy:** Principle of Nuclear Medicine; Radioisotope Production; Choice of Radionuclide and Radiopharmaceuticals; Imaging and Function Test of Thyroid Gland, Liver, Spleen, Kidney, Lungs, Brain, Heart and Bone; Introduction to Teletherapy and Brachytherapy.

   Intended learning outcomes: Enables successful students to:
   (i) Describe the process of radioisotope production.
   (ii) Select the appropriate radionuclide and radiopharmaceuticals for treatment of a specific disease.
   (iii) Perform imaging and function test for various organs inside a human body.
   (iv) Plan a radiotherapy treatment.
   (v) Understand and implement teletherapy and brachyatherapy.

4. **Nuclear Analytical Techniques:** Scintillation and Semiconductor Detectors; Photon Induced X-ray Emission (XRF); Particle Induced X-ray Emission; Proton

Induced Gamma-ray Emission; Neutron/Proton Activation Analysis; Neutron Capture Prompt Gamma-ray Analysis.

Intended learning outcomes: Enables successful students to:

- **(i)** Detect radiation by using different detectors.
- **(ii)** Calculate radiation level.
- **(iii)** Comprehend the functions of different detectors.
- **(iv)** Explain the principles of neutron/proton activation analysis.

5. **Radiation Dosimetry:** Radiation Units; Absorbed Dose; Exposure; Absorbed Dose Measurement: Bragg-Gray Principle, Kerma, Internally Deposited Radioisotope; Calculations of Dose Rate from a Point and Distributed Sources.

Intended learning outcomes: Enables successful students to:

- **(i)** Convert among different radiation units.
- **(ii)** Calculate radiation exposure, absorbed dose for different source strength and geometry.
- **(iii)** Calculate internal deposition of radioisotope.
- **(iv)** Explain and employ Bragg-Gray principle.

6. **Biological Effects of Radiation:** Dose Response Characteristics; RBE; REM; Sievert; QF; Direct and Indirect Action; Chemical Changes; Changes of Biological Molecules; Acute, Delayed and Genetic Effects.

Intended learning outcomes: Enables successful students to:

- **(i)** Estimate dose-response characteristics.
- **(ii)** Explain direct and indirect action.
- **(iii)** Describe the changes in biological molecules due to radiation.
- **(iv)** Describe the effect of radiation on genes.

7. **Radiation Protection:** Principle of Radiation Protection; Exposure of Individuals in General Public; Maximum Permissible Dose.
   - **a) External:** Techniques of External Radiation Protection Shielding; Primary Protective and Secondary Protective Barrier; Charged Particle and Neutron Shielding.
   - **b) Internal:** Internal Radiation Hazard; Principle of Control; Control of Source; Environmental Monitoring and Control; Protective Clothing; Respiratory Protection; Waste Management.

Intended learning outcomes: Enables successful students to:

- **(i)** Understand maximum permissible dose.
- **(ii)** Design radiation shielding arrangement.
- **(iii)** Design a nuclear waste management system.

Books Recommended

Text Books

Cameron, JR and Skofronick, JG	Medical Physics
Hende, WR	Medical Radiation Physics
Johns, HE and Cunningham, JR	Physics of Radiology
Cember, H	Introduction to Health Physics

Reference Books

Sprawls, P	Physical Principles of Medical Imaging
Pedrose de Lima, JJ	Nuclear Medicine and Mathematics
Cesareo, R	Nuclear Analytical Techniques in Medicine
Turner, M	Principle of Radiation and Protection
Knoll, GF	Radiation Detection and Measurements
Price, WJ	Nuclear Radiation Detection
Glasstone, S	Source Book on Atomic Energy

PH406 CRYSTALLOGRAPHY AND X-RAY SPECTROSCOPY (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisite: PH305.

Course objectives and summary: X-ray diffraction crystallography is well established and widely used in the field of materials characterization to obtain information on the atomic scale. Various diffraction methods play important role in this regard. Systematic absences and intensity statistics give information about the atomic arrangement and symmetry elements present in the unit cell. Symmetry elements help to determine space group of the crystalline sample. Physical processes of x-ray absorption are also used to extract structural and compositional information. All these topics are used to elucidate structure of the crystalline materials.

1. **Geometry of Crystalline State:** Crystal Symmetry; Point Group and Space Group; Reciprocal Lattice.

