UNIVERSITY OF CALCUTTA

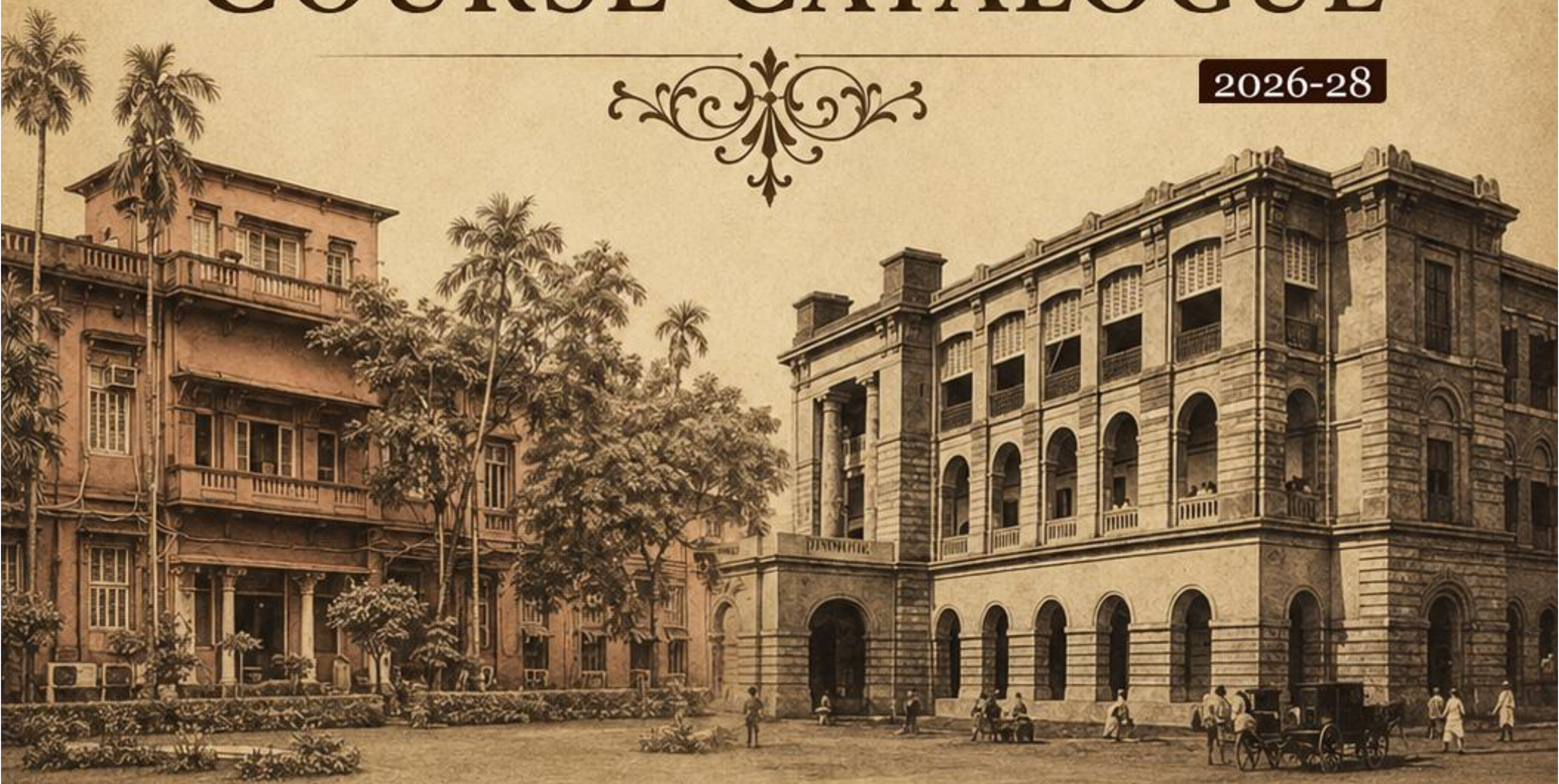
BOSE INSTITUTE

AND

M.Sc.-Ph.D.

COURSE CATALOGUE

2026-28



In Pursuit of Knowledge
For the Advancement of Science and Humanity

UNIVERSITY OF CALCUTTA

AND

BOSE INSTITUTE

Integrated M.Sc. - Ph.D. Programme

| LIFE SCIENCES | AND
| PHYSICAL SCIENCES |

2026-2028

http://www.jcbose.ac.in/integrated-phd

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Bose Institute in collaboration with the University of Calcutta offers Integrated M.Sc.-Ph.D. Program (duration 2+4 years) in Life Sciences and Physical Sciences. The Life Sciences programme was initiated in September 2011 and Physical Science in August 2012. With specialized topics in Life Sciences and Physical Sciences, this program is designed to nurture curiosity, foster innovation, and build a strong foundation for a career in advanced research.

Bose Institute

The historic Bose Institute – a temple of science – was founded by the visionary scientist Acharya Jagadish Chandra Bose on November 30, 1917, to investigate "the many and ever opening problems of the nascent science which includes both life and non-life." The Bose Institute is one of the earliest modern institutes in India, with a strong tradition of scientific research. This institute played a pivotal role in the Indian scientific renaissance during the colonial era, marked by the groundbreaking contributions of Acharya Bose himself, his students, Prof. D. M. Bose, and many other globally recognized scientists.

Bose Institute boasts seven campuses across different geographical regions of West Bengal. On 29th June 2017, the Unified Academic Campus (UAC), equipped with modern amenities, was inaugurated by the President of India. The UAC now hosts all research laboratories. Ever since the establishment of the Department of Science and Technology (DST), Government of India, in May 1971, Bose Institute has been an autonomous grant-in-aid institution of DST.

Acharya Jagadish Chandra Bose

Acharya Jagadis Chandra Bose (November 30, 1858 — November 23, 1937) was a pioneering Indian scientist renowned for his groundbreaking work in both physics and plant physiology. He studied in Kolkata and later attended the University of Cambridge and University College London in the United Kingdom. Acharya Bose made significant contributions to the study of radio and microwaves, becoming one of the earliest scientists to demonstrate their transmission and reception using semiconductor detectors. Using the ingenious Crescograph, an instrument that could measure minute movements in plants, he proved that plants respond to external stimuli, such as light, heat, and chemicals—similar to animals. He was the first from the Indian subcontinent to obtain a US patent. A true polymath, Acharya was also a writer and founded the Bose Institute in Kolkata, which became a hub for interdisciplinary scientific research. His legacy continues to inspire generations of scientists in India and around the world.

University of Calcutta

Established on 24 January 1857, University of Calcutta is located in the city of Kolkata (previously Calcutta), and is one of the most renowned universities in the Indian subcontinent. Over time, it has played a vital role in the development of India's nationhood not only by spreading progressive social ideas and values but also by establishing the ability of Indian researchers to carry out advanced scientific and technological research and rediscover the great philosophical, cultural and literal heritage of the country. The university website is http://www.caluniv.ac.in

About the Program

The integrated M.Sc.-Ph.D. programme in Life Sciences and Physical Sciences are offered as a combination of a two-year (four semesters) M.Sc. course followed by a Ph.D. programme at Bose Institute, subject to qualifying conditions as mentioned later.

The M.Sc. curriculum of Life Sciences programme consists of following specializations during project work: (i) Molecular & Cellular Biology, (ii) Plant Molecular Biology & Biotechnology, (iii) Biophysical Chemistry and (iv) Computational & Systems Biology.

In the M.Sc. curriculum of Physical Sciences programme specialization is available in the form of a one-semester project in one of the following areas: (i) High Energy Physics, Astrophysics and Cosmology, (ii) Space Science, Fluid Mechanics and Solar Physics and (iii) Condensed matter Physics and Complex Systems.

Course Objectives

- To deepen students' understanding of the fundamental principles in Life Sciences and Physical Sciences, enabling them to build a robust conceptual foundation essential for advanced scientific inquiry and interdisciplinary exploration.
- To nurture the curiosity of young minds, cultivate their critical thinking skills and foster a spirit of innovation.
- To develop skilled human resources equipped to address contemporary scientific and societal challenges.

Course Highlights

- The academicians of Bose Institute and other leading Institutes in Kolkata and across the country will teach and mentor the students for a Research Career in Modern Biology.
- Students will get extensive exposure to theory and experimental aspects of Modern Biology as well as computational techniques of Modem Biology.
- Extensive exposure to the theory, experimental methodologies of Modern Physics and computational techniques.
- Students will be encouraged to participate in the institutional and journal club seminars, interactive

sessions and other relevant scientific activities.

- All necessary institutional facilities including Library and Internet facilities will be available for use by the students during the course.

Fellowship

- **M.Sc. Fellowship:**

During the first two years of the M.Sc. programme, all students are provided a fellowship of ₹12,000 per month. Continuation of the fellowship is subject to the following conditions:

- The student must secure a minimum SGPA of B+ grade in the previous semester.
- The student must not receive an F grade in any individual paper.
- The student must maintain at least 80% attendance in classes during the previous semester.

- **Ph.D. Fellowship:**

Students enrolled in the Ph.D. programme are expected to obtain fellowship support through national-level examinations.
Eligible candidates may also receive institute fellowship, in accordance with the rules specified under “Admission to Ph.D. Course” (Page 14).

Examination

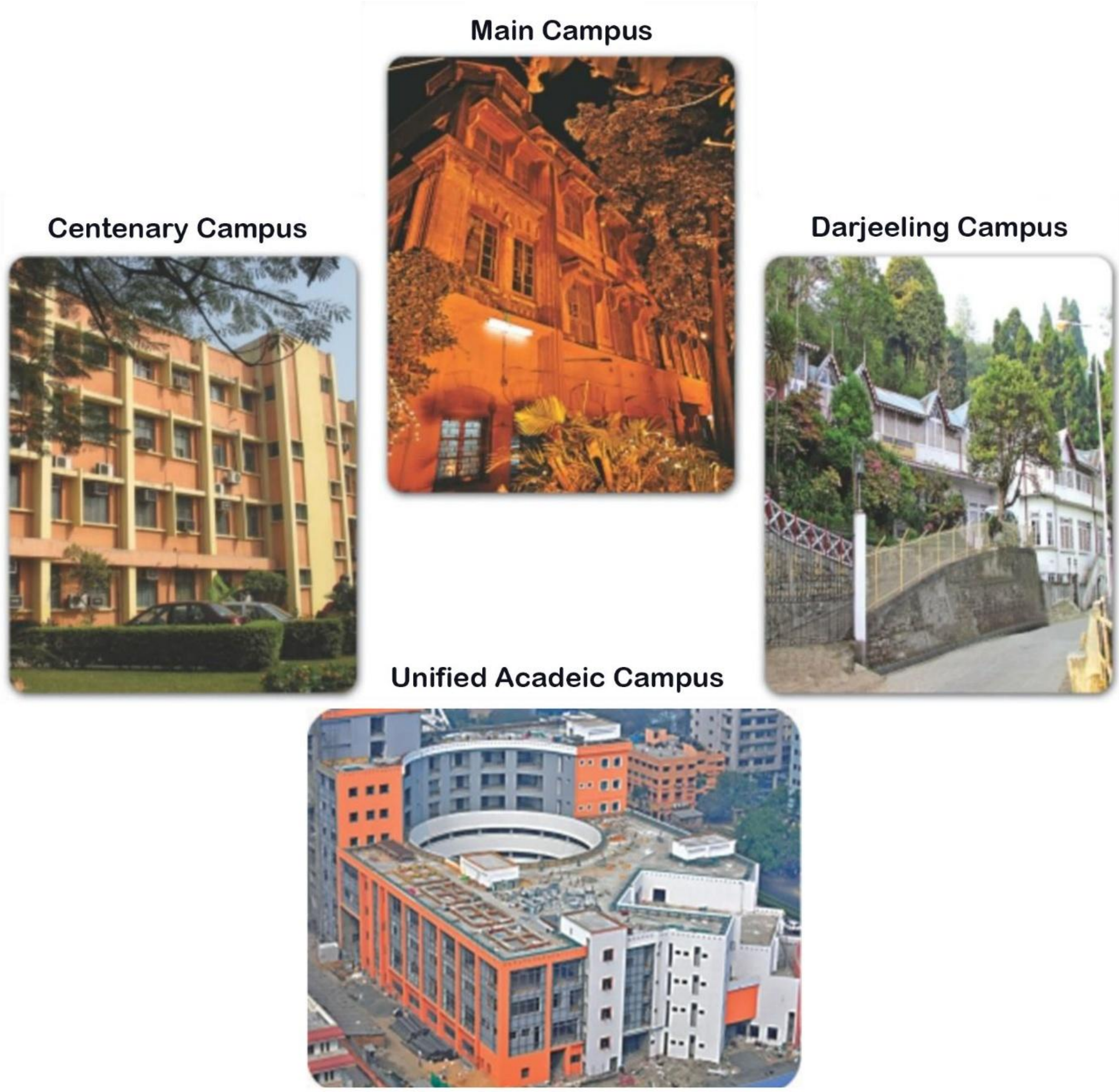
There shall be following four examinations in the M. Sc. course in the span of two years.

