



**Curriculum for  
M.Sc. in Physics  
Session: 2016-17**

**Examination 2017**



**DEPARTMENT OF PHYSICS**



University of Rajshahi

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 Mollere, 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, Rajshahi University, 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 28 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, 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.

### **Mission and Objectives of the Department**

Since its inception in 1958, the mission of the Department of Physics, University of Rajshahi has been to advance 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.

### **Intended Learning Outcomes (ILOs) of the Program**

#### **Knowledge and Understanding:**

The B.Sc. and M.Sc. degree programs offered by the Department cover the fundamental topic 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 students should have demonstrated-

1. Knowledge and understanding of most fundamental physical laws and principles and competence in the application of these principles to diverse areas of Physics.
2. An ability to solve problems in Physics using appropriate mathematical tools.
3. An ability to execute and analyze critically the results of an experimental investigation or theoretical modelling 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 advanced areas of Physics - the forefront of the discipline.
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 especially in the form of clear and accurate scientific reports.

Knowledge and understanding of areas 1 - 2, and 4 - 6 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.

### Resources

The department has 28 members of teaching staff consisting of 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
<b>Professor Emeritus</b>	
Dr. Arun Kumar Basak <i>MSc(Raj), PhD(Birmingham), FInstP (London), CPhys</i>	Nuclear Physics, Atomic Physics
<b>Professors</b>	
Dr M Shafiqul Islam (PRL) <i>MSc(Raj), PhD(Nagpur)</i>	X-ray Spectroscopy and Crystallography
Dr M Obaidul Hakim <i>MSc(Raj), PhD(Raj)</i>	Condensed Matter Physics (Expt.) Thin Films
Dr Somnath Bhattacharjee <i>MSc(Raj), PhD(Banaras)</i>	Theoretical Physics, Fibre Optics

Dr M Enamul Haque <i>MSc(Raj), PhD(Raj)</i>	Theoretical Solid State Physics
Dr M Golam Mortuza <i>MSc(Raj), PhD(Warwick)</i> <i>C in Comp.(Coventry)</i>	Condensed Matter Physics, Glass and Glass Ceramics, Superconductivity
Dr M Mozibur Rahman <i>MSc(Raj), PhD(Ukraine)</i>	Condensed Matter Physics (Expt.), Electronics, Metallurgy
Dr M Khalilur Rahman Khan <i>MSc(Raj), PhD(Japan)</i>	Condensed Matter Physics, Mat. Science (Expt.), Thin films, Superconductivity
Dr Irine Banu Lucy <i>MSc(Raj), PhD(Brunel,UK)</i>	Condensed Matter Physics (Expt.)
Dr M Rafiqul Ahsan <i>MSc(Raj), PhD(Raj)</i>	Condensed Matter Physics, Glass and Glass Ceramics, X-ray Crystallography
Dr F Nazrul Islam <i>MSc(Raj), PhD(Raj)</i>	Cond. Matter Physics (Comp. simulation), Superconductivity, Nuclear Physics
Dr Saleh Hasan Naqib <i>MSc(Raj), PhD(Cambridge)</i>	Superconductivity
Dr Abul Kalam Fazlul Haque <i>MSc(Raj), PhD(Raj)</i>	Nuclear Physics
Dr Abdullah Shams Bin Tariq <i>MSc(Raj), PhD(Southampton)</i>	Particle Physics, Nuclear Physics
<b>Associate Professors</b>	
Mr A F M Abdul Wahed <i>MSc(Raj)</i>	X-ray Crystallography
Dr Laila Arjumand Banu <i>MSc(Raj), PhD (Raj)</i>	Condensed Matter Physics (Expt.)
Dr M Rezaur Rahim <i>MSc(Raj), PhD(Brunel,UK)</i>	Condensed Matter Physics (Expt.), Electronics
Ms Dilruba Akhter Banu <i>MSc(Raj)</i>	Nuclear Physics
Dr Raihana Shams Islam <i>MSc (Raj), MPhil(Cambridge), PhD(Cambridge)</i>	Superconductivity
Dr Fahmida Parvin <i>MSc(Raj), PhD(Raj)</i>	Superconductivity

Dr M A Razzaque Sarker <i>MSc(Raj), PhD(Japan)</i>	Materials Science
Dr M Atiqur Rahman Patoary <i>MSc(Raj), PhD(Japan)</i>	Nuclear Physics, Condensed Matter Physics (Theory)
Dr M Samiul Islam Sarker <i>MSc(Raj), MSc(Adelaide, Australia), PhD(Tohoku, Japan)</i>	Nuclear Physics, Fibre-laser, Materials Science
Dr M Monirul Haque <i>MSc(Raj), PhD (Japan)</i>	Medical Physics, Radiation and Health Physics

### Assistant Professors

Mr M Masum Billah <i>MSc( Raj)</i>	Nuclear Physics
Mr K M Mahmudul Hasan <i>MSc(Raj)</i>	Nuclear Physics
Ms Monira Jannatul Kobra* <i>MSc(Raj), PGD(ICTP)</i>	Nuclear Physics
Mr M Leaket Ali <i>MSc(Raj)</i>	Condensed Matter Physics
Mr M Ismail Hossain <i>MSc(Raj)</i>	Theoretical Atomic Physics
Mr M Alamgir Hossain <i>MSc(Raj)</i>	Medical Physics

### Lecturer

Mr M Saiful Islam* <i>MSc(Raj)</i>	Condensed Matter Physics
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\* on 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 has 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 is about to start a rental library for students. Groups of students will soon be able to 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 with internet facilities for students and teachers. Recently an NComputing system has been introduced in the student section of the lab on trial basis. If this is successful, there are plans for a major expansion of the student section in the near future. 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 the 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 hour. This club is open to all the students of Department of Physics, University of Rajshahi (RU).

#### **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.

### **Students' Association**

There is a student association in the department called Physics Students' Association. All students of the department are the members of the association. This Students' Association regularly organizes farewell for the outgoing M.Sc. students and welcome reception for the fresher's admitted in the B.Sc. course. Besides, the Association arranges various cultural and sports related activities.

### **Physics Alumni Association**

Department of Physics has an active Alumni Association. 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 in the academic development of the department and 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.





UNIVERSITY OF RAJSHAHI

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

Curriculum for M.Sc. in Physics

Session: **2015 - 16**

Examination: **2016**

The M.Sc. Examination in Physics is divided into two groups:

Group A: General

Group B: Thesis

All students will have to take six Theoretical courses including at least one course from PH501 and PH502 (subject to the approval of the Chairman of the Department). Additionally, the students of the General group will have to take the practical course, while the students of Thesis group will have to take a research topic approved by the Department.

A **full-unit** course shall carry 100 marks and a **half-unit** course 50 marks out of which 80% is for the Final Exam, 15% is for Tutorial/Terminal and 5% is for Class Attendance.

**Total GPA Round off:**

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

The M.Sc. curriculum in Physics shall consist of:

- |                                 |   |
|---------------------------------|---|
| i) Theory courses (6 units),    | $100 \times 6 = 600$ marks = 24 Credits |
| ii) Practical /Thesis (2 units) | = 200 marks = 08 Credits                |
| iii) General Viva-voce (1 unit) | = 100 marks = 04 Credits                |

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Total (10 course units) = 900 marks = 36 Credits

Mode of Examination: Written test 80% at the end of the year and two tutorial written examinations will be held for 15% within the classes.

**Award of Degree:**

The degree of M.Sc. shall be awarded on the basis of the Grade Point Average (GPA) obtained by a candidate in his/her M.Sc. examination. In order to qualify for the degree, a candidate must obtain (within three academic years from the date of first admission):

- i) A minimum GPA of 2.50,
- ii) A minimum Grade point (GP) of 2.00 in Practical/Thesis, and

iii) A minimum total Credit points (TCP) of 32.

**Result Improvement:**

A student obtaining GPA less than 3.00 shall be allowed to improve his/her courses up to 12 credits including 'F' Grade only once within 3 academic years. Here, it is noted that GP of courses, which he/she wants to improve should be less than 3.00.