   Intended learning outcomes: Enables successful students to:
   (i) Classify different crystal systems according to their symmetry.
   (ii) Draw Brillouin zones in reciprocal space for different crystal structures.

2. **Scattering of X-rays:** Scattering of X-Rays from a Single Electron; Scattering of X-Rays by a Pair of Electrons; Scattering of X-Rays by Gases.

   Intended learning outcomes: Enables successful students to:
   (i) Explain the phenomenon of X-ray scattering by electrons.
   (ii) Calculate the X-ray scattering amplitude.

3. **Diffraction by Crystals:** Diffraction of X-Rays by Crystals; Laue and Bragg's Equation; Structure Factor.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Establish Bragg and Lau conditions for X-ray diffraction.
   - **(ii)** Establish inequality relation to show why the white light is not diffracted when it falls upon a material.
   - **(iii)** Employ these equations to determine crystal structure.
   - **(iv)** Calculate the structure factor for different crystal systems.

4. **Experimental Collection of Diffraction Data:** Powder Method; Laue; Oscillation/Rotation; Weissenberg Methods of Collection of Data; Interpretation of Diffraction Photographs.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Understand and explain the experimental arrangements to obtain X-ray diffraction spectra.
   - **(ii)** Interpret diffraction patterns to elucidate underlying crystal structure, e.g. Inter planer spacing, identification of phases, Miller indices etc.

5. **Determination of Space Groups:** Symmetry of X-Ray Photographs; Systematic Absences; Intensity Statistics.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Understand symmetry of X-ray pattern.
   - **(ii)** Identify and explain systematic absences.
   - **(iii)** Explain intensity statistics.

6. **Physical Processes of X-ray Absorption:** X-ray Absorption Edge; Chemical Shifts of Absorption Edge; X-Ray Absorption near Edge Structure; Extended X-Ray Absorption Fine Structure: Applications of XANES and EXAFS.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Explain the origin of X-ray absorption edge.
   - **(ii)** Extract structural and compositional information from chemical shifts.
   - **(iii)** Interpret XANES and EXAFS profiles.

<u>Books Recommended</u>

Text Books

Woolfson, MM	Introduction to X-ray Crystallography
Azaroff, L	Elementary X-ray Crystallography
Woolfson, MM	Direct Methods in Crystallography
Buerger, MJ	Introduction to X-ray Crystallography

Reference Books

Lipton, H and Cochran, W	Crystalline State, Vol. III
Stout, GH and Jensen, LH	Practical Structure Determination

Cullity, BD	Elements of X-ray Crystallography
Agarwal, BK	X-ray Spectroscopy
Bonnele, C and Mande, C	Advances in X-ray Spectroscopy
Compton, AH and Allison, SK	X-ray in theory and Experiment
Buerger, MJ	Vector Space
Buerger, MJ	Crystal Structure Analysis

PH407 REACTOR PHYSICS (~ 75 *lectures*)

Course Type: Major *Credit Point: 04*

Full Marks: ***100*** (*Written Examination 80, In-course evaluation 15 and Attendance 5*)

(*5 questions to be answered out of 8 questions*) *Examination duration:* ***4*** *hours*

Prerequisite: PH304.

Course Objective and Summary: This course deals with nuclear reactions involving thermal and fast neutrons. Reactor fuel, reactor theory, reactor control and energy removal from the core of the reactor system are also discussed in this course.

1. **Neutron Reactions:** Interaction of Neutrons with Matter; Neutron Cross-section and its Determination; Yields and Mass Distribution; Energy Dependence of Neutron Cross-section; Fission Cross-section.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Calculate the energy dependent neutron reaction cross-section.
   - **(ii)** Explain the fission process.
   - **(iii)** Estimate the energy yield in a fission reaction.

2. **Diffusion and Slowing Down of Neutrons:** Thermal Neutron Diffusion; Diffusion Equations; Fast Neutron Diffusion and Fermi Age Equation; Energy Distribution and Cross-section of Thermal Neutrons; Slowing down of Neutrons; One Group Critical Equation and Reaction Buckling.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Deduce neutron diffusion equation and obtain the solutions.
   - **(ii)** Solve and understand Fermi age equation.
   - **(iii)** Calculate the neutron flux distribution in a nuclear reactor.
   - **(iv)** Describe neutron slowing down process in a reactor.
   - **(v)** Calculate the required multiplication factor to keep a reactor critical.