Examination-I: On completion of the course specified for the first semester.
Examination II: On completion of the course specified for the second semester
Examination III: On completion of the course specified for the third semester
Examination IV: On completion of the course specified for the fourth semester and assigned project work and specialized subjects.

Attendance: Other than project work, no candidate shall be deemed to have pursued a regular course of study unless he/she has attended at least 75% of theory, practical and tutorial classes, in each course.

Dissertation: Dissertation shall consist of either original project work, or a detailed Review of Literature, or both, in thesis format, to be evaluated at the end of the second year.

Note: The medium of instruction and examination shall be English. Practical paper will be based on continuous assessment throughout each semester



Unified Academic Campus
EN-80, Sec-V, Salt Lake City
Kolkata – 700091, West Bengal
Phone: (+91)(33) 2569-3123
Fax: (+91)(33) 2569-3127

Main Campus
93/1, Acharya Prafulla Chandra Road
Kolkata – 700009, West Bengal, India

Centenary Campus
P-1/12, C.I.T. Scheme VII (M)
Kolkata-700054, West Bengal

ACADEMIC CALENDAR FOR M.Sc.

The academic session for M.Sc. curriculum in the Integrated M.Sc.-Ph.D. programme starts in September. The full session is divided into four semesters of 26 weeks each. The following is a generic academic calendar:

WEE	SEMESTER 1	SEMESTER 2	SEMESTER 3	SEMESTER 4
01	REGULAR COURSES	REGULAR COURSES	REGULAR COURSES	REGULAR COURSES
02				
03				
04				
05				
06				
07				
08				
09	MID-SEM EXAMINATION	MID-SEM	MID-SEM	
10		EXAMINATION	EXAMINATION	MID-SEM EXAM
11	REGULAR COURSES	REGULAR COURSES	REGULAR COURSES	REGULAR COURSES
12				
13				
14				
15				
16				
17				
18	STUDY BREAK	STUDY BREAK	STUDY BREAK	SUBMIT PROJECT REPORT
19				
20				STUDY BREAK
21	EXAMINATIONS	EXAMINATIONS	EXAMINATIONS	
22				EXAMINATIONS
23				
24	SEMESTER BREAK & RESULTS	SEMESTER BREAK & RESULTS	SEMESTER BREAK & RESULTS	SEMESTER BREAK & RESULT
25				
26				

FEE STRUCTURE FOR M.Sc.-Ph.D. Programme

The following are the fees to be paid by each student at the time of admission

Details of fee payable	Amount	Frequency	Remarks
Admission Fee	₹ 1000 (waived for SC/ST/DAP)	One time	Non-refundable
Caution Money (Laboratory)	₹ 12000	One time	Refundable at the end of the course
Caution Money (Library and Computer)	₹ 3000	One time	Refundable at the end of the course
Tuition Fee	₹ 6000 (₹ 3000 for SC/ST/DAP)	Per semester	Non-refundable
Hostel Seat Rent*	₹ 2000	Per month	Non-refundable

* Based on Availability

COURSE STRUCTURE FOR M.Sc. | PHYSICAL SCIENCES

SEMESTER I | Class Weeks: 15 | Total Credits: 20 | Total Marks: 250

Paper	Module	Subject	Contact Hours/ Week	Credits	Marks
PS 4101	CT-MP-I	Mathematical Physics I	2	2	25
	CT-MP-II	Mathematical Physics II	2	2	25
PS 4102	CT-CM	Classical Mechanics	3	3	35
	CT-NLD	Nonlinear Dynamics	1	1	15
PS 4103	CT-MP-III	Mathematical Physics III	1	1	15
	CT-QM-I	Quantum Mechanics I	3	3	35
PS 4104	CT-SP-I	Statistical Physics I	2	2	25
	CT-ED-I	Electrodynamics I	2	2	25
PS 4151	CE-GE-I	General Experiments I	8	4	50
Total			**24**	**20**	**250**

SEMESTER II | Class Weeks: 15 | Total Credits: 20 | Total Marks: 250

Paper	Module	Subject	Contact Hours/ Week	Credits	Marks
PS 4205	CT-QM-II	Quantum Mechanics II	2	2	25
	CT-QM-III	Quantum Mechanics III	2	2	25
PS 4206	CT-SP-II	Statistical Physics II	2	2	25
	CT-ED-II	Electrodynamics II	2	2	25
PS 4207	CT-SSP1	Solid State Physics I	2	2	25
	CT-SSP-II	Solid State Physics II	2	2	25
PS 4252	CC-NI	Numerical & Interfacing	8	4	50
PS 4253	CE-GE-II	General Experiments II	8	4	50
Total			**28**	**20**	**250**

SEMESTER III | Class Weeks: 15 | Total Credits: 20 | Total Marks: 250

Paper	Module	Subject	Contact Hours/ Week	Credits	Marks
PS 4308	CT-ATM	Atomic Physics	2	2	25
	CT-MOL	Molecular & Laser Physics	2	2	25
PS 4309	CT-NP	Nuclear Physics	2	2	25
	CT-PP	Particle Physics	2	2	25
PS 4310	CT-EL	Electronics	2	2	25
	CT-INT	Instrumentation	2	2	25
PS 4354	CE-EC	Electronics & Communication Experiment	8	4	50
PS 4355	CE-GE-III	General Experiments III	8	4	50
Total			**28**	**20**	**250**

SEMESTER IV | Class Weeks: 15 | Total Credits: 20 | Total Marks: 250

Paper	Module	Subject	Contact Hours/ Week	Credits	Marks
PS 4461	SP-PRJ	Project and Dissertation	20	12	150
PS 4471*	CBCC-I	Complex Systems	4	4	50
PS 4472*	CBCC -II	Nanoscale Materials	4	4	50
PS 4473*	CBCC -III	Biomedical Nanotechnology	4	4	50
PS 4474*	CBCC -IV	Atmospheric Science	4	4	50
PS 4475*	CBCC -V	Climate Change and Global Environmental Sustainability	4	4	50
Total (PS 4461 and any two papers from the remaining)			**28**	**20**	**250**

***Any two may be chosen by each candidate. Final distribution to be decided by the Dean, Students Affairs.**

The above course structure is subject to modifications from time to time as decided by the Board of Studies.

COURSE STRUCTURE FOR M.Sc. | LIFE SCIENCES

SEMESTER I | Class Weeks: 15 | Total Credits: 20 | Total Marks: 260

Code	Subject	Contact Hours/ Week	Credits	Marks
BS401	Biochemistry-I	1	1	15
BS402	Cell Biology	2	2	25
BS403	Microbiology	1	1	15
BS404	Molecular Biology	2	2	25
BS405	Biophysical Chemistry-I	2	2	25
BS406	Mathematical and Computational Tools in Biology	2	2	25
BS407	Chemical principles in Biological Processes	2	2	25
BS408	Physiology of Animal	1	1	15
BS409	Plant Physiology & Biochemistry	1	1	15
BS410	Practical	12	6	75
	Total	**26**	**20**	**260**

SEMESTER II | Class Weeks: 15 | Total Credits: 20 | Total Marks: 250

Code	Subject	Contact Hours/ Week	Credits	Marks
BS501	Biochemistry-II	2	2	25
BS502	Genetics and Genomics	2	2	25
BS503	Immunology	2	2	25
BS504	Developmental Biology	2	2	25
BS505	Cell Signaling	2	2	25
BS506	Biophysical Chemistry-II	2	2	25
BS507	Bioinformatics and Computational Biology	2	2	25
BS510	Practical	12	6	75
	Total	**26**	**20**	**250**

SEMESTER III | Class Weeks: 15 | Total Credits: 20 | Total Marks: 250

Code	Subject	Contact Hours/ Week	Credits	Marks
BS601	Advanced Methods in Structural Biology	2	2	25
BS602	Ecology and Evolution	2	2	25
BS603	Disease Etiology in Animals	2	2	25
BS604	Pathophysiology in Plants & Crop Improvement	2	2	25
BS605	Fundamentals of Systems Biology	1	1	15
BS606	Entrepreneurship & Product Development	1	1	15
BS607	Any two from CBCS-A/ CBCS-B/ CBCS-C	8	8	100
BS610	Choice Based Laboratory Practical	4	2	20
	Total	**22**	**20**	**250**

SEMESTER IV | Class Weeks: 15 | Total Credits: 20 | Total Marks: 240

Code	Subject	Contact Hours/ Week	Credits	Marks
BS701	Term Paper	1	1	20
BS702	Project, Dissertation and Seminar	34	17	180
BS703	Comprehensive Viva	-	2	40
	Total	35	**20**	**240**

EVALUATION STRUCTURE FOR M.Sc.

The evaluation structure will be as follows:

Theory Papers:

Continuous Internal Assessment: 10%
Mid Semester Examination: 30%
End Semester Examination: 60 %

Experiment/Computation papers:

Continuous Internal Assessment: 50%
End Semester Examination: 50%

Choice based Practical

Continuous Internal Assessment: 70%
Lab Work Report- 30%

Term Paper

Report: 50%
Presentation: 50%

Project and Dissertation:

Continuous Internal Assessment: 20%
Mid Semester Presentation & Viva: 25%
End Semester Presentation & Viva: 25%
M.Sc. Project Report: 30%

Grand Viva:

End Semester Examination: 100%

End semester examination duration-

4 credit - 2.5 hours
3 credit - 2 hrs
2 credit- 1.5 hrs
1 credit - 45 minutes

Credits and Grade Points

Credits

One credit corresponds to 1 contact hour per week for theory courses and 2 contact hours per week for other courses for 15 weeks. In all semesters a candidate attending equal or more than 80% of classes in aggregate will receive full credit. Otherwise, the candidate has to continue from the same semester in the very next year.

In the exceptional cases, where aggregate attendance is less than 80%, but at least 60%, competent authority may examine and give condonation of attendance in deserving cases.

Grades

Grading is done only for candidates eligible to appear in the end-semester examinations. A ten-point credit system is adopted. Pass grade point is 4.000. If in a paper ia candidate secures a percentage of marks PM_i^E, where $PM_i^E$is at least 40, then the grade point of the candidate is $PM_i^E = 4.000 + 0.1(PM_i^E - 40)$ to be rounded off to two decimal places. Numerical grade point for a failed paper is zero. The grading table is as follows.