**Gradation of the Results:**

Numerical Grade (NG)	Letter Grade (LG)	GP (Grade Point)
80% or above	A+ (A plus)	4.00
75% or above	A (A regular)	3.75
70% or above	A- (A minus)	3.50
65% or above	B+ (B plus)	3.25
60% or above	B (B regular)	3.00
55% or above	B- (B minus)	2.75
50% or above	C+ (C plus)	2.50
45% or above	C (C regular)	2.25
40% or above	D	2.00
Less than 40%	F	0.00
Incomplete	I	0.00

**Eligibility for the M.Sc. examination:**

Class attendance (both in theory and practical classes)

Below 75%: Non-collegiate;

Below 60%: Discollegiate (Discollegiate students will not be allowed to sit for the examination).

**The Detailed Distribution of Courses**

Course no.	Title	Marks	Exam. duration	Credit Point
<b>PH501</b>	Advanced Nuclear Physics	100	4 Hours	04
<b>PH502</b>	Advanced Solid State Physics	100	4 Hours	04
<b>PH503</b>	Electronic Communications	100	4 Hours	04
<b>PH504</b>	Advanced Medical Physics	100	4 Hours	04
<b>PH505</b>	Materials Science	100	4 Hours	04
<b>PH506</b>	Superconductivity	100	4 Hours	04
<b>PH507</b>	Physics of Environment	100	4 Hours	04
<b>PH508</b>	Crystallography and Spectroscopy	100	4 Hours	04
<b>PH509</b>	Particle Physics and Cosmology	100	4 Hours	04
<b>PH510</b>	Advanced Reactor Physics	100	4 Hours	04
<b>PH511</b>	Biomedical Instrumentation and Imaging System	100	4 Hours	04
<b>PH512</b>	Quantum Field Theory	100	4 Hours	04
<b>PH513</b>	Optical Fibre Physics	100	4 Hours	04
<b>PH521</b>	General Viva-Voce	100		04
<b>PH522</b>	Study Tour -Industrial / Scientific exposure			(Non Credit)
<b>PH523</b>	Practical (Compulsory for General Group)	200		08
	<i>a) Continuous evaluation</i>	60		
	<i>b) Annual Examination (28×4)</i>	112	(Four days)	
	<i>c) Defense on Experiments</i>	28	(One day)	
	- OR - Thesis group (Compulsory for Thesis Group)	200		08
	<i>a) Thesis evaluation</i>	150		
	<i>b) Defense on Thesis</i>	50		

**N.B.** Submission of Report on industrial trip is compulsory for all participants. Students unable to go outside Rajshahi may visit local Industries to have their experience. They have to also submit report on their visit.

**PH501 ADVANCED NUCLEAR PHYSICS**

(~75 lectures)

Full Marks: 100 (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: 4 hours

**Prerequisite Knowledge:** PH301, PH303, PH306, PH401, PH403

**1. Direct Nuclear Reactions:** Reaction kinematics: non-relativistic and relativistic; Theory of transfer reactions; Selection rules in a transfer reaction; Theory of inelastic scattering; Importance of direct reactions.

**Intended learning outcome:** Enables successful students to:

- (i) Identify direct reactions.
- (ii) Obtain expressions for transition amplitudes for transfer and inelastic processes.
- (iii) Verify shell model predictions from direct reaction observables.

**2. Nuclear Shell Models:** Single particle shell model; Iso-spin formalism; Two-particle system; Shell model Hamiltonian; Perturbation theory and configuration mixing, Allowed states; Anti-symmetric wave functions, More than two particles in one orbit; Coefficient of fractional parentage; Spectroscopic factors; Spectroscopic factors for mixed configurations; Sum rules for single particle transfer reactions.

**Intended learning outcome:** Enables successful students to:

- (i) Understand advanced models to identify basic nuclear structure and outline their theoretical descriptions.
- (ii) Calculate isospin and third component of isospin for nuclei.
- (iii) Represent a wave function diagrammatically or pictorially.
- (iv) Calculate coefficient of fractional percentage and spectroscopic factor for transfer reactions.

**3. Collective Models:** Shortcomings of the shell model and the nuclear collective models; Nuclear rotational motion; Rotational energy spectra and nuclear wave functions for even and odd A nuclei; Nuclear deformation; Collective oscillation; Quadrupole deformation; Electromagnetic properties.

**Intended learning outcome:** Enables successful students to:

- (i) Describe various models of collective nuclear excitation.
- (ii) Compare rotational and vibrational energy spectra.

**4. Electromagnetic Interactions with Nuclei:** Infinitesimal rotations in vector fields; Intrinsic angular momentum of vector fields; Total angular momentum of vector fields and vector spherical harmonics; Multipole fields; Sources of multipole fields; Transition probability of a multipolar radiation; Multipole moments; Selection rules in a gamma transition; Angular distribution of a gamma transition; Angular correlations; Relative strengths of different multipolar radiations in a transition between two low-lying states of an excited nucleus.

**Intended learning outcome:** Enables successful students to:

- (i) Describe the significance of nuclear charge and current distributions in regard to nuclear structure and decays.
- (ii) Discuss sources of multipole fields and selection rules in gamma transition.
- (iii) Calculate relative transition probabilities of different multipolar radiations.

**5. Nuclear Astrophysics:** Primordial nucleosynthesis; pp chain and CNO cycle; Stellar synthesis of light elements; Synthesis of heavy elements; Stellar evolution and different stages of burning; White dwarfs and neutron stars, Supernova explosions.

**Intended learning outcome:** Enables successful students to:

- (i) Recognize the importance of stars as the factory of nuclides, including red supergiants and supernova.
- (ii) Describe the importance of the Hoyle resonance and similar resonance states in explaining the creation and survival of carbon and oxygen.

**6. Rare or Exceptional Nuclei:** Driplines and nuclei far from stability; Exceptional light nuclei: Halo nuclei, Borromean nuclei; Transuranic nuclei.

**Intended learning outcome:** Enables successful students to:

- (i) Describe key properties of rare nuclei and analyze issues related to their synthesis and stability

Books recommended:

<i>Satchler, GR</i>	Direct Nuclear Reactions
<i>Glendenning, NK</i>	Direct Nuclear Reactions
<i>Roy, RR and Nigam, BP</i>	Nuclear Physics
<i>Blatt, JM and Weiskopff, VF</i>	Theoretical Nuclear Physics

Thompson, IJ and Nunes, FM	Nuclear Reactions for Astrophysics
Brussaard, PJ and Glaudemans, PWM	Shell Model Applications in Nuclear Spectroscopy
Lawson, RD	Theory of the Nuclear Shell Model
Pal, MK	Theory of Nuclear Structure
Sen Gupta, HM	Nucleo Padartha Bidya (in Bangla)
Greiner, W and Maruhn, JA	Nuclear Models
Bertulani, DA and Danielewicz, P	Nuclear Reactions
Bertulani, DA	Nuclear Physics in a Nutshell
Iliadis, C	Nuclear Physics of Stars
Krane, K	Nuclear Physics

## PH502 ADVANCED SOLID STATE PHYSICS

(~ 75 lectures)

Full Marks: 100 (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: 4 hours

Prerequisite Knowledge: PH 304, PH404

**1. Periodic Structure:** Symmetry operations; Groups; Function spaces; Bravais lattice; Periodic functions; Bloch's theorem; Brillouin zones and crystal symmetry; Fermi surface construction; Experimental method: de-Hass-van Alphen oscillation.

**Intended learning outcome:** Enables successful students to:

- (i) Locate an atom in a crystal with different symmetry.
- (ii) Understand the origin of periodic potential.
- (iii) Understand the use of Bloch function.
- (iv) Calculate the zone boundary of Brillouin zones and draw them in reciprocal space.
- (v) Show the impact of zone boundary on the solution of Schrodinger equation.
- (vi) Construct the Fermi surface.

**2. Electron States and Energy Bands in Solids:** The nearly free electron model; Tight binding method; Cellular method; Muffin-Tin potentials; Orthogonalized plane wave method; Pseudopotentials; Wannier function and its uses.

**Intended learning outcome:** Enables successful students to:

- (i) Know the origin of energy bands

- (ii) Differentiate between energy bands obtained from the free electron model and nearly free electron model.
- (iii) Calculate the free electron energy bands using different models.
- (iv) Show the distant nature of energy bands due to use of different approximations.
- (v) Relate the Wannier function with Hartree-Fock equation.
- (vi) Demonstrate the orthogonality properties of Wannier function.