3. **Reactor Theory:** Multiplication Factors; Four-Factor Formula; Neutron Leakage and Critical Size; Calculation of $K\infty$ for Homogeneous & Heterogeneous Reactors; Classification of Reactors: Research Reactors Swimming Pool, TRIGA, Power Reactors, Pressurized Water Reactor, Boiling Water Reactor, Water-Water Energetic Reactor (WWER).

   Intended learning outcomes: Enables successful students to:

- **(i)** Explain multiplication factor.
- **(ii)** Employ four-factor formula for reactors.
- **(iii)** Classify nuclear reactors.
- **(iv)** Calculate the amount of thermal and electrical energies produced in a fission reactor.
- **(v)** Design a fission power plant.

4. **Non-Steady Nuclear Reactor:** Thermal Life-Time and Generation Time; Time Dependent Reactor Equation; Excess Reactivity and Reactor Period; Effect of the Delayed Neutrons; Delayed Neutrons and Reactor Periods; Fission Product Poisoning; Burnable Poisons.

Intended learning outcomes: Enables successful students to:
- **(i)** Understand thermal life-time and generation time.
- **(ii)** Solve time dependent reactor equation.
- **(iii)** Calculate excess reactivity and reactor period.
- **(iv)** Learn about fission product poisoning and their management.

5. **Control of Nuclear Reactors:** Reactor Kinematics, General Features of Reactor Control; Effect of Temperature on Reactivity; Design of the Control System and Reactor Operation; Fission Product Poisoning; Burnable Poisons.

Intended learning outcomes: Enables successful students to:
- **(i)** Understand how the control system work in a reactor core.
- **(ii)** Describe the dependence of temperature on reactivity.
- **(iii)** Explain the functioning of control rods.
- **(iv)** Decide what is to be done in any emergency situation

6. **Energy Removal:** Thermal Problems in Reactor Design; Design of Cooling System; Heat Sources in Reactor Systems; Reactor Coolants.

Intended learning outcomes: Enables successful students to:
- **(i)** Identify thermal problems in reactor design.
- **(ii)** Design the layout for cooling system.
- **(iii)** Choose appropriate reactor coolant.

7. **Reactor Fuels:** Fuel Cycle; Production of Reactor Fuels; Sources of Uranium; Separation of Uranium Isotopes; Re-Processing of Irradiated Fuel; Radioactive Waste Disposal.

Intended learning outcomes: Enables successful students to:
- **(i)** Explain the reactor fuel cycle.
- **(ii)** Describe production of reactor fuels.
- **(iii)** Understand the re-processing procedure of irradiated nuclear fuel.
- **(iv)** Generate a layout for radioactive waste disposal.

Books Recommended

Text Books

Liverhant, SE	Elementary Intro. to Nuclear Reactor Physics
Glasstone, S and Sesonske, A	Nuclear Reactor Engineering
Lamarsh, J	Introduction to Nuclear Reactor Theory
Lamarsh, JR	Introduction to Nuclear Engineering
Singal, RK	Nuclear Reactors

Reference Books

Stacey, WM	Nuclear Reactor Physics
Garg, S et al	Nuclear Reactor Physics
Murray, RL	Introduction to Nuclear Engineering
Islam, AKMA and Islam, A	Nucleo Padarthavijnan (*in Bangla*)
Jacobs, AM et al	Basic Principles of Nuclear Science and Reactors
Kesslev, G	Nuclear Fission Reactor
King, DG	Nuclear Power Systems

PH408 NON-CONVENTIONAL ENERGY (~ 40 *lectures*)

Course Type: Major *Credit Point: 02*

Full Marks: **50** (*Written Examination 40, In-course evaluation 7.5 and Attendance 2.5*)

(*4 questions to be answered out of 6 questions*) *Examination duration:* **3** *hours*

Prerequisite: PH305.

Course Objectives and Summary: The objective of this course is to describe the importance of non-conventional sources of energy. It describes how to collect and store solar energy. This course also explains the working principle of photovoltaic system and its application to meet the energy crisis.

1. **Introduction:** World Energy requirement and Reserve; Energy crisis; Production of Energy in the Sun; Solar Constant; Solar Geometry; Azimuth; Declination; Day Length; Solar Time, Solar Radiation on the Tilted Surface; Measurement of Solar Radiation.