% of Marks (PM)	Grade Points (GP)	Letter Grades	
90 ≤ PM ≤ 100	9.00 ≤ GP ≤ 10.00	O	Outstanding
80 ≤ PM < 90	8.00 ≤ GP < 9.00	A+	Excellent
70 ≤ PM < 80	7.00 ≤ GP < 8.00	A	Very Good
60 ≤ PM < 70	6.00 ≤ GP < 7.00	B+	Good
55 ≤ PM < 60	5.50 ≤ GP < 6.00	B	Above Average
50 ≤ PM < 55	5.00 ≤ GP < 5.50	C+	Average
40 ≤ PM < 50	4.00 ≤ GP < 5.00	C	Below Average
40	4.00	P	Pass
< 40	0.00	F	Fail
Absent	0.00	AB	Absent

If the credit in the i^{th}paper is C_i, and $C_i^E$is the credits earned and GP_i^E is the grade points earned, then credit point in the paper is $C_i^E GP_i^E$. The Semester Grade Point Average (SGPA) is given as $SGPA = \sum_{i=1}^{n} C_i^E GP_i^E / C_S$, where the total semester credit is $C_S = \sum_{i=1}^{n} C_i$, and there are total n individual papers in the semester. Similarly, if there are N papers in the entire M.Sc. course, then the Cumulative Grade Point Average (CGPA) is given as $CGPA = \sum_{i=1}^{N} C_i^E GP_i^E / C_T$, where the total course credit is $C_T = \sum_{i=1}^{N} C_i$. All the SGPAs and CGPAs are rounded off to three decimal places. On the basis of CGPA obtained by a candidate, final grade and class are awarded as follows:

CGPA	Grades		Class
9.000 ≤ CGPA ≤ 10.000	O	Outstanding	1st Class
8.000 ≤ CGPA < 9.000	A+	Excellent	1st Class
7.000 ≤ CGPA < 8.000	A	Very Good	1st Class
6.000 ≤ CGPA < 7.000	B+	Good	1st Class
5.500 ≤ CGPA < 6.000	B	Above Average	2nd Class
5.000 ≤ CGPA < 5.500	C+	Average	2nd Class
4.000 ≤ CGPA < 5.000	C	Below Average	2nd Class
CGPA < 4.000	F	Fail	Fail

Examination Regulations

(1) ***Attendance:***

a) A candidate is eligible to appear in the end semester examination, provided that the candidate has attended at least 80% of the total number of classes* held in the semester.
b) A candidate attending at least 60% but less than 80% of the total number of classes* held shall, however, be eligible to appear at the concerned semester examination upon obtaining condonation order from the competent authority.
c) A candidate with less than 60% attendance is not allowed to appear in the respective semester examination. He/she must continue from the same semester in the very next year.

**Such attendance will be calculated from the date of commencement of classes or date of admission, whichever is later.*

(2) ***General Rules:***

a) Passing criteria is to obtain **P** grade in each and every paper in all the four semesters. A candidate is required to clear all the semesters within a span of four years from the year of admission, failing which enrolment of the candidate shall stand cancelled.
b) Internal Assessment has to be done in the semester in which a candidate becomes eligible to appear in the respective end-semester examination. Candidates remaining absent in the written examination for Internal Assessment are awarded zero (0) marks in the written part of internal examination. Marks obtained in Internal Assessment are retained for the entire duration of his/her enrolment.
c) Marks for the papers in which the candidate secures at least pass marks as stated in Clause (2a), are retained for the entire duration of his/her enrolment.
d) A candidate eligible to appear in any of the end-semester examinations of 1st and 2nd semester, but does not do so or fails to secure **P** grade in any paper(s), may reappear in the next equivalent end-semester examination. In case of such a situation in the 3rd and / or 4th semester, the candidate can appear in supplementary examinations for those paper(s) to be held after the declaration of the 4th semester results, to be scheduled by competent authority.
e) A candidate who is eligible to appear in any of the end-semester examinations, but does not do so or fails to secure **P** grade in any paper(s), will be allowed to attend the classes in the next higher semester, as applicable.
f) A candidate may appear in an end-semester examination without appearing in the previous end-semester examinations subject to Regulation 1.

(3) ***Review Rules:***

a) Candidates seeking review may apply within seven (7) working days from the date of issue of Grade Card.
b) Application for review shall be restricted to theoretical papers only.
c) Maximum two (02) theoretical papers in any semester examination may be re-examined on request by the examinee subject to the condition that she / he secures a minimum of **P** grade in the rest of theoretical and computational papers in a semester.
d) In re-examination of scripts in a paper, the marks awarded by the re-examiner will be taken as the marks obtained by the examinee in that paper.
e) If on re-examination in a paper the marks get enhanced by more than 15% or get reduced by more than 5% than that awarded by the original examiner (the percentage be calculated on the basis of the full marks in that paper), the script of the paper will be referred to a third examiner and average of two marks (excluding the lowest one) as awarded by the three examiners shall be taken as the marks obtained by the examinee in that paper, provided that such a final award does not result in lowering of the Letter Grade of SGPA / CGPA / Class obtained by the examinee prior to re-examination in which cases the original award will be retained.

M.Sc. Degree:

On successful completion of the course, the M.Sc. degree will be awarded to the candidates.

Exit Option:

The candidates may leave the programme after the completion of the M.Sc. course. They will be awarded M.Sc. degree in respective subject.

Admission to Ph.D. Course

Admission to the Ph.D. course at Bose Institute is subjected to the following conditions:

(i) A candidate who would obtain 60% or above marks in aggregate in 1st, 2nd and 3rd semesters and at least 75% marks in the project work in the 4th semester, will be allowed to continue for Ph.D. degree under the guidance of a particular supervisor. They will also be declared as have passed M.Sc. examination.

(ii) A candidate must qualify either in CSIR-UGC NET, GATE or equivalent examinations conducted by Central Government Departments and their Agencies and Institutions such as CSIR, UGC, DST, DBT, DAE, DOS, DRDO, MHRD, ICAR, ICMR, IIT, IISC, IISER for enrolment to the Ph.D. programme.

(iii) An eligible faculty member at Bose Institute having vacancy for registration of Ph.D. student under his/her direct supervision, as per the guideline of the UGC, GoI, is willing to accept the student under his/her guidance.

Ph.D. Degree:

For every candidate enrolled for the Ph.D. course, the subsequent registration, conduct and conferment of the Ph.D. degree will be in accordance with the rules and regulations of the University of Calcutta.

SYLLABUS FOR M.SC. | PHYSICAL SCIENCES

SEMESTER - I

Paper – PS 4101

Module: CT-MP-I [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Mathematical Physics I

1. *Theory of second order linear homogeneous differential equations:* Singular points – regular and irregular singular points; Frobenius method; Fuch's theorem; Linear independence of solutions – Wronskian, second solution. Sturm-Liouville theory; Hermitian operators; Completeness.
2. *Inhomogeneous differential equations:* Green's functions
3. *Special functions:* Basic properties (recurrence and orthogonality relations, series expansion) of Bessel, Legendre, Hermite and Laguerre functions.
4. *Integral transforms:* Fourier and Laplace transforms and their inverse transforms, Bromwich integral [use of partial fractions in calculating inverse Laplace transforms]; Transform of derivative and integral of a function; Solution of differential equations using integral transforms.

Module: CT-MP-II [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Mathematical Physics II

1. *Complex variables:* Recapitulation: complex numbers, triangular inequalities, Schwarz inequality, Function of a complex variable – single and multivalued function. Limit and continuity. Differentiation – Cauchy-Riemann equations and their applications. Analytic and Harmonic Functions. Complex integrals. Cauchy's theorem (elementary proof only), converse of Cauchy's theorem, Cauchy integral formula and its corollaries, Series – Taylor and Laurent expansion, classification of singularities, branch point and branch cut, residue theorem and evaluation of some typical integrals using this theorem.

2. *Matrices and Tensors:* Representation of linear transformations and change of base; Eigenvalues and eigenvectors; Functions of a matrix; Cayley-Hamilton theorem; Commuting matrices with degenerate eigenvalues; Orthonormality of eigenvectors. Transformation of tensors, mathematical operation with tensors (addition, subtraction & multiplication), metric tensors, raising and lowering of indices, unit tensor.

Paper - PS 4102

Module: CT-MP-II [Class weeks: 15 /\ Contact Hours/Week: 3 /\ Credits: 3 /\ Marks 35]

Classical Mechanics

1. *An overview of the Lagrangian formalism:* Some specific applications of Lagrange's equation; small oscillations normal modes and frequencies.
2. *Rigid bodies:* Independent coordinates; orthogonal transformations and rotations (finite and infinitesimal); Euler's theorem, Euler angles; Inertia tensor and principal axis system; Euler's equations; Heavy symmetrical top with precession and nutation.
3. *Hamilton's principle:* Calculus of variations; Hamilton's principle; Lagrange's equation from Hamilton's principle; Legendre transformation and Hamilton's canonical equations; Canonical equations from a variational principle; Principle of least action.
4. *Canonical transformations:* Generating functions; examples of canonical transformations; group property; Integral variants of Poincare; Lagrange and Poisson brackets; Infinitesimal canonical

transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum Poisson bracket relations.

5. *Hamilton-Jacobi theory:* The Hamilton Jacobi equation for Hamilton's principle function; The harmonic oscillator problem; Hamilton's characteristic function; Action angle variables.
6. *Lagrangian formulation for continuous systems:* Lagrangian formulation of acoustic field in gases; the Hamiltonian formulation for continuous systems; Canonical equations from a variational principle, Poisson's brackets and canonical field variables.

Module: CT-NLD [Class weeks: 15 /\ Contact Hours/Week: 1 /\ Credits: 1 /\ Marks 15]

Nonlinear Dynamics

Why Nonlinear Dynamics --The basic differences of Nonlinear Systems with Linear ones –

Flows and Maps, Fixed Point Analysis in 1-D Systems, Fixed point analysis and Qualitative features of Phase Portraits in 2-D systems, Limit Cycles, Generalization of ideas in higher dimensions, Bifurcations-- 1-D systems, Bifurcations-- 2-D systems -- mainly local ones with some notions of Global Bifurcations, Hamiltonian systems- integrability and non- integrability-- onset of chaos in nearly integrable systems, Poincare Section and Maps along with Stroboscopic Maps , 1- D and 2-D Maps -- Logistic, Standard and Baker's Maps -- Chaos and Liapunov Exponents, Ideas of strange attractors and chaos – Nonlinear Oscillators, Fractals and Fractal dimensions.

Paper - PS 4103

Module: CT-MP-III [Class weeks: 15 /\ Contact Hours/Week: 1 /\ Credits: 1 /\ Marks 15]

Mathematical Physics III

1. *Linear Vector space:* Axiomatic definition, linear independence, bases, dimensionality, inner product, Gram Schmidt orthogonalization.
2. *Group Theory:* Symmetries, representation theory, broad overview of finite and continuous groups, rotation group, the nature of time-reversal and space-inversion operations, point groups and crystal tensors, application to X-ray analysis of structures and molecular vibrations, the Wigner-Eckart theorem, Lie groups and representations, Young tableaux, Dynkin diagrams, SU(2), Gauge invariance, equivalence with angular momentum, Clebsh-Gordan coefficients.

Module: CT-QM-I [Class weeks: 15 /\ Contact Hours/Week: 3 /\ Credits: 3 /\ Marks 35]

Quantum Mechanics I

1. *Recapitulation of basic concepts* : Wave packet, Gaussian wave packet, Fourier transform, spreading of a wave packet, Fourier transforms of delta and sine function, co-ordinate and momentum space: co-ordinate and momentum representation, Parseval's theorem, eigenvalues and eigenvectors: Momentum and parity operators, commutativity and simultaneous eigenfunctions, complete set of eigenfunctions: expansion of wave functions in terms of a complete set, one dimensional problems: square well potential (E>0), delta function, double delta potential, application to molecular inversion, multiple potential well, Kronig-Penney model.
2. *Operator method in quantum mechanics:* Formulation of quantum mechanics in vector space language, uncertainty principle for two arbitrary operators, one dimensional harmonic oscillator by operator method.
3. *Quantum theory of measurement and time evolution:* Double Stern-Gerlach experiment for spin ½ systems, Schrodinger, Heisenberg and interaction pictures.
4. *Three dimensional problems:* Three dimensional problems in Cartesian and spherical polar co-ordinates, 3 d well and Fermi energy, radial equation for a free particle and 3 d harmonic oscillator, eigenvalue of a 3-d harmonic oscillator by series solution.
5. *Angular momentum:* Angular momentum algebra, raising and lowering operators, matrix representation of j = ½ and j = 1, spin, addition of two angular momenta: Clebsch-Gordan co-efficients, examples.