**3. Energy Band beyond the Independent Electron Approximation:** Hartree equation; Hartree-Fock equation: Hartree-Fock theory of free electrons; Density functional theory for band structure calculations; Screening; Dielectric function; Thomas-Fermi theory of screening; Lindhard theory of screening.

**Intended learning outcome:** Enables successful students to:

- (i) Differentiate between Hartree and Hartree-Fock(H-F) equations.
- (ii) Solve the equations for free electron case.
- (iii) Demonstrate the utility of the presence of the exchange term in the H-F equations.
- (iv) Demonstrate the effect of exchange term on free electron graphically.
- (v) Calculate the effect of screening and demonstrate how this effect changes the potential with the consideration of various models.

**4. Theory of Electronic Processes in Semiconductors:** Carrier effective mass and band structure; Effects of temperature and pressure on band gap; Carrier scattering phenomena; Semiconductor statistics: Energy distribution function; Density of states; Density of carriers in intrinsic and extrinsic semiconductors; Compensation of carriers; Charge neutrality condition; Consequences of heavy doping; Conduction processes in intrinsic and extrinsic semiconductors.

**Intended learning outcome:** Enables successful students to:

- (i) Link the electronic band structure to carrier effective mass.
- (ii) Demonstrate the variation of effective mass, group velocity, momentum with wave vector.
- (iii) Explain the temperature and pressure induced changes in the band gap
- (iv) Obtain expressions for the energy density of states for carriers in the conduction and valence bands.

- (v) Calculate carrier density for intrinsic and extrinsic semiconductors.
- (vi) Calculate the shift in Fermi energy with doping.
- (vii) Understand the changes in the electronic structure due to heavy doping.
- (viii) Calculate the total current density for intrinsic and extrinsic semiconductors.

**5. Theory of Optical Processes:** Reflectivity at an interface; Absorption of radiation; Kramers-Kronig relations; Determination of optical constants; Free carrier absorption: Experimental results for metals and semiconductors; Interband transition: Fundamental absorption near band gap; Theory of vertical and non-vertical transition; Optical processes in amorphous materials; Measurement of absorption and luminescence spectra.

**Intended learning outcome:** Enables successful students to:

- (i) Explain various optical transitions in semiconductors and metals.
- (ii) Obtain the Kramers-Kronig(KK) relations.
- (iii) Apply the KK relations to obtain all the frequency dependent optical constants.
- (iv) Understand optical processes in amorphous semiconductors.
- (v) Describe experimental arrangements for obtaining optical absorption and photoluminescence spectra.

**6. Junction Theory:** Mathematical derivation of contact potential and space charge in p-n junction; Built-in voltage; Physical mechanisms of breakdown in p-n junction; Schottky barrier and Ohmic contacts; Metal-Semiconductor junction; Semiconductor heterojunction; I-V and C-V relationships.

**Intended learning outcome:** Enables successful students to:

- (i) Calculate contact potential from doping.
- (ii) Draw the electric field and potential profile across the junction.
- (iii) Obtain the expression for junction capacitance and understand its effect in practical uses.
- (iv) Obtain the diode equation that can be related to rectification process and other diode applications.
- (v) Draw the band-bending features of homo- and hetero-junctions.
- (vi) Explain the function of Schottky barrier and their applications.
- (vii) Understand various junction breakdown mechanisms.



Books recommended:

Ziman, JM	Principles of the Theory of Solids
Clark, H	Solid State Physics: an Introduction to Its Theory
Kittel, C	Quantum Theory of Solids
Ashcroft, NW and Mermin, ND	Solid State Physics
McKelvey, JPM	Solid State and Semiconductor Physics
Bhattacharya, P	Semiconductor Optoelectronic Devices (2nd edn)
Mario, PT- edited	Crystalline Semiconducting Materials and Devices
Fraser, DA	The Physics of Semiconductor Devices

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**PH503 ELECTRONIC COMMUNICATIONS**

(~75 lectures)

Full Marks: **100** (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: **4 hours**

**Prerequisite Knowledge:** PH305,PH402

**1. Communications Fundamentals:** Communications model; Frequency allocations; Types of signals; Analogue and Digital data transmissions; Transmission impairments; Noises: Types and measurements of noises.

**Intended learning outcome:** Enables successful students to:

- (i) Describe the electrical and logical characteristics of analogue and digital data transmission and transmission impairments.

**2. Modulation and Demodulation:** Principles; Modulations: Amplitude, Frequency, Phase, Pulse modulations; Demodulations: FM discrimination, Demodulation of PM waves.

**Intended learning outcome:** Enables successful students to:

- (i) Get familiar with pulse-based communication, different pulse modulation schemes, applicability of these to different design scenarios in telecommunications.

**3. Digital Communications:** Transmission modes: Asynchronous and Synchronous; Data transmission circuits; Digital codes; Matched filter; Digital carrier system; Differential Phase Shift Keying (DPSK); Baseband &

Broadband communications: Channels, ISDN; Multiplexing: FDM, TDM and STDM.

**Intended learning outcome:** Enables successful students to:

- (i) Comprehend the underlying technology of fiber-optic communication system.

**4. Transmission Media and Antennas:** Guided transmission media: Open-wire, Coaxial, Optical fibers; Wireless transmission media: Radio and Microwave; Antennas: VHF, UHF and Microwave antennas.

**Intended learning outcome:** Enables successful students to:

- (i) Analyze components associated with digital and analog communication in guided and wireless communication systems.

**5. Optical and Satellite Communications:** Optical communication: Principles, Transmission and losses, Dispersion, Light sources and Photodetectors; Satellite communications: Orbits and inclinations, Types of satellites, Satellite construction, Satellite links.

**Intended learning outcome:** Enables successful students to:

- (i) Explain the various ways in which satellites systems are classified, including the standard communication satellite system.

**6. Modern Communication Systems:** Television Fundamentals: Beam scanning, Blanking and sync pulses; TV system: Transmitter and Receiver; Mobile cellular telephony: Concept of cellular technology, Operations of cellular systems; Cellular systems: GSM and CDMA; Radar: Types and uses, Radar Range, Pulse and CW Radars; Navigation: Global positioning system (GPS), Air traffic control: ILS and GCA.

**Intended learning outcome:** Enables successful students to:

- (i) Identify the technology features which enable cell phone communication.
- (ii) Describe the basic function, principles of operation, and interrelationships of the basic units of a radar system.
- (iii) Comprehend the concept of modern navigation systems, like the global positioning system(gps), ils and gca in air traffic controls, and their uses.
- (iv) Get conceptual and implementation aspects of computer networking applications.

- (v) Find problem solving solutions using the information gained through the component manuals and manufacturer web sites.

**7. Computer Networking and Internet:** Computer networking: Categories, Types and Topologies; Internetworking; The Internet; World Wide Web (WWW).

**Intended learning outcome:** Enables successful students to:

- (i) Calculate contact potential from doping.

Books recommended:

<i>Frenzel, LE</i>	Communication Electronics: Principles & Applications
<i>Stallings, W</i>	Data and Computer Communications
<i>Roddy, D and Coolen, J</i>	Electronic Communications
<i>Roden, SR</i>	Digital and Data Communications
<i>Singh, A</i>	Principles of Communication Engineering
<i>Martin, J</i>	Communication Satellite System
<i>Chellis, J, Perkins, C and</i>	
<i>Streb, M</i>	MCSE: Networking Essentials
<i>Tanenbaum, AS</i>	Computer Networks
<i>Pfaffenberger, B</i>	Mastering Internet World Wide Web

**PH504 ADVANCED MEDICAL PHYSICS**

(~75 lectures)

Full Marks: **100** (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: 4 hours

**Prerequisite Knowledge:** PH405

**1. Medical Internal Radiation Dosimetry (MIRD):** Internal radiation dosimetry; Radiation dose: quantities and units; Calculation of radiation dose: absorbed fraction method; Cumulated activity  $\bar{A}$ ; Equilibrium absorbed dose constant  $\Delta$ ; Absorbed fraction  $\phi$  and the dose reciprocity theorem; Mean dose per cumulated activity.