   Intended learning outcomes: Enables successful students to:
   - **(i)** Describe the process of energy production in the sun.
   - **(ii)** Calculate solar intensity, declination, hour angle, and day length.
   - **(iii)** Calculate solar time.
   - **(iv)** Explain and use various solar radiation measurement techniques.

2. **Solar Collectors:** Flat Plate Collectors; General Description of Flat Plate Collector; Heat Transfer Properties of Flat Plate Collector; Energy Balance; Temperature

Distribution; Collector Overall Heat Transfer Coefficient; Collector Efficiency Factor; Heat Removal Factor and Flow Factor.

Intended learning outcomes: Enables successful students to:

(i) Collect and transfer solar energy for practical purposes.
(ii) Derive and solve energy balance equation for solar collectors.
(iii) Calculate overall heat transfer coefficient of a solar collector.
(iv) Estimate collector efficiency, heat removal factor, and flow factor.
(v) Prepare selective surfaces to minimize thermal loss.
(vi) Prepare anti-reflection coating to reduce optical loss.

3. **Energy Storage:** Types of Energy Storage; Sensible Heat Storage; Latent Heat Storage; Thermochemical Storage.

Intended learning outcomes: Enables successful students to:

(i) Describe different solar energy storage arrangements.
(ii) Design different solar energy storage systems.

4. **Photovoltaics:** Interaction of Light with Semiconductor; Absorption and Recombination Processes; Photovoltaic Principles; Semiconductor Junction; Materials for Solar cell; Fabrication; Assembly of Homojunction and Heterojunction solar cell, Solar cell Characteristics, Power Output, Efficiency and Efficiency Limit.

Intended learning outcomes: Enables successful students to:

(i) Understand optical absorption and recombination processes in semiconductors.
(ii) Explain working principle of photovoltaic cells.
(iii) Choose suitable materials for solar cell.
(iv) Calculate and explain solar cell characteristics.
(v) Estimate the power factor and efficiency of solar cells.

5. **Photovoltaic System and Modules:** Basic Photovoltaic System for Power Generation; Solar Modules; Module Circuit Design; Application of Photovoltaic System; New Developments of Solar Panel.

Intended learning outcomes: Enables successful students to:

(i) Design photovoltaic modules for power generation.
(ii) Design solar panels.

6. **Other Sources of Non-conventional Energy:**

a) Wind Power: Suitability of Wind Power; Factors of Wind Speed; Height above Ground and Terrain Characteristics; Betz' Law; Basic Wind Power System; Advantages and Disadvantages of Wind Power.

b) Biomass and Biogas; Introduction to Tidal Power and Fuel Cells.

Intended learning outcomes: Enables successful students to:

(i) Design a basic wind power system.

(ii) Apply Betz' law for wind power utilization.
(iii) Design biogas plant.
(iv) Learn about the prospects of tidal power and fuel cells to meet energy crisis.

Books Recommended

Text Books

Rai, GD	Non-conventional Source of Energy
Rapp, D	Solar Energy
Anderson, EE	Fundamental of Solar Energy Conversion

Reference Books

Rai, GD	Solar Energy Utilization
Duffiee, JA	Solar Engineering of Thermal Process
Green, MA	Solar Cell
Magal, BS	Solar Power Engineering
Neville, RC	Solar Energy
Fisk, MJ and Anderson, HCW	Introduction to Solar Technology
Khan, BH	Non-conventional Energy Resources

PH411 PHYSICS PRACTICAL

Course Type: Major *Credit Point: 08*

Full Marks: **200** (*Continuous Assessment 60, Practical Examination 140 marks*)

(*4 days for Experiments and 1 day for Defense on Experiments*)

Examination duration: (**6+6+6+6+6**) *hours*

Prerequisites: PH109, PH209, PH310

List of Experiments

Group: A

(Two experiments to be performed in the examination in two days)

1. Study of Linear and Non-Linear Waveshapings

Learning outcomes: Successful students should be able to:
(i) Construct and analyze practical waveshaping circuits.
(ii) Investigate the performance of integrators and differentiators on electrical signals using waveshaping circuits.

2. Construction and Study of a Transistorized Regulated Power Supply.

Learning outcomes: Successful students should be able to:
(i) Investigate the effects of load resistance on series voltage regulation.
(ii) Analyze power supply regulation to determine their performance criteria and limitations.