Paper – PS 4104

Module: CT-SP-I [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Statistical Physics I

1. *Introduction:* Objective of statistical mechanics. Macrostates, microstates, phase space and ensembles. Ergodic hypothesis, postulate of equal a priori probability and equality of ensemble average and time average. Boltzmann's postulate of entropy. Counting the number of microstates in phase space. Entropy of ideal gas: Sackur-Tetrode equation and Gibbs' paradox. Liouville's Theorem.
2. *Canonical Ensemble:* System in contact with a heat reservoir, expression of entropy, canonical partition function, Helmholtz free energy, fluctuation of internal energy.
3. *Grand Canonical Ensemble:* System in contact with a particle reservoir, chemical potential, grand canonical partition function and grand potential, fluctuation of particle number. Chemical potential of ideal gas.
4. *Classical non-ideal gas:* Mean field theory and Van der Wall's equation of state; Cluster integrals and Mayer- Ursell expansion.

Module: CT-ED-I [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Electrodynamics I

1. *Electrostatics and Magnetostatics:* Scalar and vector potentials, gauge transformations, multipole expansion of (i) scalar potential and energy due to a static charge distribution, (ii) vector potential due to a stationary current distribution, electrostatic and magnetostatic energy, Poynting's theorem, Maxwell's stress tensor.
2. *Radiation from time dependent sources of charges and currents:* Inhomogeneous wave equations and their solutions, Radiation from localized sources and multipole expansion in the radiation zone.
3. *Special Relativity:* Lorentz transformations, four- vectors, tensors, transformation properties, metric tensor, raising and lowering of indices, contraction, symmetric and antisymmetric tensors, four-dimensional velocity and acceleration, four- momentum and four-force, covariant equations of motion, relativistic kinematics (decay and elastic scattering), Lagrangian and Hamiltonian of relativistic particles.
4. *Relativistic electrodynamics:* Equation of motion in an electromagnetic field, electromagnetic field tensor, covariance of Maxwell's equations, Maxwell's equations as equations of motion, Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion, field invariants, covariance of Lorentz force equation and the equation of motion of a charged particle in an electromagnetic field, the generalized momentum, energy-momentum tensor and the conservation laws for the electromagnetic field, relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.

Paper - PS 4151

Module: CE-GE-I [Class weeks: 15 /\ Contact Hours/Week: 8 /\ Credits: 4 /\ Marks 50]

General Experiments I

1. Michelson's Interferometer
2. Planck's Constant by Photoelectric effect / By means of LED characteristics
3. Franck-Hertz experiment
4. Measurement of e/m with Bar magnets/ with He filled tube and Helmoltz's coil
5. Audio oscillators
6. Stefan's Law

SEMESTER - II

Paper – PS 4205

Module: CT-QM-II [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Quantum Mechanics II

1. *Approximation Methods:* Time independent perturbation theory: First and second order corrections to the energy eigenvalues; First order correction to the eigenvector; Degenerate perturbation theory; Application to one- electron system – Relativistic mass correction, Spin-orbit coupling (L-S and j-j), Zeeman effect and Stark effect. Variational method: He atom as example; First order perturbation; Exchange degeneracy; Ritz principle for excited states for Helium atom.
2. WKB Approximation: Quantisation rule, tunnelling through a barrier, qualitative discussion of α-decay.
3. Time-dependent Perturbation Theory: Time dependent perturbation theory, interaction picture; Constant and harmonic perturbations – Fermi's Golden rule; Sudden and adiabatic approximations.
4. Scattering theory: Laboratory and centre of mass frames, differential and total scattering cross-sections, scattering amplitude; Scattering by spherically symmetric potentials; Partial wave analysis and phase shifts; Ramsauer-Townsend effect; Relation between sign of phase shift and attractive or repulsive nature of the potential; Scattering by a rigid sphere and square well; Coulomb scattering; Formal theory of scattering – Green's function in scattering theory; Lippman-Schwinger equation; Born approximation.

Module: CT-QM-III [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Quantum Mechanics III

1. *Symmetries in quantum mechanics:* Conservation laws and degeneracy associated with symmetries; Continuous symmetries – space and time translations, rotations; Rotation group, homomorphism between SO(3) and SU(2); Explicit matrix representation of generators for $j = 2$ and $j = 1$; Rotation matrices; Irreducible spherical tensor operators, Wigner-Eckart theorem; Discrete symmetries — parity and time reversal.
2. *Identical Particles:* Meaning of identity and consequences; Symmetric and antisymmetric wavefunctions; Slater determinant; Symmetric and antisymmetric spin wavefunctions of two identical particles; Collisions of identical particles.
3. *Relativistic Quantum Mechanics:* Klein-Gordon equation, Feynman-Stuckelberg interpretation of negative energy states and concept of antiparticles; Dirac equation, covariant form, adjoint equation; Plane wave solution and momentum space spinors; Spin and magnetic moment of the electron; non-relativistic reduction; Helicity and chirality; Properties of γ matrices; Charge conjugation; Normalisation and completeness of spinors.

Paper – PS 4206

Module: CT-SP-II [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Statistical Physics II

1. *Quantum statistical mechanics:* Density Matrix; Quantum Liouville theorem; Density matrices for microcanonical, canonical and grand canonical systems; Simple examples of density matrices — one electron in a magnetic field, particle in a box; Identical particles — B-E and F-D distributions.
2. *Ideal Bose and Fermi gas:* Equation of state; Bose condensation; Equation of state of ideal Fermi gas; Fermi gas at finite T.
3. *Special topics:* Ising model: partition function for one dimensional case; Chemical equilibrium and Saha ionisation formula. Phase transitions: first order and continuous, critical exponents and scaling relations. Calculation of exponents from Mean Field Theory and Landau's theory, upper critical dimension.
4. *Irreversible Thermodynamics:* Flux and affinity. Correlation function of fluctuations. Onsager reciprocity theorem (including proof). Thermoelectric effect.

Module: CT-ED-II [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Electrodynamics II

1. *Radiation from moving point charges:* Lienard-Wiechert potentials; Fields due to a charge moving with uniform velocity; Fields due to an accelerated charge; Radiation at low velocity; Larmor's formula and its relativistic generalisation; Radiation when velocity (relativistic) and acceleration are parallel, Bremsstrahlung; Radiation when velocity and acceleration are perpendicular, Synchrotron radiation; Cherenkov radiation (qualitative treatment only). Thomson and Compton scattering.
2. *Radiation reaction:* Radiation reaction from energy conservation; Problem with Abraham-Lorentz formula; Limitations of CED.
3. *Plasma physics:* Definition of plasma; Its occurrence in nature; Dilute and dense plasma; Uniform but time- dependent magnetic field: Magnetic pumping; Static non-uniform magnetic field: Magnetic bottle and loss cone; MHD equations, Magnetic Reynold's number; Pinched plasma; Bennett's relation; Qualitative discussion on sausage and kink instability.

Paper – PS 4207

Module: CT-SSP-I [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Solid State Physics I

1. *Crystal structure:* Bravais lattice – primitive vectors, primitive unit cell, conventional unit cell, Wigner-Seitz cell; Symmetry operations and classification of 2- and 3-dimensional Bravais lattices; Crystal structures: basis, crystal class, point group and space group (information only); Common crystal structures: NaCl and CsCl structure, crystals of alkali and noble metals, close-packed structure, cubic ZnS structure; Reciprocal lattice and Brillouin zone; Bragg-Laue formulation of X-ray diffraction by a crystal; Atomic and crystal structure factors; Experimental methods of X-ray diffraction: Laue, rotating crystal and powder method; Electron and neutron diffraction by crystals (qualitative discussion); Intensity of diffraction maxima; Extinctions due to lattice centering.
2. *Band theory of solids:* Bloch equation; Empty lattice band; Nearly free electron bands; Band gap; Number of states in a band; Tight binding method; Effective mass of an electron in a band: concept of holes; Band structures in copper, GaAs and silicon; Classification of metal, semiconductor and insulator; topology of Fermi-surface; cyclotron resonance – de Haas - van Alphen effect; Boltzmann transport equation – relaxation time approximation, Sommerfeld theory of electrical conductivity.
3. *Lattice dynamics:* Classical theory of lattice vibration under harmonic approximation; Vibrations of linear monatomic and diatomic lattices, acoustical and optical modes, long wavelength limits; Optical properties of ionic crystal in the infrared region; Adiabatic approximation (qualitative discussion); Normal modes and phonons; Inelastic scattering of neutron by phonon; Lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity; Anharmonic effects in crystals — thermal expansion and thermal conductivity; Mossbauer effect.
4. *Dielectric properties of solids:* Static dielectric constant: electronic and ionic polarisation of molecules, orientational polarisation, static dielectric constant of gases; Lorentz internal field; Static dielectric constants of solids; Complex dielectric constant and dielectric losses, relaxation time; Classical theory of electronic polarisation and optical absorption; Ferroelectricity — dipole theory, case of BaTiO.

Module: CT-SSP-II [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Solid State Physics II

1. *Magnetic properties of solids:* Origin of magnetism; Diamagnetism: quantum theory of atomic diamagnetism; Landau diamagnetism (qualitative discussion); Paramagnetism: classical and quantum theory of paramagnetism; case of rare-earth and iron-group ions; quenching of orbital angular momentum; Van-Vleck paramagnetism and Pauli paramagnetism; Ferromagnetism: Curie-Weiss law, temperature dependence of saturated magnetisation, Heisenberg's exchange interaction, ferromagnetic domains; Ferrimagnetism and anti- ferromagnetism.
2. *Magnetic resonances:* Nuclear magnetic resonances, Bloch equation, longitudinal and transverse relaxation time; Hyperfine field; Electron-spin resonance.
3. *Imperfections in solids and optical properties:* Frenkel and Schottky defects, defects in growth of crystals; The role of dislocations in plastic deformation and crystal growth; Colour centers and photoconductivity; Luminescence and phosphors; Alloys – order-disorder phenomena, Bragg-Williams theory; Extra specific heat in alloys.
4. *Superconductivity:* Phenomenological description of superconductivity – occurrence of superconductivity, destruction of superconductivity by magnetic field, Meissner effect; Type-I and type-II superconductors; Heat capacity, energy gap and isotope effect; Outlines of the BCS theory; Giaver tunnelling; Flux quantisation; a.c. and d.c. Josephson effect; Vortex state (qualitative discussions); High Tc superconductors (information only).

Paper - PS 4252

Module: CC-NI [Class weeks: 15 /\ Contact Hours/Week: 8 /\ Credits: 4 /\ Marks 50]

Numerical Techniques and Computer Interfacing

1. *Recapitulation of the following in a popular programming language:*
   Constants and variables. Assignment and arithmetic expressions. Logical expressions and control statements, DO loop, array, input and output statements, function subprogram, subroutine. Processing of text and strings.
2. *Numerical analysis:*
   Computer arithmetic and errors in floating point representation of numbers, different numerical methods for (i) finding zeros of a given function (ii) solution of linear simultaneous equations (iii) numerical differentiation and integration (iv) solution of first-order differential equations (v) interpolation and extrapolation (vi) least square fitting. Random number generation, sorting.
3. *Computer Interfacing*
   Scientific Computing using Python/Numeric/Scipy/Matplotlib: Language essentials. Principles of Computer interfaced experiments: Sensors, Sampling, ADC width and delay, DAC limitations, Precision in digitized experiments. Components of the IUAC Phoenix/ Expeyes box: Digital I/O, DAC, PWG, Counter, ADC, Amplifiers. Familiarization with the python API. Software and Hardware triggers, Hardware control, Data acquiring and analysis using unipolar and bipolar signals: Fast Vs. Precision experiments, Design / Coding for simple experiments using available thermo/mechanical/audio sensors.