**Intended learning outcome:** Enables successful students to:

- (i) Calculate radiation dose absorbed in patient at various biologic conditions.

**2. Cancer Biology and Treatment:** What is cancer; Mutation of cells; Genes involved in cancer development; Tumor formation; Risk factors; Metastasis; Overview of methods of treatment; Radiation therapy- Teletherapy, Brachytherapy, Systemic radiation therapy; How radiation cures cancer; Fascination of radiation therapy.

**Intended learning outcome:** Enables successful students to:

- (i) Understand the formation, development and cure of cancer and the basic techniques of cancer treatment.

**3. Clinical Radiation Generators:** Kilo-voltage units; Linac: X-ray and electron beam, Target and flattening filter, Beam collimation and monitoring, Gantry; Multileaf collimator (MLC); Co-60 unit: Source housing; Beam collimation and penumbra.

**Intended learning outcome:** Enables successful students to:

- (i) Design teletherapy beam (x and  $\gamma$ -ray) line, develop idea regarding beam collimation and intensity modulation.

**4. Dose Distribution and Scatter Analysis:** Phantoms; Depth dose distribution; Percentage depth dose; Tissue-air ratio; Backscatter factor; Scatter-air ratio; Dose calculation parameters; Collimator scatter factor; Phantom scatter factor; Tissue-Phantom and Tissue-Maximum ratios; Properties of TMR; Scatter-Phantom and Scatter-Maximum ratios; Practical applications.

**Intended learning outcome:** Enables successful students to:

- (i) Calculate dose in clinical situation.

**5. Isodose Distribution:** Isodose chart; Measurement of isodose curves; Parameters of isodose curves; Wedge filters; Combination of radiation fields; Isocentric techniques; Wedge field technique; Tumor dose specification.

**Intended learning outcome:** Enables successful students to:

- (i) Characterize a radiation beam that produces a dose distribution in a 3D-volume.

**6. Patient Data, Corrections and Setup:** Acquisition of patient data; Treatment simulation; Treatment verification; Corrections for contour irregularities; Corrections for tissue inhomogeneities; Tissue compensation; Patient positioning.

**Intended learning outcome:** Enables successful students to:

- (i) Acquire sufficient knowledge about treatment planning and treatment simulation.

**7. Modern Radiation Therapy:** Introduction to 3-D conformal radiation therapy (3-D CRT); Intensity-modulated radiation therapy (IMRT); Image-Guided radiation therapy (IGRT), Stereotactic radiotherapy; Proton beam therapy.

**Intended learning outcome:** Enables successful students to:

- (i) realize the advantages of 3-D teletherapy over 2-D technique.
- (ii) demonstrate the differences between 3-D CRT, IMRT, IGRT and SRT.
- (iii) explain the advantages of proton beam therapy.

**8. Brachytherapy:** Radioactive sources; Calibration of brachytherapy sources; Calculation of dose distribution; Systems of implant dosimetry; Computer dosimetry; Implantation techniques; Remote afterloading units; High dose rate brachytherapy.

**Intended learning outcome:** Enables successful students to:

- (i) Name brachytherapy sources and list their characteristics.
- (ii) Understand source implant techniques and dosimetry.

Books recommended:

Waston, EE

Khan, FM & Gibbons, JP

Mayles, P, Nahum, A and

Rosenwald, JC

Podgorsak, EB

Levitt, SH, Purdy, JA and Perez, CA

Godden, TJ

Johns, HE and Cunningham, JR

Sorenson, JA and Phelps, ME

Dyson, NA

MIRD primer

The Physics of Radiation Therapy (5<sup>th</sup> Ed)

Handbook of Radiotherapy Physics, Theory and Practice

Radiation Oncology Physics

-A Handbook for Teachers and Students

Technical Basis of Radiation Therapy

Physical Aspects of Brachytherapy

The Physics of Radiology (4th Edition)

Physics In Nuclear Medicine (2nd Edition)

An Introduction to Nuclear Physics with Applications in Medicine and Biology

**1. Microstructure Examination (brief review):** Experimental methods for the physical examination of materials; Metallurgical microscope; Microscopy of surfaces; TEM (Transmission Electron Microscopy); SEM (Scanning Electron Microscopy); STM (Scanning Tunneling Microscopy) and AFM (Atomic Force Microscopy); Thermal analysis – DTA, TGA, DSC (Differential Thermal Analysis, Thermogravimetric Analysis, Differential Scanning Calorimeter).

**Intended learning outcome:** Enables successful students to:

- (i) Demonstrate the principle of photography.
- (ii) Know the difference between SEM and TEM sample preparation.
- (iii) Predict the micrographs of SEM and TEM.
- (iv) Know how to do qualitative analysis of the elements in a material.
- (v) Demonstrate the process of STM and AFM.
- (vi) Predict the STM and AFM data for practical purposes.
- (vii) Differentiate among DTA, TGA and DSC.
- (viii) Calculate thermodynamic variable and determine glass transitions, crystallographic and metallic temperature.

**2. Solidification:** Homogeneous and heterogeneous nucleations; Theory of liquid-solid phase transformation; Crystal growth technique; Sintering of materials; Glassy phase; Experimental facts regarding glass transition; V-T diagram; Non-equilibrium and thermodynamic views of glass transition; Free volume theory.

**Intended learning outcome:** Enables successful students to:

- (i) differentiate between homogeneous and heterogeneous nucleations.
- (ii) Differentiate between solid and liquid phase.
- (iii) Use V-T diagram to explain glass and crystal transition.
- (iv) Know how do the crystals grow.
- (v) Know how the difference in cooling process changes the structure of materials.
- (vi) Know the necessity of sintering as well as controlled heat treatment.

**3. Equilibrium Phase Diagrams:** Solid solution of two-component system; Simple eutectic diagram; Hume-Rothery electron compounds; Order-disorder phase transformation; Long-range and short-range order theories.

**Intended learning outcome:** Enables successful students to:

- (i) Know what does solid solution means.
- (ii) Demonstrate the homogeneous solid mix needed to form a joint super lattice.
- (iii) Describe the properties of Hume-Rothery compounds.
- (iv) Explain order-disorder phase transformation.

**4. Diffusion:** Fick's laws for isothermal diffusion; Atomic mechanisms of diffusion; Hydrogen diffusion; Thermodynamics of diffusion of Pd-H system; Effect of lattice defects.

**Intended learning outcome:** Enables successful students to:

- (i) Derive Fick's first and second law of diffusion and know the physical significance of these equations.
- (ii) Demonstrate the mechanism of diffusion process by solving Fick's equations.
- (iii) Demonstrate the pressure and temperature effect on diffusion.

**5. Engineering Alloys:** Ferrous and non-ferrous alloys; Production of steel; The iron-carbon phase diagram; The structure and classification of plain carbon steel; Heat treatment of steel; Alloy, Steel, Stainless steel; Cast-iron and malleable iron; Tool steels.

**Intended learning outcome:** Enables successful students to:

- (i) Differentiate between ferrous and non-ferrous alloys.
- (ii) Know the purification process of ferrous ores.
- (iii) Know how the binary or ternary phase diagrams help to calculate the amounts of components and particular temperature needed to prepare a specific phase of a material.
- (iv) Know the necessity of heat treatment of steel.
- (v) Calculate the amount of components needed to prepare alloy, steel and stainless steel.
- (vi) Know the distinctive characteristics of different steels.

**6. Optoelectronic Materials and Devices:** Optical materials for LED, LASER and Photo detectors and their preparation and characterization; Physical processes in these materials; Graphene.

**Intended learning outcome:** Enables successful students to:

- (i) Know the preparation and characterization process for materials needed to LED, LASER and photodetector.
- (ii) Know the necessity of optoelectronic materials.

**7. Composite Materials:** Fibers for reinforced plastic; Composite materials; Formation of composites; Open-mold and closed-mold process of preparation; Metal matrix and ceramic-matrix composites; Elastic properties of composites; Strength and toughness of fiber reinforced composites.

**Intended learning outcome:** Enables successful students to:

- (i) Know the necessity of reinforcement in plastics and other materials as well.
- (ii) Predict the cause of change of physical, chemical and electrical properties of composite materials.
- (iii) Demonstrate the preparation techniques for composite materials.
- (iv) Explain the cause of formation of various matrix in composite materials.
- (v) Know the measurement process of elastic properties, strength and toughness of ordinary and fiber reinforced composites.