3. Construction and Study of an Emitter-follower (Common-Collector) Amplifier Circuit.

Learning outcomes: Successful students should be able to:

(i) Use this circuit as a great voltage buffer due to the high current gain combined with near unity voltage gain of the circuit.

(ii) Understand how this amplifier is used as an impedance matching circuit.

4. Construction and Study of Pulse Generators:

a) Astable Multivibrator.

b) Monostable Multivibrator.

Learning outcomes: Successful students should be able to:

(i) Understand the function of the astable multivibrator to produce quasi-stable states of the circuit.

(ii) Learn how the rounding-off of the rising edge of output pulse can be minimized.

(iii) Measure the duty cycle from the output waveforms.

5. Construction and Study of a Schmitt Trigger Circuit using Transistor Op-amp.

Learning outcomes: Successful students should be able to:

(i) Understand the functions of the Schmitt Trigger circuit and to convert noisy square waves, sine waves or slow edges inputs into clean square waves.

(ii) Learn how the hysteresis or two different threshold voltage levels occur for the rising and falling edges.

6. Construction and Study of Logic Gates using Diodes and Transistors.

Learning outcomes: Successful students should be able to:

(i) Investigate AND, OR, NOT, NAND and NOR gate operations.

(ii) Understand the fundamental laws of Boolean algebra associated with the AND, OR, NOT, NAND and NOR operation

(iii) Use of universality of NAND and NOR gates.

7. Construction and Study of Flip-flop (RS and JK) Operations.

Learning outcomes: Successful students should be able to:

(i) Construct, analyze and troubleshoot circuits which incorporate sequential logic devices.

(ii) To design a sequential logic circuit from basic gates and studies the operational function by simulating R-S flip-flops comprising of cross-coupled NOR gates and NAND gates accordingly.

(iii) Design and construct a synchronous counter.

8. Study of Operational Amplifiers:

a) Determination of the CMRR and the Slew-rate;

b) Inverting, Non-inverting and Summing Amplifiers.

Learning outcomes: Successful students should be able to:

- **(i)** Investigate the performances of an op-amp chip (DIP package) in three ways:
  - ***a.*** Experimentally determine the gain of standard inverting and non-inverting op-amp circuits.
  - ***b.*** Compare experimental results with the ideal predictions.
  - ***c.*** Determine op-amp performance criteria and limitations.
- **(ii)** Demonstrate a circuit containing operational amplifier can be used to perform mathematical operation.
- **(iii)** Demonstrate the application of an op-amp circuit is the voltage-follower, which serves as an isolator between two parts of a circuit.

9. Construction and Study of High-Pass and Low-Pass Active Filters using Op-Amps.

Learning outcomes: Successful students should be able to:

- **(i)** Sketch the frequency responses of high-pass, low-pass and band pass active filters, and to calculate their cut-off frequencies.
- **(ii)** Determine and interpret the limitations of frequency responses of active filter.

Group: B

(One experiment to be performed in the examination)

1. Determination of Temperature Factor using X-Ray Diffraction Data.

Learning outcomes: Successful students should be able to:

- **(i)** Understand (i) and (ii) of experiment B(2).
- **(ii)** Understand the concept of Debye-Waller correction.
- **(iii)** Calculate temperature factor from a structure factor data set.

2. Determination of Unitary Structure Factor using X-Ray Diffraction Data.

Learning outcomes: Successful students should be able to:

- **(i)** Understand the concept of X-ray diffraction.
- **(ii)** Understand Miller indices, Bravais lattice and reciprocal lattice.
- **(iii)** Calculate unitary structure factor from intensity data set.

3. Determination of the Ferromagnetic Curie Temperature.

Learning outcomes: Successful students should be able to:

- **(i)** Understand the concept of Curie temperature, intrinsic magnetic moment, ferromagnetic material, paramagnetic and ferromagnetic material.
- **(ii)** Understand the concept of induced magnetism and magnetic susceptibility.
- **(iii)** Demonstrate Curie and Curie Weiss laws.
- **(iv)** Calculate the Curie temperature investigating emf-temperature and voltage gradient-temperature curves.