Paper – PS 4253

Module: CE-GE-II [Class weeks: 15 \ Contact Hours/Week: 8 \ Credits: 4 \ Marks 50]

General Experiments II

1. Hall Effect I
2. Hall Effect II
3. Resistivity measurement using four-probe
4. Dielectric constant as a function of frequency for different solids
5. Dielectric constant and Curie temperature of ferromagnetic ceramics
6. Study of optical absorption and optical band gap determination of semiconductors
7. Determination of precise lattice parameter and crystallite size of materials by X-Ray powder diffractometer

SEMESTER - III

Paper – PS 4308

Module: CT-ATM [Class weeks: 15 \ Contact Hours/Week: 2 \ Credits: 2 \ Marks 25]

Atomic Physics

1. *One Electron Atom:* Introduction: Quantum States; Atomic orbital; Parity of the wave function; Angular and radial distribution functions.
2. *Interaction of radiation with matter:* Time dependent perturbation: Sinusoidal or constant perturbation; Application of the general equations; Sinusoidal perturbation which couples two discrete states – the resonance phenomenon. Interaction of an atom with electromagnetic wave: The interaction Hamiltonian - Selection rules; Nonresonant excitation – Comparison with the elastically bound electron model; Resonant excitation - Induced absorption and emission.
3. *Fine and Hyperfine structure:* Solution of Dirac equation in a central field; Relativistic correction to the energy of one electron atom. Fine structure of spectral lines; Selection rules; Lamb shift. Effect of external magnetic field - Strong, moderate and weak field. Hyperfine interaction and isotope shift; Hyperfine splitting of spectral lines; selection rules.
4. *Many electron atom:* Independent particle model; He atom as an example of central field approximation; Central field approximation for many electron atom; Slater determinant; L-S and j-j coupling; Equivalent and non-equivalent electrons; Energy levels and spectra; Spectroscopic terms; Hunds rule; Lande interval rule; Alkali spectra.

Module: CT-MOL [Class weeks: 15 \ Contact Hours/Week: 2 \ Credits: 2 \ Marks 25]

Molecular Physics & Laser Physics

1. *Molecular Electronic States:* Concept of molecular potential, Separation of electronic and nuclear wave functions, Born-Oppenheimer approximation, electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function, The LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and Overlap integral, Symmetries of electronic wavefunctions; Shapes of molecular orbital; π and σ bond; Term symbol for simple molecules
2. *Rotation and Vibration of Molecules:* Solution of nuclear equation; Molecular rotation: Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential.
3. *Spectra of Diatomic Molecules:* Transition matrix elements, Vibration-rotation spectra: Pure

vibrational transitions, Pure rotational transitions, Vibration-rotation transitions, Electronic transitions: Structure, Franck- Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules, Continuous spectra, Raman transitions and Raman spectra.

4. *Vibration of Polyatomic Molecules: Application of Group Theory:* Molecular symmetry; Matrix representation of the symmetry elements of a point group; Reducible and irreducible representations; Character tables for C2v and C3v point groups; Normal coordinates and normal modes; Application of group theory to molecular vibration.

Laser Physics:

Basic elements of a laser; Threshold condition; Four-level laser system, CW operation of laser; Critical pumping rate; Population inversion and photon number in the cavity around threshold; Output coupling of laser power. Optical resonators; Cavity modes; Mode selection; Pulsed operation of laser: Q-switching and Mode locking; Experimental technique of Q-switching and mode locking. Different laser systems: Ruby, CO_2, Dye and Semiconductor diode laser.

Paper – PS 4309

Module: CT-NP [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Nuclear Physics

1. *Nuclear Properties:* Nuclear size, Rutherford scattering, nuclear radius and charge distribution, nuclear form factor, mass and binding energy, angular momentum, parity and symmetry, magnetic dipole moment and electrical quadrupole moment, experimental determination, Rabi's method.
2. *Two-body state:* Properties of deuteron, Schrodinger equation and its solution for ground state of deuteron, rms radius, spin dependence of nuclear forces, electromagnetic moment and magnetic dipole moment of deuteron and the necessity of tensor forces.
3. *Two-body scattering:* Experimental n-p scattering data, partial wave analysis and phase shifts, scattering length, magnitude of scattering length and strength of scattering, significance of the sign of scattering length, scattering from molecular hydrogen and determination of singlet and triplet scattering lengths, effective range theory, low energy p-p scattering, nature of nuclear forces: charge independence, charge symmetry and isospin invariance of nuclear forces.
4. *Nuclear structure*: Liquid drop model, Bethe-Weizsacker binding energy/mass formula, Fermi model, Shell model and collective model.
5. *Nuclear reactions and Fission:* Different types of reactions, quantum mechanical theory, resonance scattering and reactions – Breit-Wigner dispersion relation, compound nucleus formation and break-up, statistical theory of nuclear reactions and evaporation probability, optical model, principle of detailed balance, transfer reactions, nuclear fission: experimental features, spontaneous fission, liquid drop model, barrier penetration, statistical model, super-heavy nuclei.

Module: CT-PP [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Particle Physics

1. *Symmetry:* Symmetries and conservation Laws. Elementary ideas about electroweak unification and Standard Model. SU(2) and SU(3) Groups, algebras and generators, Young tableaux rules for SU(2) and SU(3).
2. Weak interactions: Energetics of various β decays, $V-A$ theory of allowed β decay, Selection rules for Fermi and Gamow-Teller transitions, Parity non-conservation and Wu's experiment, Goldhaber's experiment; Elementary ideas about the gauge theory of weak interaction. The problem of mass generation and the need for the Higgs mechanism.
3. *Strong interactions:* Hadron classification by isospin and hypercharge, quarks, colour.

Elementary ideas about gauge theory of strong interactions - quantum chromodynamics.

4. *Big Bang theory:* Elementary ideas about Big Bang cosmology. Big Bang neucleosynthesis, relative abundance of chemical elements, neutron star.

Paper – PS 4310

Module: CT-EC [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Electronics

1. Carrier concentration in semiconductors, p-n junction band diagram, I-V and C-V Characteristics; basic semiconductor equations, depletion and diffusion capacitance, Reverse Breakdown; Noise; Bipolar Junction Transistors (BJT); Ebers-Moll equation. Frequency response;
2. *Digital MOS circuits:* NMOS and CMOS gates (AND, NAND and NOT), Dynamic MOS circuits, ratio inverter, two phase inverter; dynamic MOS shift register, static MOS shift registers, four phase shift registers. Memory Devices; Static and dynamic random-access memories (SRAM and DRAM)
3. Metal semiconductor junctions: Schottky barriers; Rectifying and ohmic contacts; Tunnel diode; Uni-junction transistor (UJT); Field Effect Transistor (FET): types, structure, JFET, MESFET, MOSFET: characteristics, threshold voltage.

Module: CT-INT [Class weeks: 15 /\ Contact Hours/Week: 2 /\ Credits: 2 /\ Marks 25]

Instrumentation

1. *Analog circuits:* Comparators, Multivibrators, Waveform generators: Square wave, triangle wave and pulse generators.
2. *Transmission line:* Transmission line equation and solution; Reflection and transmission coefficient; Standing wave and standing wave ratio; Line impedance and admittance; Smith chart.
3. Production and measurement of high vacuum: Rotary pump, Diffusion pump, Turbomolecular pump, Ion pump; McLeod gauge, Pirani gauge, Penning gauge.
4. Introduction to cryogenics.
5. *Communication:* Introduction to signals; Concepts of Voice & Data Communication; Transmission lines, Transmission Channels; Modulation & Multiplexing of Analog and Digital Signals; CCITT / ITU Standards of Voice & Data Communication Systems; Pulse Code Modulation (PCM); Digital Multiplexing (PDH&SDH).
6. *Experimental design:* Scintillation detectors; Solid state detectors (Si and HPGe). Measurement of energy and time using electronic signals from the detectors and associated instrumentation, Signal processing; Multi channel analyzer; Time of flight technique; Coincidence measurements true-to-chance ratio.

Paper – PS 4354

Module: CE- EC [Class weeks: 15 /\ Contact Hours/Week: 8 /\ Credits: 4 /\ Marks 50]

Electronics & Communication Experiments

1. Determination of band gap and reverse saturation current of a p n junction diode
2. Construction of Astable Multi-vibrator and VCO
3. To study UJT Characteristics
4. To study Active Filters (High pass, Low pass, Band pass, Notch)
5. To study T Filters (High and Low pass filter)

6. To study Pi Filters (High and Low pass filter)
7. Pulse Width Modulation and Demodulation
8. Study of Frequency Modulation and its Demodulation using IC PLL565
9. Pulse Position Modulation and Demodulation
10. Study of Amplitude Shift Keying and Demodulation
11. Study of Frequency Shift keying and Demodulation [IC 8038 Function Generator used]
12. Study of Amplitude Modulation and Demodulation [IC Version 1496]

Paper – PS 4355

Module: CE-GE-III [Class weeks: 15 /\ Contact Hours/Week: 8 /\ Credits: 4 /\ Marks 50]

General Experiments III

1. Iodine absorption spectra
2. Laser: Parametric down conversion
3. Detection of single photon
4. Single photon interference
5. Two photon interference and/or quantum eraser
6. Plasma Physics: Determination of basic parameters of plasma using Plasma discharge tube.
7. Determination of energy peaks of γ rays from radioactive sources using NaI detector.

SEMESTER - IV

Paper – PS 4461

Module: SP-PRJ [Class weeks: 15 /\ Contact Hours/Week: 20 /\ Credits: 12 /\ Marks 150]

Project and Dissertation

Each student is required to undertake a research project on an advanced topic to be chosen in consultation with a supervisor. The topic will be usually centered around the research activities carried out in the institute. Apart from advanced learning it is expected that each project shall have a research component. The progress of the student will be examined in the mid-semester and in the end-semester examinations. At the end of the project the students have to submit a detailed project report (dissertation) and deliver a seminar in support of their work. Submission of the dissertation has to be done ten days before (excluding) the seminar date. 20% marks will be deducted from the project report component of the marking scheme for each day of delay in submission of the report.

The broad area of research will be considered as the area of specialization in the M.Sc. course.

Paper – PS 4471

Module: CBCC-I [Class weeks: 15 /\ Contact Hours/Week: 4 /\ Credits: 4 /\ Marks 50]

Complex Systems

1. The 'limitations' of mathematics: Cantor, Godel and Turing
2. Church-Turing thesis and Turing machines
3. Computational complexity, P and NP: About knapsacks and traveling salesman
4. Uncertainty, Entropy and information: From Boltzmann and Gibbs to von Neumann and
5. Shannon
6. Disordered systems: spin glasses, neural networks and protein folding
7. Noise, fluctuations and reexamination of the second law of thermodynamics
8. Studying economies and societies using physics : An overview

Paper – PS 4472

Module: CBCC-II [Class weeks: 15 /\ Contact Hours/Week: 4 /\ Credits: 4 /\ Marks 50]
Nanoscale Materials

Classification and Nomenclature of Nanomaterials(10L): Length scales in physics, Nanostructures, 1D, 2D and 3D nanostructures (nanodots, thin films, nanowires, nanorods), Band structures and density of states of materials at nanoscales, size effects at nano systems, Quantum confinement: Applications of Schrodinger equation, Infinite potential well, potential step, potential box, quantum confinement of carries in 3D,2D and 1D nanostructures and its consequences. Origin of charge on colloidal sols, zeta potential - DLVO theory; Implications of colloids in making building blocks; Catalytic and photocatalytic properties, Mechanical properties.

Synthesis by Physical Methods(3L): Nucleation and growth of Nanosystems; self-assembly; Physical methods – mechanical milling, laser ablation, sputtering and microwave plasma.

Synthesis by Chemical Methods (4L): Chemical reduction and oxidation, hydrothermal, micelles, sol-gel processes, photolysis, radiolysis, and metallo-organic chemical vapor deposition; Designing of advanced integrated nanocomposites, functional nanomaterials and nanostructured thin films.

Novel Properties of Nanomaterials and Related Theoretical Background (10L): Size and shape dependent optical, emission, electronic, transport, photonic, refractive index, dielectric, mechanical, magnetic, non-linear optical properties; Transition metal sols, origin of plasmon band, Mie theory, influence of various factors on the plasmon absorption.