**8. Corrosion:** Definition, Electrochemical considerations; Electrode potentials and EMF series; Nernst equations; Polarization; Evan's diagram; Forms of corrosion; Corrosion rate; Mechanism of oxidation; Corrosion prevention methods; Corrosion testing; Quasi-crystals.

**Intended learning outcome:** Enables successful students to:

- (i) Know the meaning of corrosion in material science.
- (ii) Calculate the rate of corrosion.
- (iii) Know the mechanisms of preparation of corrosion. E.g., anodic/cathodic process, which are used for protection of gas and oil pipeline, should be known to the students.
- (iv) Prevent and test corrosion in physical systems.



Books recommended:

Owen, FD	Topics in Metallurgical Thermodynamics
Heyer, RH	Engineering Physical Metallurgy
Compbell, JS	Principles of Manufacturing Material & Processes
Verron, J	Introduction of Engineering Materials
Hench, LL and Gould, RW	Characterization of Ceramics
McMillan, PW	Glass-Ceramics
Smith, NF	Principles of Material Science and Engineering
Pascoe, KJ	Intro. to the Properties of Engineering Materials
Haasen, P	Physical Metallurgy
Callister Jr, WD	Mater. Science and Engineering- an Introduction
Fontana, Mars G	Corrosion Engineering
Uhlig, HH, Revie, R	Corrosion and Corrosion Control
Bhattacharya, P	Semiconductor Optoelectronic Devices (2nd edn).
Norman, HM, Robert, AS and Mario, PT- edited	Amorphous Solids and the Liquid State
Butcher, PN and Norman, HM Mario, PT-edited	Crystalline Semiconducting Materials and Devices

**PH506 SUPERCONDUCTIVITY**

(~ 75 lectures)

Full Marks: **100** (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: **4 hours**

**Prerequisite Knowledge:** PH304, PH404

- 1. Phenomenological Theory:** London model; Thermodynamics of the superconducting state; Ginzburg-Landau (G-L) theory of phase transition: G-L free energy; G-L equation and its applications; Penetration depth; Coherence length; Type-I and type-II superconductors; Critical fields.

**Intended learning outcome:** Enables successful students to:

- Relate current with electromagnetic field and explain Meissner effect.
  - Interpret microscopic properties of superconductivity.
  - Demonstrate the second order phase transition using G-L theory.
  - Calculate penetration depth, coherence length.
  - Differentiate between type-I and type-II superconductor in terms of critical field.
- 2. Microscopic BCS Theory:** BCS Theory: Cooper pairs; BCS ground state; Excitations in the BCS model; Energy gap equation; Critical temperature;

Isotope effect; Specific heat and coherence effects; BCS theory and G-L theory.

**Intended learning outcome:** Enables successful students to:

- (i) Demonstrate the variation of critical magnetic field with temperature.
- (ii) Explain the condition and process of formation of cooper pairs.
- (iii) Demonstrate the superconducting band gap at the Fermi level.
- (iv) Demonstrate the isotope effect on critical temperature.
- (v) Demonstrate the change in heat capacity near the critical temperature for some superconductors.
- (vi) Compare the BCS and G-L theory.

**3. Vortex Behaviour and Critical Current:** Mixed states; Interaction between vortices; The Abrikosov lattice; Flux dynamics: Flux flow; Flux glass; Flux creep; Magnetic hysteresis (M-H) loop; The Bean Model; Pinning of vortices.

**Intended learning outcome:** Enables successful students to:

- (vii) Explain the formation of vortex in type-II superconductor.
- (viii) Demonstrate the formation of Abrikosov vortex of supercurrent in type-II superconductor.
- (ix) Explain the pinning of superconductor in space above a magnet.
- (x) Explain the irreversible magnetization behavior of hard type-II superconductor.

**4. High- $T_c$  Superconductors:** Introduction to high- $T_c$  superconductors: Cuprate, Organic, Diboride and Fe-based superconductors; Cuprates: Structure, Physical properties, Anisotropy, Electronic and Magnetic phase diagrams; Diborides: Structure and Physical properties; Applications of high- $T_c$  superconductors.

**Intended learning outcome:** Enables successful students to:

- (xi) Have working knowledge on various high- $T_c$  superconductors.
- (xii) Have detailed knowledge on diboride superconductors.

**5. Heavy Fermion Systems:** Heavy fermion superconductors: Structure and physical properties of heavy fermion systems; Magnetically mediated pairing; Electronic phase diagram of heavy fermion superconductors.

**Intended learning outcome:** Enables successful students to:

- (i) Have detailed knowledge on heavy fermion superconductors.

- (ii) Acquire detailed knowledge on the structure, properties and phase diagrams of Cuprate systems and use this knowledge for application purposes.

**6. Josephson Effect:** The tunnel effect: Metal-Insulator-Superconductor (MIS); Superconductor-Insulator-Superconductor (SIS) junctions; dc and ac Josephson effects; Josephson effect and Ginzburg-Landau equation; Josephson Junction in a circuit: The Resistance-Capacitance-Shunted Junction (RCSJ) model; Pendulum analog; Weak links: The Aslamazov-Larkin scenario; SQUIDS and their applications.

**Intended learning outcome:** Enables successful students to:

- (i) Explain the functioning of Josephson junctions in detail.
- (ii) Acquire considerable knowledge on SQUID magnetometry.
- (iii) Calculate junction current under different conditions.

**7. Fluctuation Effects in Superconductors:** TDGL equation, Paraconductivity and Fluctuation diamagnetism, Fluctuation heat capacity.

**Intended learning outcome:** Enables successful students to:

- (i) Explain the basic features of order parameter fluctuations in superconductors.
- (ii) Calculate fluctuation effects in superconductors.

Books recommended:

Waldram, JR	Superconductivity of Metals and Cuprates
Cyrot, M and Pavuna, D	Intro. to Superconducting and High- $T_c$ Materials
Poole, CP, Farah, HA,	
Creswick, RJ and Prozorov, R	Superconductivity (2nd Edition)
Ketterson, JB and Song, SN	Superconductivity
Burns, G	High Temperature Superconductivity (an Intro.)
Tinkham, M	Introduction to Superconductivity

**PH507 PHYSICS OF ENVIRONMENT**

(~75 lectures)

Full Marks: **100** (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: **4 hours**

**Prerequisite Knowledge:** PH202, PH407

**1. The Essentials of Environmental Physics:** The environment; The impact of environment upon human and vice versa; Global temperature; Greenhouse effect; The Energy Balance: A zero dimensional greenhouse model; Radiative

forcing; Global warming; Green house effect enhancement; Elements of weather and climate; Climate variations; Climate models.

**Intended learning outcome:** Enables successful students to:

- (i) Explain global warming.
- (ii) Demonstrate greenhouse effect.
- (iii) Analyze temperature, pressure, wind, humidity and precipitation to study weather and climate.
- (iv) Determine the effective earth emissivity of long wave radiation emitted to space.

**2. Mass and Energy Transfer:** Materials balance: Conservative and non-conservative systems; Pollutants; Step function response.

**Intended learning outcome:** Enables successful students to:

- (i) Demonstrate the adverse and undesired effects of pollutants.
- (ii) Explain the long- or short-term damage caused by pollutants by changing the growth rate of plant or animal species, or by interfering with human amenities, comfort, health, or property values.
- (iii) Demonstrate the horizontal and vertical zones of influence of pollutants.

**3. Air Pollution:** General consideration; Comparison of polluted and unpolluted air; Types of air pollutants- formation and sources; Effects of air pollutants on plants and human body; Acceptable limits of air pollutants; Control of air pollutants.

**Intended learning outcome:** Enables successful students to:

- (i) Differentiate between polluted and unpolluted air.
- (ii) Demonstrate the formation of air pollution.
- (iii) Demonstrate the effects of air pollution on plants and human.
- (iv) Construct a model to control air pollution.