4. Determination of Energy Gaps of Si and Ge Crystal using Semiconductor Diode.

Learning outcomes: Successful students should be able to:

- **(i)** Understand the concept of intrinsic and extrinsic semiconductors.
- **(ii)** Demonstrate the concept of biasing and depletion layer.
- **(iii)** Calculate the energy band gap of semiconductor sample and investigate the voltage-temperature curve.

5. Determination of Planck's Constant.

Learning outcomes: Successful students should be able to:

- **(i)** Understand the concept of photoelectric effect, work function, absorption, photon energy, anode and cathode.
- **(ii)** Understand the concept of photocell, diffraction grating, Colour filters.
- **(iii)** Calculate Planck's constant h, from the photoelectric voltages measured and investigate the voltage of the photocell ~ frequency of the irradiated light curve.

Group: C

(One experiment to be performed in the examination)

1. Determination of Resolving Time of a G-M Counter by Double Source Method.

Learning outcomes: Successful students should be able to:

- **(i)** Determine the resolving time of a G-M tube;
- **(ii)** Understand the necessity of double source method instead of single source method to determine resolving time;
- **(iii)** Understand the concept of resolving time in this experiment.

2. Determination of Efficiency of a G-M Tube for Beta Counting.

Learning outcomes: Successful students should be able to:

- **(i)** Demonstrate the operation of the G-M tube including the concepts of threshold voltage, operating voltage, quenching, plateau, avalanche, tube's geometrical structure and its circuit details.
- **(ii)** Explain the concept and interpret the conservation rules for beta decay.
- **(iii)** Explain the concept of stability of nucleus and radioactivity.
- **(iv)** Calculate the efficiency of a G-M counter.

3. Verification of Inverse Square Law for Gamma Rays and Comparison of Source Intensities.

Learning outcomes: Successful students should be able to:

- **(i)** Verify the inverse square law for gamma rays and determine the intensity of an unknown source;
- **(ii)** Apply the principle to calculate the radiation dose.

4. Study of the Absorption of Gamma Rays by Matter and Determination of Absorption Coefficients of Different Materials.

Learning outcomes: Successful students should be able to:

- **(i)** Explain the different physical phenomenon by which the gamma rays absorb in matter;
- **(ii)** Calculate the half-value thickness, linear and mass absorption coefficient of different materials;
- **(iii)** Apply the principle to select the shielding material for radiation protection.

5. Determination of the Maximum Energy of Beta Particles Emitted from Source and Estimation of Thickness of an Unknown Foil.

Learning outcomes: Successful students should be able to:

- **(i)** Demonstrate the operation of the G-M tube including the concepts of threshold voltage, operating voltage, quenching, plateau, avalanche, tube's geometrical structure and its circuit details.
- **(ii)** Explain the energy spectrum of beta decay.
- **(iii)** Interpret the role of neutrino in beta decay.
- **(iv)** Illustrate the absorption of beta particles in matter.
- **(v)** Calculate the maximum energy of beta particles.

6. Determination of the relative efficiency of a GM tube.

Learning outcomes: Successful students should be able to:

- **(i)** Illustrate the operation of the G-M tube including the concepts of threshold voltage, operating voltage, quenching, plateau, avalanche, tube's geometrical structure and its circuit details.
- **(ii)** Explain the concept of stability of nucleus and radioactivity.
- **(iii)** Explain the concept of beta and gamma decay.
- **(iv)** Interpret the conservation rules for beta decay.
- **(v)** Calculate the relative efficiency of a G-M counter.

Books Recommended

Text Books

Bar, Z and Malvino, AP	A Text Lab. Manual: Basic Electronics
Millman, J and Taub, H	Pulse, Digital and Switching Waveforms
Blueler, E and Goldsmith, GJ	Experimental Nucleonics
Person, FJ and Osborne, RR	Practical Nucleonics
Stout, E and Jensen, GJ	Practical Structure Determination

Academic Calendar

1st Year B.Sc. (Honours), Session: 2019-20; Examination 2020

Class Starts	Class Ends	Exam starts
21 January 2020	13 September 2020	18 October 2020

2nd Year B.Sc. (Honours), Session: 2020-21; Examination 2021

Class Starts	Class Ends	Exam starts

3rd Year B.Sc. (Honours), Session: 2021-22; Examination 2022

Class Starts	Class Ends	Exam starts

4th Year B.Sc. (Honours), Session: 2022-23; Examination 2023

Class Starts	Class Ends	Exam starts