Characterization of Nanomaterials(10L): Structural Characterization - XRD, SAXS, SEM, TEM, SPM/AFM; Chemical Characterization – Optical spectroscopy, Electron spectroscopy, Vibrational spectroscopy, Ionic spectrometry; Physical properties – Melting point, Lattice constant, Electrical and magnetic characterization; Mechanical properties – nanoindentaion.

Density Functional Theory(8L): Many-body Schrodinger equations to Density Functional Theory (DFT) – Hohenberg-Kohn theorem, Kohn-Sham equations, Self-consistent solutions; Software for DFT calculations; Electronic property of system employing DFT software.

Applications (5L): Applications of nanoparticles, quantum dots, nanowire and thin films for photonic devices (LED, Solar cell). Single electron based transfer devices (no derivation). CNT based transistors. Optical switching, optical data storage. Magnetic data storage.

Paper – PS 4473

Module: CBCC-III [Class weeks: 15 /\ Contact Hours/Week: 4 /\ Credits: 4 /\ Marks 50]
Biomedical Nanotechnology

Synthesis of nanoparticles by biological methods; Cell organization and subcellular structure; Cell–nanostructure Interactions; Molecular Biomimetics; Nanostructures for medicinal applications.

Introduction to genetic engineering and gene therapy; Virus-based nanoparticles for gene therapy; Nanotechnology in nonviral gene delivery.

Introduction to tissue engineering; Nanotechnology in tissue Engineering; Nanostructured extracellular matrix; Nanomaterials for cell engineering; Nanostructured biomaterials; Nanostructured surface modifications for biomedical implants; Artificial cells; Stem cells in tissue engineering; Nanotechnology for regenerative medicine.

Nano pharmaceuticals; Biodegradable targeted nano drug delivery system; Diagnostic and therapeutic applications of nanoparticles; Theranostic nanoparticles; Pharmacokinetics of nanocarrier-mediated drug and gene delivery; Nano-enabled components and systems for biodefense.
Design and applications of nanotechnology in the fields of Oncology, Neurology, Cardiology, Orthopedics, Microbiology, Ophthalmology, Dermatology, Pulmonology and Dentistry. Cytotoxicity and genotoxicity; Cell toxicity mechanisms and method of analysis; Toxicity of nanoparticles in vivo.

Paper – PS 4474

Module: CBCC-IV [Class weeks: 15 /\ Contact Hours/Week: 4 /\ Credits: 4 /\ Marks 50]

Atmospheric Science

Unit 1: Structure and the vertical profile of atmosphere [3 Lectures]

Layers of the atmosphere and characteristics
Vertical profiler of the pressure of the atmosphere
Vertical profile of the temperature of the atmosphere
Expressing the concentration of any substance in the atmosphere

Unit 2: Thermodynamics of the atmosphere [8 Lectures]

Virtual temperature, Geopotential, Scale height, Hypsometric equation
Adiabatic processes: Lapse rate, potential and equivalent potential temperature, thermodynamic diagrams
Water vapour in air: Humidity, specific humidity, saturation vapour pressure, dew point, frost point, lifting condensation level, wet bulb temperature
Atmospheric stability: Unsaturated and saturated air, conditional stability, stability classes

Unit 3: Atmospheric radiation [8 Lectures]

Basics of electromagnetic radiation, Black body radiation, Greenhouse Effect
Scattering of air molecules and particles, Absorption by particles, Absorption and emission by gas molecules, optical depth
Radiative transfer, radiative heating rate, radiation balance at the TOA

Unit 4: Microstructure and properties of clouds [8 Lectures]

Nucleation of water vapour, Kelvin equation, Kohler curves, Cloud Condensation Nuclei
Warm clouds: microstructure, cloud liquid water content, growth of cloud droplets
Cold clouds: microstructure, ice nuclei, ice particles
Artifical modification of clouds

Unit 5: Atmospheric electricity [5 Lectures]

Generation of charge in the clouds
Lightning and thunder

Electrosphere: Characteristics
Global electrical circuit
Atmospheric electric field

Unit 6: General circulation of the atmosphere [5 Lectures]
Hadley Cell, Ferrell Cell, Polar Cell
Coriolis Force: Characteristics and effects
Cyclone and anticyclone
Geostrophic winds

Unit 7: Atmospheric chemistry [5 Lectures]
Chemistry of the troposphere: CO, NOx, NOy, Ozone, OH radicals, Halogens
Chemistry of the stratosphere: Ozone, Ozone hole, NOx and N2O

Unit 8: Air pollution and air quality [8 Lectures]
Aerosols: Sources, types, size distribution, formation mechanisms, chemical composition and reactions
Carbonaceous compounds: Black carbon, Elemental and organic carbon, polynuclear aromatic hydrocarbon (PAH), Volatile organic compounds (VOC)
Biogenic emissions and Bioaerosols
Deposition of pollutants: Dry and wet deposition, aerosol-raindrop collision, scavenging
Role of aerosols in the formation of clouds, fog, smog and visibility degradation
Monitoring of air pollutants: Ground-based and remote sensing, satellite observations
Air quality index (AQI), Air quality standards (NAAQS and WHO)

Paper – PS 4475

Module: CBCC-V [Class weeks: 15 /\ Contact Hours/Week: 4 /\ Credits: 4 /\ Marks 50]

Climate Change and Global Environmental Sustainability

1: Fundamentals of Climate Science
- Earth's atmosphere: structure, composition, and energy balance
- Greenhouse effect and radiative forcing
- Climate drivers: natural vs. anthropogenic
- Paleoclimatology and evidence of past climate change

2: Basic Physics of Climate Change
- Blackbody radiation, Planck’s law, Stefan-Boltzmann law
- Solar radiation and Earth’s energy budget
- Basic fluid dynamics and Coriolis effect
- Equations of motion in the atmosphere

3: Environmental Systems and Global Change
- Carbon cycle and biogeochemical systems
- Deforestation, desertification, and biodiversity loss
- Radiative forcing, greenhouse gases, and the greenhouse effect
- Role of aerosols, clouds, and solar radiation

4: Measuring and Modeling Climate

- Climate observations: satellites, in-situ & remote sensing instruments
- Data sets and time series analysis
- Climate models: basics of GCMs, downscaling, and predictions
- Uncertainty and validation in models

5: Impacts of Climate Change

- Sea-level rise and extreme weather
- Human health, food security, and water resources
- Socio-economic impacts and climate justice
- Vulnerable communities and regional disparities

6: Principles of Environmental Sustainability

- Definition and pillars: environmental, economic, and social sustainability
- Sustainable development goals (SDGs)
- Renewable energy technologies and energy efficiency
- Circular economy, waste management, and sustainable land use

7: Policy, Ethics, and Governance

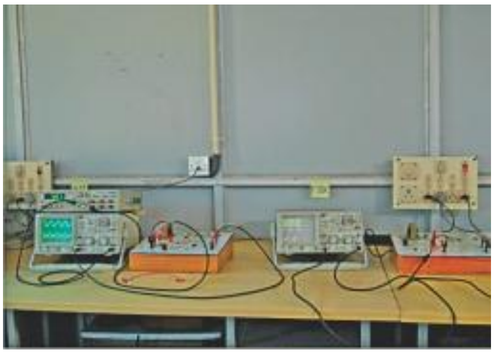
- International climate policy: Kyoto Protocol, Paris Agreement, COPs
- Role of IPCC and UNFCCC
- Environmental ethics and intergenerational equity
- National policies and grassroots movements

Suggested References for Physical Sciences: Core Courses & Advanced Topics

Link: https://jcbose.ac.in/assets/uploads/5974751f1dd8fb4987c43383d5465519.pdf

FACILITIES AVAILABLE

The following are some of the facilities available to students.



Laboratory on communications

Plasma Physics Laboratory

Space Science Laboratory

Cosmic Ray Laboratory

Library

Raman Spectroscopy Laboratory

Central Instrument Facility

Madhyamgram Experimental Farm

SYLLABUS FOR M.Sc. | LIFE SCIENCES

SEMESTER - I

BS401: Biochemistry-I

Credit:1 Lecture hours: 15 Marks: 15
Course Coordinator: Dr. Subhas Halder

Topic	Contact hrs.
Introduction to Biomolecules	
Proteins: Basic structure of amino Acids and their classification, Chemical Bonds in Protein structure including non-peptide bonds. Brief overview of primary, secondary, tertiary, and quaternary structure of proteins.	2
Carbohydrates: General structure of mono-, di-, oligo-, and polysaccharides with examples such as Lactose, sucrose, starch, glycogen, and cellulose. Brief overview of carbohydrate classification, stereochemistry and optical isomerism.	1
Lipids: Classification of lipids, alcohols and fatty acids, simple versus compound Lipids. Structure and physical properties of lipids including solubility and micelle formation. Chemical Properties of lipids and common reactions.	1
Nucleic acids: Nucleosides & Nucleotides including non-natural bases such as inosine, bromo-deoxyuridine and their linkages. Evolution of the double helical DNA structure, variants of the double helical DNA and DNAs with unusual structures. Difference in RNA and DNA structures. Structure and folding of RNA with examples of rRNA, tRNA and ribozymes.	1
Vitamins, Co-factors & trace elements: Classification, water-soluble & fat-soluble vitamins, sources, brief overview of vitamin biosynthesis. Importance of vitamins in biology and co-factors of enzymes. Trace elements and their role in cells. Roles of elements Mg, Fe, Zn, Se and Mn.	2
Protein & carbohydrate metabolism in cells	
Metabolism of proteins and amino acids: Brief overview of sources of amino acids and biosynthetic pathways of non-essential amino acids. Degradation reactions of amino acids such as transamination, oxidative deamination and urea cycle.	4
Metabolism of carbohydrates: Synthesis of polysaccharides like glycogen. Gluconeogenesis. Breakdown mechanisms of polysaccharides. Glycolysis and Krebs' cycle. Pentose phosphate pathway.	4

BS402 Cell Biology

Credit:2 Lecture hours: 30; Marks: 25

Course Coordinator: **Prof. Kaushik Biswas**

Topic	Contact hrs.
Cell and its organization	
Evolution of a Cell: A Brief introduction to Pre-Biotic Life, From Molecules to Cells, From Prokaryotic Cell to Eukaryotic Cell, From Single Cells to Multicellular Organisms.	1
Cell membrane: Biochemistry of the cell membrane, Membrane lipids, Lipids and Membranes; Different kinds of lipids present in the cell; Membrane structure, fluid-mosaic model; Rafts; membrane potential and electron transfer; Endo-membrane system - structure and function of microbodies, membrane maturation and specialization.	3
Functional Organization of Subcellular Organelles in eukaryotes: Membrane bound and non-membrane bound organelles. Organization of the nucleus and nuclear envelope. Brief introduction to chromatin structures. Structure and function of nucleolus.Structure, function and origin of mitochondria and chloroplast, Structure and functions of endoplasmic reticulum, Golgi apparatus, and lysosomes, Brief overview of the structure, organization and function of ribosome and proteasome.	4
Cell membrane: Biochemistry of the cell membrane, Membrane lipids, Lipids and Membranes; Different kinds of lipids present in the cell; Membrane structure, fluid-mosaic model; Rafts; membrane potential and electron transfer; Endo-membrane system - structure and function of microbodies, membrane maturation and specialization.	4
The Cytoskeleton: Structure and function of cytoskeleton, cytoskeletal proteins, e.g., actin, tubulin etc., microtubules and microfilaments.	4
Cellular processes:	
Cellular transport: Active and passive membrane transport, plasmodesmata and its structural and functional significance; ion channels, vesicular trafficking.	5
Intra- and Inter-cellular processes: Inter-cellular signaling and Intra-cellular signaling, Basic concepts and models of Intra-cellular signaling.	2
The cell cycle: Overview of cell proliferation, the cell cycle and its control, molecular mechanisms for regulating mitotic events, meiotic division, cell cycle control in mammalian cells, checkpoints in cell cycle regulation, cellular homeostasis.	3
Cell Death: Apoptosis and its key differences with other cell death processes.	2
The relevance of cell biology in human health and disease. Disorders in cellular processes and pathological developments.	2