**4. Water Pollution:** Water pollutants; Surface water quality: Rivers and streams, Effects of oxygen demanding waste in rivers, Ground water; Arsenic in drinking water: Source, Effects, Measurements, Prevention and control, Arsenic pollution in Bangladesh; Water purification process: in natural systems, physical process, chemical process, Bio-chemical process.

**Intended learning outcome:** Enables successful students to:

- (i) Learn about what causes water pollution and how to be environmentally aware.
- (ii) Assess the quality of surface water.
- (iii) Calculate the critical time and distance downstream at which the oxygen deficit is maximum.
- (iv) Know the causes, mechanism and effects of arsenic communication in ground water.
- (v) Increase the awareness among the people in our country about arsenic pollution.

**5. Noise Pollution and Control:** Sources of Noise pollution; Noise intensity; Human perception and noise criteria; Effect of noise on people; Factors affecting threshold shift; Noise pollution control.

**Intended learning outcome:** Enables successful students to:

- (i) Identify the sources of noise pollution.
- (ii) Grasp the various adverse impacts of noise pollution.
- (iii) Control the noise pollution.

**6. Mechanism of Pollutants Transport:** Diffusion and its application in practical purposes; Flow in rivers: One dimensional approach, the influence of turbulence, a continuous point emission; Ground water flow: Vertical flow in the unsaturated zone, Conservation of mass, Stationary flow, Vertical flow.

**Intended learning outcome:** Enables successful students to:

- (i) Calculate diffusion equation.
- (ii) Learn about Darcy's law and how water moves through an aquifer.
- (iii) Determine the hydraulic conductivity of aquifer material.
- (iv) Explain how quicksand is formed.

**7. Nuclear Waste and the Environment:** Power plant emissions: Radioactive gases and effluents; Radioactive waste, High-level waste; Impact of reactor accidents on the environment; Radioactive waste management; Decommissioning.

**Intended learning outcome:** Enables successful students to:

- (i) Learn about the radioactive wastes and their effects on the environment.
- (ii) Know about the impact of reactor accidents on the environment.
- (iii) Acquire knowledge about nuclear decommissioning.

Books recommended:

Masters, GM	Introduction to Environment Engineering and Science
Boecker, E and van Grondelle, R	Environmental Physics
Manahan, SE	Environmental Science & Technology
Stoker, HS and Scott, SLS	Environmental Chemistry
Monteith, JL and Unsworth, M	Principles of Environmental Physics
Peavy, HS and Rowe, DR	Environmental Engineering
Nevers, ND	Air Pollution Control Engineering
Bhatia, HS	A Textbook on Environmental Pollution and Control
Revenscroft, P, Brammer, H and Richards, K	Arsenic Pollution
Botkin, DB and Keller, EA	Environmental Science: Earth as a Living Planet
McGuffie, K and Henderson-Sellers, A	A Climate Modelling Primer

**PH508 CRYSTALLOGRAPHY & SPECTROSCOPY** (~75 lectures)

Full Marks: **100** (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: **4 hours**

**Prerequisite Knowledge:** PH304, PH404, PH406

1. **Symmetry Elements:** Point groups; uniaxial point groups; sub- and super-group of the point groups and space groups; their formation, general equivalent points, plane groups and their uses.

**Intended learning outcome:** Enables successful students to:

- (i) Demonstrate different symmetry elements.
- (ii) Differentiate between point group and space group.

2. **Fourier Transform:** Fourier series; Diffraction and Fourier transform; Convolution; Diffraction by a periodic distribution; Electron density equation.

**Intended learning outcome:** Enables successful students to:

- (i) Know the applicability of Fourier transform.
- (ii) Use Fourier transform to derive diffraction equation in reciprocal space.
- (iii) Calculate the inequality to show the condition of diffraction.
- (iv) Distinguish between diffractions from periodic and nonperiodic distribution of atoms.
- (v) Explain the effect of convolution and deconvolution.
- (vi) Calculate electron density.

**3. Factors Affecting X-ray Intensities:** Diffraction from a rotating crystal; Absorption of X-rays; Absorption correction; Temperature factor; Lorentz and polarization factors.

**Intended learning outcome:** Enables successful students to:

- (i) Know the mechanism of production of x-rays from atomic shell.
- (ii) Demonstrate the effect of crystal rotation on diffraction.
- (iii) Calculate the degree to which the electron density is spread out either for an atom or for a group of atoms.

**4. Determination of Crystal Structure:** Patterson function; Sharpened Patterson function; Harker line and section; Heavy atom method; Inequality relationship; Least Square Refinement; Fourier Refinement.

**Intended learning outcome:** Enables successful students to:

- (i) Calculate the coordinates of atoms and hkl/uvw values of the planes.
- (ii) Predict the differences among the various relationships.

**5. Infrared Spectroscopy:** Introduction to IR spectroscopy; Energy of diatomic molecule; Simple harmonic oscillator; Anharmonic oscillator; Molecular vibration; IR spectrum; Scanning of IR spectrum; Sampling Technique; Qualitative and quantitative interpretation of the IR spectra.

**Intended learning outcome:** Enables successful students to:

- (i) Demonstrate the way of calculating  $\chi^2$  value.
- (ii) Know the process of refining the crystal structure.

**6. Nuclear Magnetic Resonance Spectroscopy:** Nuclei in a magnetic field; Larmor precession; Bloch equation; Free induction decay; Nuclear interaction: Chemical shifts; Dipolar interaction; Quadrupolar interaction;

Relaxation process: Spin-Spin and Spin-lattice relaxation time; Magic angle spinning (MAS); A basic NMR Spectrometer; Interpretation of NMR spectra.

**Intended learning outcome:** Enables successful students to:

- (i) Know the range of IR radiation.
- (ii) Differentiate between harmonic and an-harmonic oscillator.
- (iii) Calculate the energy associated with various bonds.
- (iv) Vibrational mechanisms of various chemical bonds in a crystal and amorphous material.
- (v) Calculate the amounts of various components needed to prepare sample.
- (vi) Know the mechanism for preparation of sample and collection of IR spectrum.
- (vii) Predict the various chemical bonds and calculate their amounts.

**7. Neutron Scattering Theory and Application:** Basic properties of neutrons; Advantages of using neutron as an experimental probe; Basics of neutron diffraction; Neutron scattering – elastic and inelastic scattering; Small angle neutron scattering; Scattering by magnons and determination of magnetic order; Scattering by phonons – relevance to structure of materials and lattice dynamics.

**Intended learning outcome:** Enables successful students to:

- (i) Know the effect of static magnetic field upon nuclei.
- (ii) Know what is NMR signal and how it is detected.
- (iii) Know the effect of various interactions on static lineshapes and how do the adverse effects can be removed.
- (iv) Know the effect of  $t_1$  and  $t_2$  times on the collection of nmr spectrum.
- (v) Know the necessity of Fourier transform on NMR spectrum.
- (vi) Draw block diagram for NMR spectrometer.
- (vii) Assign various peaks with different chemical environments of the investigated nuclei.

Books recommended:

*Abragam, A*

*Azaroff, L*

*Buerger, MJ*

*Carlson, TA*

Introduction to Nuclear Magnetic Resonance

Elementary X-ray Crystallography

X-ray Crystallography

Photoelectron and Auger Spectroscopy



Harris, RK	Nuclear Magnetic Resonance Spectroscopy
Stout, GH and Jensen, LH	Practical Structure Determination
Woolfson, MM	X-ray Crystallography
Stranghan, BP and Walker, S	Spectroscopy
Sharma, BK	Spectroscopy
Akitt, JW	NMR and Chemistry
Bacon, GE	Neutron Diffraction
Willis, BTM and Carlile, CJ	Experimental Neutron Scattering
Squires, GL	Introduction Theory of Thermal Neutron Scattering

## PH509 PARTICLE PHYSICS AND COSMOLOGY

(~75 lectures)

Full Marks: **100** (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: **4 hours**

Prerequisite: PH 403, PH 407

**1. a) Relativistic Kinematics:** Lorentz transformations and covariance; Four-vector notation.

**b) Groups and their Representations:** Introductory group theory; Lie groups and algebra; Irreducible representations; SU(2); SU(3); Young's tableaux.

**Intended learning outcome:** Enables successful students to:

- (i) Describe the fundamentals of groups and their representations.
- (ii) Describe representations of symmetric group using young's tableaux.
- (iii) Calculate dimension of a representation.