BS403 Microbiology

Credit:1 Lecture hours: 15 Marks: 15

Course Coordinator: **Dr. Wriddhiman Ghosh & Dr. Abhrajyoti Ghosh**

Topic	Contact hrs.
History of Microbiology: Theory of spontaneous generation, Experiments of Pasteur and Tyndall, Koch's Postulates. Prokaryotic cell structure, Control of Microorganisms, Antibiotic and chemotherapeutic agents, Antibiotic resistance, and 2-component systems	2
Microbial diversity and classification: Prokaryotic and eukaryotic microbes; Identification and classification of prokaryotes (bacteria and archaea); Microbial taxonomy including molecular taxonomy.	1

Microbial growth and nutrition: Growth kinetics, Batch and continuouscultures, Nutritional classification of microorganisms. Physico-chemical factors such as pH, temperature, oxygen, influencing bacterial growth. Mechanism of survival of acidophiles, alkaliphiles, halophiles.	2
Microbial ecology & Environmental Microbiology: Microbial habitats; Community concept; community exploration; Stringent response, Chemotaxis, Biofilm formation. Nature of anthropogenic wastes, xenobiotics, Enrichmentcultures, Xenobiotic degrading consortia, Bioremediation.	2
Prokaryotic metabolism: Mechanisms of bacterial and archaeal nutrition; Ancient metabolisms; Chemotrophy versus phototrophy.	2
Industrial Microbiology: Microbial production of commercially important products such as citric acid, Vitamin B12, antibiotics, and beverages. Application of extremophiles in industries.	1
Medical microbiology: Host- pathogen interactions, Public health microbiology.	1
Virology: Basics of virology, virus types and subtypes, viral replication, viral life cycle, lysogeny and lysis, viral diseases.	4

BS404 Molecular Biology

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Dr. Basudeb Maji**

Topic	Contact hrs.
Introduction to Molecular Biology: The central dogma, denaturation and renaturation of nucleic acids, chromosome organization in prokaryotes and eukaryotes, organization of genetic material: split genes, overlapping genes, pseudo genes, cryptic genes, chromatin structure & importance of histones and nucleosome assembly, transposable elements.	5
DNA replication: Prokaryotic replication: Mechanism of replication in prokaryotes, replication origin and their identification, regulation of replication. Eukaryotic replication: Similarities and key differences with prokaryotes, Replication of linear chromosomes and telomeric structure, extension of telomere and telomerase.	6
Prokaryotic Transcription: Bacterial transcription- mechanism and components, Regulation of transcription in prokaryotes and operons with examples of typical operons. Introduction to Archaeal transcription-the Third way.	5
Eukaryotic Transcription: Key features and RNA polymerases, basic transcription, core promoters; general transcription factors. Transcription activation: activators; DNA binding specificities of activators; functional domains of activators; transcription through nucleosomes.	5
Translation: Translation in prokaryotes and eukaryotes, key similarities and differences, ribosome structure, processing of mRNA in eukaryotes, tRNAs and codon bias, loading of tRNAs with specific amino acids.	4
RNA replication: Mechanisms of RNA replication, reverse transcriptase and RNA-dependent RNA polymerases	2
Epigenetics: Epigenetic gene regulation, chromatin remodelers, modification of histones and DNA	3

BS405 Biophysical Chemistry-I

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Prof. Ajit Bikram Datta & Dr. Abhrajyoti Ghosh**

Topic	Contact hrs.
Liquid Chromatography: General principles of separation, Concept of plate number, Different steps involved in Column Chromatography (preparation of column, sample loading, wash and elution).	2
Chromatographic techniques used in biology: Affinity Chromatography: Principles and selected applications. IMAC, drawbacks and advantages. Ion-exchange chromatography: Operating principles, various cation and anion exchangers, adsorptive capacities and conditions of adsorption, buffers, methods of elution. Gel filtration chromatography: principles and applications including measurement of molecular weight, SEC-MALS technique. Reverse phase& Hydrophobic interaction chromatography: general principles, similarities and differences, typical applications.	4
Centrifugation Basic equations, sedimentation coefficient, S-value and k-factor, different types of centrifugations (differential pelleting, rate zonal, isopycnic), types of rotors (fixed angle, swinging bucket and vertical) and their applications, care of rotors.	2
Analytical Ultracentrifugation: Difference with preparative centrifugation, rotor geometry, typical applications	1
Electrophoresis Basic principles, components of an electrophoretic unit, types of support media (agarose and polyacrylamide), pore size and resolution, buffers, dyes (loading, staining), native and denaturing gels, SDS PAGE, principles of isoelectric focusing and 2D gels**.**	3
Radiochemical Methods Application of radioisotopes in biology, units of radioactivity, detection and measurement of radioactivity, Geiger-Muller counters, scintillation counters.	2
Mass Spectrometry: Basic Principle, components of mass spectrometer, MALDI and ESI MS, LC-MS and its application, sample preparation and data analysis.	2
Absorption spectroscopy: Light-matter interaction, electronic states& absorption of light, allowed and dis-allowed transitions, UV-vis spectra of peptides, aromatic side chains and DNA. Beer's law – its application and limitations.	2
Vibrational spectroscopy: Introduction to IR & Raman spectroscopy with emphasis of complementary selection rules. Applications to select problems.	1
Circular dichroism spectroscopy: Polarization of light and 'handedness' of macromolecular structure. Different absorption of circularly polarized light by peptide bonds in proteins and its correlation with secondary structure.	2
Fluorescence spectroscopy: Origin of fluorescence vis-à-vis deactivation processes associated with electronic states. Fluorescence yield, position of emission maximum and its variation with solvent polarity. Fluorescence spectrum of Trp and simple applications (protein unfolding and ligand binding). Basic idea of FRET with examples. Basic idea of fluorescence polarization and some applications.	3
Calorimetry & Surface Plasmon resonance: Isothermal calorimetry, differential scanning calorimetry, principles and their use in biologywith examples. Basic idea of surface plasmon resonance and its application.	3
Microscopic techniques:	3

Microscopic techniques used in biology and their resolution power, Confocal microscopy: Principles, microscope design, advantages and limitations, sample preparation techniques and computational tools. Electron Microscopy: scanning and transmission microscopes, Preparation of sample for EM,. typical applications in biology**.**	

BS406 Mathematical and computational tools in biology

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Prof. Subhra Ghosh Dastidar & Dr. Sudipto Saha**

Topic	Contact hrs.
Mathematical Tools:	
Measurements and numbers in biology: Concentration, volume, and amount; accuracy versus precision in measurements, significant values, real, imaginary, and complex numbers and their importance	1
Mathematical functions and their application in biology such as logarithmic, exponential with typical examples, concepts of variables and constants, dependent and independent variables.	2
Vectors and coordinate systems, basics of vector algebra, cross product and dot products, coordinate transformations.	2
Differential calculus and its application such as growth curve analysis, peak identification, differential equations, integration and its application.	3
Matrix and determinants, matrix multiplication, identity matrix	2
Statistical Tools:	
Sample vs. Population: Sampling distribution, discrete and continuous distribution, Normal distribution. Introduction to probability, probablilty distributions.	3
Statistical properties (mean, median, mode, standard deviation, coefficient of variation), Error analysis, Meaning of confidence interval, graphical representation of data	3
Hypothesis testing, non-parametric tests such as Kruskal-Wallis test and Mann-Whitney test, Pearson correlation, Regression analysis.	3
Random sampling and inferential statistics, One-sample t-test, two-sample t-test, paired t-test,one-way ANOVA, two-way ANOVA	3
Introduction to R-for statistical analysis	2
Computational Tools:	
Introduction to the structure of a UNIX and Windows OS, File system structures, shell command interpreters.	1
Data Types (Integer, Real, Complex and Double Precision), ASCI and binary files and reading data from files, variables and arrays.	1
Introduction to programming, programming in python, library functions, logic operations.	4

BS407 Chemical principles in biological processes

Credit:1 Lecture hours: 15 Marks: 15

Course Coordinator: **Prof. Ajit Bikram Datta & Prof. Jayanta Mukhopadhyay**

Topic	Contact hrs.
Thermodynamics:	
Importance of thermodynamics in biological processes. Concepts of system, universe, state functions and path functions, first law of thermodynamics, enthalpy in chemical reactions, specific heat capacity and their significance.	4
Second law of thermodynamics and Entropy, free energy and its relation with enthalpy and entropy, concept of coupled reactions with examples.	2
Chemical Equilibrium&law of Mass action, association and dissociation constants, binding isotherms,single site binding and binding of multiple ligands to a receptor; analysis of ligand binding to macromolecules, Cooperativity and different models of cooperativity, temperature dependence of equilibrium constant and Van't Hoff equation.	3

Chemical Kinetics:	
Concept of reaction rate, order of a reaction, zeroth order, first-order, second order, and pseudo-first order rate equations, activation energy and Arrhenius equation, Intermediates and transition states,concept of half-life	3
Kinetics and thermodynamics in protein folding:	
The protein folding problem, application of chemical principles, thermodynamic and kinetic aspects of protein folding, protein denaturation, single-state versus multi-state unfolding	3
Defining Solutions:	
Concept of Moles, Molar concentrations. pH and ionic strength. Buffers and Buffer strength; acid and base dissociation constants; Henderson-Hasselbach equation.	3
Molecular Interactions:	
Covalent and non-covalent interactions in biological molecules, electrostatic interactions, Van der Waal's interactions, hydrogen bonds, hydrophobic interactions.	3
Reaction Mechanisms:	
Basic concepts of organic chemistry, including conjugation, resonance, and aromaticity, different types of chemical reactions such as S_N1, S_N2, elimination with biological examples.	4
Coordination chemistry	
Revisiting coordinate bond, Common metals found in biological systems and their coordination state, geometry of coordinate complexes, amino acid residues involved in metal coordination, structure and role of porphyrins in metal chelation. Role of different metal ions in metalloenzymes with examples.	3
Radiochemistry:	
Radioisotopes and their properties, α-, β-, and γ-emitters, commonly used radioisotopes in biology, radioactive decay and half life.	2

BS408 Physiology of Animals

Credit:1 Lecture hours: 15 Marks: 15

Course Coordinator: **Prof. Biswanath Maity**

Topic	**Contact hrs.**
The animals:	**15**
Animal Kingdom: Classification of animals and concepts of species, unicellular and multicellular organisms, organization of tissues and organs.	2
Systems in animals: Introduction to various systems in eukaryotes such as cardiovascular system, respiratory system, excretory systems, sense organs, & reproductive systems.	4
Nervous system: central and peripheral nervous systems, neuron structure, action potentials, anatomy of mammalian brain and the spinal cord.	3
Endocrine system: endocrine glands in mammals, mechanism of action of various hormones.	3
Reproduction: Gametogenesis & sperm development, ovulation, fertilization and embryo formation.	3

BS409 Plant Physiology & Biochemistry

Credit:1 Lecture hours: 15 Marks: 15

Course Coordinator: **Dr. Anupama Ghosh**

Topic	**Contact hrs.**

The plants:	
Plant Kingdom: Cyanobacteria, Algae, Fungi, Bryophytes, Pteridophytes and Gymnosperms, Angiosperms; Dicot and monocots	1
Plant tissues &organs: Root system; Shoot system - branching, - Aerial, sub-aerial and underground; simple and compound leaves, Phyllotaxy, Inflorescences- Definition and types- Racemose, Cymose etc., Mixed and special types; Flower is a modified shoot, types of stamen and carpel, Types of fruits.	2
Plant Anatomy: Fundamental or ground tissue system; Vascular tissue system, Types of vascular bundles	1
Embryology: Microsporogenesis, Development of male gametophyte; Megasporogenesis, Development of female gametophyte; Gametic fusion; Triple fusion; Development of dicot embryo-Development of monocot embryo	2
Plant Physiology: Photorespiration, Solute transport across the membrane, Long distance transport through xylem and phloem; transpiration; Plant growth regulators their transport and application; photoperiodism, vernalization, Seed dormancy, Senescence.	3
Biochemistry of plants:	
Photosynthesis: Photosynthetic Pigments, Photosystems & light harvesting complex, Photosystem I and II, Z scheme, photoinhibition, C3, C4 and CAM pathways of carbon fixation; Photorespiration.	3
Nitrogen fixation: evolution of N fixing symbiosis, Nif gene regulation in symbiont, intra- and inter- cellular symbionts, mechanism of nitrogen fixation and the enzymes, nodule organogenesis	3