**2. Feynman Diagram Techniques:** Fermi's golden rule for lifetimes and Cross-sections; Feynman rules for a toy scalar theory; Cross-sections and Lifetimes, Tree level and Higher order diagrams.

**Intended learning outcome:** Enables successful students to:

- (i) Draw relevant Feynman diagrams for a given process up to required order in a toy theory of three scalar particles (ABC theory).
- (ii) Calculate amplitudes for these diagrams.
- (iii) Use Fermi's golden rule to obtain cross sections and decay rates from amplitudes.
- (iv) Demonstrate the appearance of divergences in diagrams with loops.
- (v) Apply an ultraviolet cutoff to regularize a divergent amplitude.

3. **QED:** Dirac  $\gamma$ -matrices; Trace theorems; Feynman rules for QED; Calculation of cross-sections and lifetimes; Introduction to renormalisation.

**Intended learning outcome:** Enables successful students to:

- (i) Draw relevant diagrams and calculate amplitudes in QED (including manipulations of Dirac gamma matrices).
- (ii) Renormalize a vacuum polarization diagram.
- (iii) Calculate running (energy/momentum dependence) of the QED coupling.

4. **QCD:** QCD Feynman rules; Quark-antiquark and quark-quark interaction QCD; Confinement and asymptotic freedom; Perturbative and non-perturbative QCD.

**Intended learning outcome:** Enables successful students to:

- (i) Calculate potentials between quark-(anti)quark pairs in perturbative QCD for the possible colour configuration.
- (ii) Explain quark binding in hadrons in only one of possible colour configurations.
- (iii) Demonstrate the anti-screening of the strong coupling constant-leading to asymptotic freedom and confinement.
- (iv) Differentiate between the perturbative and non-perturbative regimes of QCD.

5. **Weak Interaction and Electroweak Unification:** Feynman rules for the weak interaction; Charged and neutral weak currents; Cabibbo angle; CKM matrix; Electroweak unification.

**Intended learning outcome:** Enables successful students to:

- (i) Explain the strength of flavour-changing weak decays
- (ii) Demonstrate the electroweak unification.

6. **Introduction to Lagrangians for Gauge Theories and Physics beyond the Standard Model (BSM):** Gauge Theories: Lagrangians for Scalar, Spinor and Vector particles; Derivation of Feynman rules; Global and Local gauge invariance; Spontaneous symmetry breaking; Higgs mechanism; BSM: GUTs, Neutrino masses and oscillation; Ideas of Supersymmetry and String Theory; LHC physics.

**Intended learning outcome:** Enables successful students to:

- (i) Write down Lagrangians for spinor, scalar and vector.
- (ii) Differentiate between global and local gauge invariance.
- (iii) Understand spontaneous symmetry breaking and Higgs mechanism.
- (iv) Have the basic knowledge of BSM, GUTs, neutrino oscillations, supersymmetry and string theory.

7. **Cosmology:** Expansion of the universe; Hubble's law; Big bang; Friedman equation; Hubble constant; Cosmological Models, Density parameter  $\Omega_0$ ; Deceleration parameter; Cosmological constant; Dark matter and its candidates; Dark energy; Cosmic microwave background; Inflation; Large scale structure.

**Intended learning outcome:** Enables successful students to:

- (i) Explain the ultimate fate of the universe.
- (ii) Find out whether the expansion of a model universe is acceleratory or not.
- (iii) Describe the behavior of matter dominated, radiation dominated or mixed flat universes.
- (iv) Explain the importance. of cosmological constant
- (v) Understand the dark matter and dark energy.
- (vi) Understand cosmic microwave background and its importance.

Books recommended:

<i>Griffiths, D</i>	Introduction to Elementary Particles
<i>Halzen, F and Martin, AD</i>	Quarks and Leptons
<i>Perkins, DH</i>	High Energy Physics
<i>Georgi, H</i>	Lie Algebras in Particle Physics
<i>Longair, MS</i>	High Energy Astrophysics
<i>Collins, PDB, Martin, AD &amp; Squires, FJ</i>	Particle Physics and Cosmology
<i>Rolnick, WB</i>	The Fundamental Particles and their Interactions
<i>Kane, G</i>	Modern Elementary Particle Physics
<i>Aitchison, IJR and Hey, AJG</i>	Gauge Theories in Particle Physics
<i>Bettini, A</i>	An Introduction to Elementary Particle Physics
<i>Mann, R</i>	An Introduction to Particle Physics and the Standard Model
<i>Liddle, A</i>	Introduction to Modern Cosmology
<i>Ryden, B</i>	Introduction to Cosmology

Dodelson, S

Kolb, E and Turner, M

Weinberg, S

Modern Cosmology

The Early Universe

Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity

## PH510 ADVANCED REACTOR PHYSICS

(~ 75 lectures)

Full Marks: **100** (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: **4 hours**

**Prerequisite:** PH403, PH407,

**1. Nuclear Reactors and Nuclear Power:** Components of nuclear reactors; Non-nuclear components of nuclear power plants; Power reactors and Nuclear steam supply systems; PWR, Organic-cooled reactors; Gas-cooled thermal reactors; Heavy-water reactor; Breeder reactors: LMFBR; MSBR.

**Intended learning outcome:** Enables successful students to:

- (i) Know about the nuclear and non-nuclear components of a nuclear reactor.
- (ii) Calculate the efficiency of a reactor.
- (iii) Learn how to convert fertile isotopes into fissile isotopes.
- (iv) Learn about breeding and its importance for the future of nuclear energy.
- (v) Design a nuclear reactor.

**2. Nuclear Reactor Theory:** One-group reactor equation for different reactor shapes; Two-group critical equations; Calculations of critical size; Reflected reactors.

**Intended learning outcome:** Enables successful students to:

- (i) Derive one and two group reactor and critical equations.
- (ii) Calculate the critical mass and size of the reactor.
- (iii) Calculate the critical fuel amount for a particular shape and size of a reactor.
- (iv) Know the use of reflectors.

**3. Heat Removal:** General thermodynamic considerations; Heat generation in reactors; Heat flow by conduction; Heat transfer to coolants; Boiling heat transfer; Reactor coolants and associated phenomena.

**Intended learning outcome:** Enables successful students to:

- (i) Know the sources of heat energy in a reactor.
- (ii) Know the detail of heat flow and transfer of heat to coolants.
- (iii) Know the detail procedure of removing heat for uses from the core.

**4. Reactor Materials:** Structural materials; Moderator and reflector materials; Radiation effects on materials; Corrosion and chemical reactions in coolant circuit materials.

**Intended learning outcome:** Enables successful students to:

- (i) Select the proper material for the construction of different components of a reactor.
- (ii) Know how to minimize the radiation damage.

**5. Time Dependent Reactor:** Reactor Kinetics; Control rods and chemical shim, Temperature effects on reactivity, Fission production poisoning, Core properties during lifetime.

**Intended learning outcome:** Enables successful students to:

- (i) Know the time dependent behavior of nuclear reactor.
- (ii) Know the use of control rods to control the reactor power and handle the emergency.
- (iii) Know the effect of temperature on reactivity.
- (iv) Demonstrate fission product poisoning.

**6. Reactor Shielding and Safety:** Principles of reactor shielding; Different types of shielding systems and materials; Attenuation of fast neutrons and gamma rays; Principles of Nuclear power plant safety; Reactor accidents and risk analysis.

**Intended learning outcome:** Enables successful students to:

- (i) Know the sources of  $\gamma$  and neutron radiation.
- (ii) Know the positive uses of radiation.
- (iii) Know how to dispose the high level radioactive materials.
- (iv) Understand three level of safety.
- (v) Design the reactor protector systems.
- (vi) Know the future of nuclear power.

Books recommended:

Stacey, WM

Nuclear Reactor Physics

Duderstadt, JJ and Hamilton, LJ	Nuclear Reactor Analysis
Garg, S et al	Nuclear Reactor Physics
Garland, WJ	www.nuceng.ca (website)
Glasstone, S and Sesonske, A	Nuclear Reactor Engineering
Liverhant, SE	Elementary Introduction to Nuclear Reactor Physics
Lamarsh, JR	Introduction to Nuclear Engineering
Murray, RL	Introduction to Nuclear Engineering
King, DG	Nuclear Power Systems
Henry, A	Nuclear Reactor Analysis

**PH511 BIOMEDICAL INSTRUMENTATION AND IMAGING SYSTEM**

**(~75 lectures)**

Full Marks: **100** (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: **4 hours**

- 1. Fundamentals of Medical Instrumentation:** Physiological systems of human body; Cardio vascular system; Respiratory system; Nervous system; Source of biomedical signals; Basic medical instrumentation system; Microprocessor; Interfacing of analog signals to microprocessors; PC based medical instruments.
- 2. Bioelectric Signals and Electrodes:** Origin of bioelectric signals; Electrocardiogram (ECG), Electroencephalogram (EEG); Electromyogram (EMG); Recording electrodes; Metal-electrolyte interface; Skin contact impedance; Silver-silver chloride electrodes; Electrodes for: ECG, EEG, EMG; Electrical conductivity of jellies and creams.
- 3. Instrumentation Amplifier and Recorders:** Principle of instrumentation amplifier; Carrier amplifier; Chopper amplifier; Biomedical signal analysis techniques; Fourier transform; Signal processing techniques; Writing processes: Ink jet recorder; Potentiometric recorder; Digital recorder, Biomedical recorders; ECG; Vector cardiograph (VCG); EEG; EMG; Biofeedback instrumentation.
- 4. Patient Monitoring System:** Cardiac monitor; Cardiac monitor using digital memory; Central monitors; Measurement of: Heart rate, Pulse rate, Blood pressure, Respiration rate, Foetal monitoring instruments.
- 5. Clinical Laboratory Instruments and Blood Cell Counters:** Principles of spectrophotometer; Microprocessor based spectrophotometer; Automated biochemical analysis system; Clinical flame photometer; pH measurements of blood; Blood pCO<sub>2</sub>; Blood pO<sub>2</sub> ; Complete blood gas analyzer; Methods of blood cell counting; Coulter counters; Automatic recognition and differential counting at cells.

6. **Audiometer and Hearing Aids:** Basic audiometer; Sections of audiometer; Mechanical; Electrical; Evoked response audiometer system; Hearing aids; Conventional, Digital; Cochlear implants.
7. **Modern Imaging Instrumentation:** X-ray machines; Digital radiography; X-ray computed tomography (CT); Position emission tomography (PET); Nuclear medical imaging; Magnetic resonance imaging (MRI) ; Ultrasonic imaging; Thermal imaging.
8. **Therapeutic Equipments:** Cardiac pacemaker; Cardiac defibrillators; Haemodialysis machines; Lithotripter machine; Radiotherapy equipment; Physiotherapy and electrotherapy equipment.

Books recommended:

R,S, Khandpur	Handbook of Biomedical Instrumentation
L Cromwell, F J. Weibell, E A Pfeiffer	Biomedical Instrumentation and Measuring system
B.L. Chrisfe	Introduction to Biomedical Instrumentation

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**PH512 QUANTUM FIELD THEORY**

(~ 75 lectures)

Full Marks: **100** (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: **4 hours**

1. **Canonical Quantisation:** Real Klein-Gordon field; Complex Klein-Gordon field; Dirac (Spinor) field; Electromagnetic vector field; Choice of gauge.
2. **Perturbative Expansion, Feynman Diagrams Techniques and Path Integral Quantisation:** Perturbative (loop) expansion; Feynman diagrams; Propagators and interactions; S-matrix; Path integral formalism; Generating functional; Green's function for free and interacting fields; Examples using  $\phi^4$  theory; Connected and disconnected diagrams; Fermions; LSZ reduction formula; Gauge fields; Gauge invariance; QED: Photon propagator; Self-energy; Ward-Takahashi identities; Cross-sections for some elementary processes.
3. **Renormalisation:** Renormalisability of a theory; Ultraviolet and infrared divergences; Divergences in  $\phi^4$  theory; Dimensional regularization; Renormalisation of  $\phi^4$  theory; Divergences in QED; Renormalisation of QED; Renormalisation group.
4. **Symmetry Breaking:** Goldstone theorem; Pion as a Goldstone-Nambu boson; Higgs mechanism and Glashow-Salam-Weinberg model.
5. **Applications:**

- a) Non-Abelian Gauge Theories: Yang-Mills theory; Faddeev-Popov ghosts; One-loop divergences in QCD; Asymptotic freedom.
- b) Condensed Matter Physics: Superfluids; Landau-Ginzburg theory; Superconductivity; Quantum Hall fluids.

Books recommended:

<i>Peskin, ME and Schroeder, DV</i>	An Introduction to Quantum Field Theory
<i>Ryder, LH</i>	Quantum Field Theory
<i>Zee, A</i>	Quantum Field Theory in a Nutshell
<i>Ramond, P</i>	Field Theory: A Modern Primer
<i>Weinberg, S</i>	Quantum Theory of Fields, vols. 1 and 2
<i>Itzhikson, C and Zuber, J</i>	Quantum Field Theory
<i>Kaku, M</i>	Quantum Field Theory
<i>Srednicki, M</i>	Quantum Field Theory

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**PH513 OPTICAL FIBRE PHYSICS**

(~ 75 lectures)

Full Marks: **100** (Examination 80, Tutorial/Terminal 15, and Attendance 5)

(5 questions to be answered)

Examination duration: **4 hours**

- 1. Basic Characteristics:** Ray theory; Electromagnetic theory; Single mode fibre; Multimode fibres.
- 2. Transmission Characteristics:** Material absorption loss; Linear ion linear scattering loss; Band loss; Splice loss; Different types of dispersions; Polarization.
- 3. Fabrication of Optical Fibre:** Liquid phase technology; Vapour phase deposition technique (OVP, VAD, MCVD and PCVD); Fluoride gas fibers.
- 4. Optical Communication Systems:** Sources: Different types of LASER and their characteristics; LEDs; Detectors: Principles, PIN photodiodes; APDs; Transmitter; Fibre sensors; Optical interferometers.
- 5. Optical Amplifications and Integrated Optics:** Optical amplifier; Fibre amplifier; Integrated optics principle; Planer waveguide; Integrated optical devices.
- 6. Measurement Methods in Optical Fibre:** General experimental consideration; Measurement of attenuation; Refractive index profile; Numerical aperture; Pulse dispersion and bandwidth.



Books recommended:

Ghatak, A and Thyagarajan, K	Introduction to Fibre Optics
Seuitor, JM	Optical Fibre Communication
Ghatak, A and Thyagarajan, ZK	Optical Electronics
Shydev, AW and Love, JD	Optical Waveguide Theory
Gowav, P	Optical Communication
Lacy, EA	Fiber Optics

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**PH523 PRACTICALS**

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*Full Marks: 200 (Continuous Assessment-60 marks Practical Examination 140 marks. 4 days for experiments and one day for defense on experiment)*

*Examination Duration: 5×6 hours*

**List of Experiments**

1. Determination of total cross-section by analyzing bubble chamber photos.
2. Measurement of the range of  $\pi$ -meson in liquid hydrogen.
3. Determination of the maximum energy of beta particles from its energy spectrum.
4. Measurement of the mass of  $\pi$ -meson from the analysis of the decay of pions and muons in hydrogen bubble chamber.
5. Analysis of nuclear interactions on a bubble chamber film using relativistic kinematics.
6. a) Determination of the thermal neutron flux using neutron activation method.  
b) Determination of the half-life of a radioisotope using  $^7\text{mCi}$  Ra-Be neutron source.
7. Studies of magnetic properties of a ferromagnetic sample using an oscilloscope.
8. Studies of conductivity and activation energy of a semiconducting sample and measurement of TCR.
9. Determination of Hall constant, Hall mobility and other related parameters of a semiconducting sample.
10. Study of the characteristics of a solar cell/panel.
11. Deconvolution of digitized NMR spectrum and hence identification and quantification of various species present in an amorphous material.

12. Identification and quantification of various chemical bonds present in a specific material by using IR Spectrum.
13. Estimation of absorption coefficient and optical band gap from absorption edge of amorphous and crystalline semiconductors.
14. Study of pulse width modulation (using 555 timer).