BS410 Practical-I

Credit:6 Contact hrs: 180 Marks: 75

Course Coordinator: **Prof. Atin Kumar Mandal, Dr. Nirmalya Sen, Dr Abhrajyoti Ghosh, Dr. Sudipto Saha, & Dr. Anupama Ghosh**

Topic	**Contact hrs.**
Detection and quantitation of biomolecules Detection of carbohydrate, lipid, protein and nucleic acid. Standard curve of BSA; Estimation of protein using BSA as standard. Estimation of nucleic acid by spectroscopic method.	25
Cell biology methods	35
Types of mammalian cell culture – demonstration of adherent and non-adherent cell cultures, how to propagate cell lines over several passages.	
Counting of cells using a hemocytometer	
Fractionation and isolation of subcellular organelles	
Observing Cellular Morphology & Sub-cellular organelles – Fixing & Staining of cells with fluorescent conjugated antibodies, cell permeabilization, staining of mitochondria and nucleus.	
Cell Proliferation techniques – Trypan blue method, MTT method to assess cell viability	
Demonstrate different Phases of the Cell Cycle using synchronous and asynchronous cultures	
Molecular biology methods PCR, Gel electrophoresis for DNA and protein, Western blot technique, Overexpression and protein purification from bacteria (gel filtration and affinity chromatography),	35
Microbiology Culture methods, Growth curve of bacteria, *E.coli;* measurement of CFU and MIC calculation, Gram staining,	35
Computational methods Handling of unix computers, basic handling of text and data files, plotting, elemental programming in python **Statistical Methods** Usage of R and Microsoft excel functions	25
Plant Methods staining, sectioning of plant tissue/leaves; Examination of stages of mitosis and miosis	25

SEMESTER - II

BS501 Biochemistry

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Prof. Atin K. Mandal**

Topic	**Contact hrs.**
Biochemistry of Lipids and nucleic acids:	
Different kinds of lipids present in the cell; Membrane structure, fluid-mosaic model; Rafts; membrane potential and electron transfer	2
Metabolism of lipids: Biosynthesis of fatty acids, triacylglycerols, glycerophospholipids, Cholesterol synthesis. B-oxidation of lipids and other minor lipid oxidation pathways.	4
Nucleic acid metabolism: Nucleotide biosynthesis and metabolism, salvage pathways, its regulation and diseases	5
Bioenergetics:	
Electron transport chains, oxidative phosphorylation and synthesis of ATP, mitochondrial structure, introduction to anerobic pathways.	3
Basic Enzymology	

Introduction to enzymes: Holoenzyme, apoenzyme, and prosthetic group; Interaction between enzyme and substrate- lock and key model, induced fit model. Features of active site, activation energy, Rate enhancement through transition state stabilization, Chemical mechanism for transition state stabilization. Enzyme specificity and types. Enzyme Commission system of classification and nomenclature of enzymes. Ribozymes, Abzymes. Coenzymes and their functions. Measurement and expression of enzyme activity, enzyme assays. Definition of IU, katal, enzyme turnover number and specific activity, Isolation, purification and characterisation of enzymes and criteria of purity.	5
Enzyme catalysis: Mechanisms of acid base, covalent, metal ion catalysis, Mechanisms of actions of seine proteases, Factors affecting enzymes activities.	2
Application of enzymes: Immobilized enzymes; Industrial uses of enzymes; Diagnostic and therapeutic enzymes;	1
Enzyme Kinetics:	
Steady-state approximation and Michelis-Menten enzyme kinetics. Inhibition of enzymes, and different types of inhibitors (competitive vs non-competitive)	3
Allostery in enzymes and Hill-coefficient.	2
Mechanisms and kinetics of bi-substrate enzymatic reactions.	3

BS502 Genetics and Genomics

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Dr. Wriddhiman Ghosh**

Topic	Contact hrs.
Genetics	
Mitosis & Meiosis; Mendelian Genetics	1
Chromosome Structure C-value paradox; Structure of prokaryotic and eukaryotic chromosomes; Molecular structures of centromeres and telomeres	2
Recombination Gene conversion; Double-strand break repair; Holliday junctions; Recombination hotspots; Linkage	2
Mutation and Repair Types of mutations; Molecular basis of mutation; Mutagens; Mechanisms of DNA repair.	2
Extranuclear inheritance	1
Prokaryotic and fungal genetics Mobile genetic elements (plasmids & transposons); Markers; Mechanisms of genetic exchange in bacteria; Mating type interconversion in yeast; Respiration defective mitochondrial mutants	2
Biosynthetic pathway elucidation using genetic approaches (second-site and multicopy suppression; synthetic lethality)	2
Population Genetics Allele frequencies and genotype frequencies; Concept of haplotypes; Hardy-Weinberg Principle; Inbreeding; Mutation and migration; Natural Selection; Random genetic drift; Tracing human history; 1000 genome and gnomAd	8
GENOMICS	
De novo gene discovery	1
Automated high throughput gene calling and annotation	2
Metagenomics, and its virtues and limitations	2
Metagenome-assembled genomes	1
Transcriptomics and meta transcriptomics	2
Genomics to the empowerment of cross-disciplinary science: from human to planetary health	1

BS503 Immunology

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Dr. Nirmalya Sen**

Topic	Contact hrs.
Introduction to Immunology and Immune System:	
Overview of the immune system, Innate and Adaptive Immunity, mechanisms that prevent entry of pathogenic microbes.	2
Hematopoiesis & its regulation: Differentiation of hematopoietic stem cells into mature blood cells, role of various cytokines	2
Innate Immunity:	
Mechanism of immune response and inflammation, chemokines, adhesion molecules, migration of leukocytes, microbicidal mechanisms including phagocytosis, Immediate hypersensitivity: role of eosinophils, and mast cells. Asthma. IgE receptor, prostaglandins and leukotrienes	3
Receptors of innate immunity: Toll-like receptors and sensing of PAMPs, signal transduction, opsonization, Fc receptors	2
Adaptive Immunity:	
Humoral and cell mediated Immunity, primary and secondary immune modulation, clonal selection	1
Antigens, antigenicity, and immunogenicity. B and T cell epitopes	1
Structure, function, domain organization, and classification of immunoglobulins, concept of variability, isotypes, allotypes and idiotypic markers. Antigen-antibody interactions	2
Genetic mechanisms leading to antibody diversity, VDJ rearrangements, affinity maturation, and allelic exclusion. Class switching, receptor and soluble forms of immunoglobulin	1
Major Histocompatibility Complex: genetic organization of H2 and HLA complexes. Class I and class II MHC molecules, structure and function. Antigen processing and presentation pathways	2
Differentiation and activation of B cells, BCR and pre BCR, receptor editing, Helper T-cells	1
T-cell receptors and their diversity, α β and γδ T-cells, T-cell activation, APC/T-cell interaction, Th1/Th2 cells and cytokines. Differentiation and selection of T-cells in thymus, self tolerancer, MHC restriction, super antigens	3
The complement system: classical and alternative pathway, regulation of complement activation pathways	2
Cell-mediated Immunity	
Cell-mediated effector functions: Cytotoxic T cells, Natural Killer Cells, ADCC, NK cell receptors, inverse correlation with target MHC expression, missing self hypothesis, cytotoxicity reaction	2
Applications:	
Hybridoma, monoclonal antibodies, and antibody engineering	1
Immunological Techniques (antibody generation, detection of molecules using ELISA, RIA, Western blot, immunoprecipitation, flowcytometry, mmunofluorescence microscopy etc)	1
Applications of immunological principles in vaccines, and diagnostics, tumor immunology, cancer and immunotherapy	4

BS504 Developmental Biology

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Prof. Biswanath Maity**

Topic	Contact hrs.
Animal Development:	15
Basic concepts of development and evolution of developmental patterns: Competence, induction, determination and differentiation, cell lineages and stem cells, imprinting, genomic equivalence and the cytoplasmic determinants	2
Fertilization and early embryonic development Production of gametes, cell surface molecules in sperm-egg recognition, zygote formation. Cleavage types and mechanism, blastula formation, gastrulation and cell movements, formation of germ layers.	3
Morphogenesis and organogenesis: Cell specification in amphibians and chick, tetrapod limb development and axes formation	1
Pattern formation: French flag model, polar coordinate model	1
Signaling cascades involved in the control of developmental program: Development of salamander limbs, development of hydra and planeria, mammalian liver	2
***Dictyostelium discoideum* as a model**: Life cycle, pattern formation, cAMP signaling during development	2
***C. elegans* as a model:** Invariant cell lineage, vulval development	2
Drosophila as a model: Early development, Anterior/posterior differentiation, Dorsal/ventral polarity development	2
Plant Development:	15
Basic plant architecture & developmental features: Cell and tissue structures; epidermal, ground, vascular and meristem tissues; cell division plane and pattern; tissue, cell and organ polarity. Model plants for development, specific advantages and disadvantages of Arabidopsis, tobacco, maize, petunia, rice, Physcomitrella	2
Reproduction in plants: Types of reproduction in plants, evolution of sexual reproduction, developmental differences in semelparous and iteroparous lifestyles. Seed germination and dormancy. Development of gametophytes and gametes, meiosis, developmental control, pollination, fertilization.	4
Embryonic pattern formation and development of polarity: Development of embryo from zygote, cell division pattern, initiation of shoot apical meristem (SAM), root apical meristem (RAM); development of embryonic polarity, hormonal regulation of polarity development.	2
Shoot Apical Meristem and organ size control: Initiation and organization of SAM, roles and interaction of CUC, NAM, STM, WUS, auxin and cytokinin in SAM initiation and size control.	1
Root-apical meristem and radial patterning: Initiation and organization of RAM, role of SHR, SCR, ethylene and auxin organization of radial patterning, root branching, differentiation of root epidermal layer	1
Leaf development, shape and dorsoventral patterning: Leaf initiation and expansion, phyllotaxy, positioning of leaf on SAM; dorsoventral patterning, effect of SAM dorsoventral patterning, coordination of cell division and expansion, leaf asymmetry development, stomata density and distribution control, trichome development.	2

Flower development and organ patterning: Organization of floral organs, ABC model, modification of floral organs, boundary genes; homeotic genes of plants, MADS box, evolutionary conservation between eudicot and cereal crop plants	2
Transition: Transition from vegetative and reproductive stage, photoperiodic, vernalization, GA and autonomous pathways	1

BS505 Cell signaling

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Prof. Kaushik Biswas**

Topic	Contact hrs.
Signaling in Animals	
Evolution of Cell Signaling: Why Communication is necessary, What are the various routes of Communication in Cells, The Evolution of the Language of Cellular Communication, Types of Cellular Communication, and their Sub-types.	2
Principles of Cell Signaling: Extracellular and Intra-cellular signals, Concept of Local / Distant Signaling, Concept of Signaling Specificity, How One cell responds differently to different signals, Receptors & Ligands, Intracellular Mediators, Second Messengers, Effectors, Signaling Feedback – Positive Feedback and Negative Feedback.	3
Signaling through G-protein coupled receptors: What are G-proteins, Different types of G-proteins, Structure of G-proteins, G-protein-coupled Receptors, G-proteins regulating c-AMP levels & its effects, G-proteins signaling through phosphor-lipids, G-proteins and ion channels, Sense of smell and vision regulation by G-proteins, Role of $Ca2+$ as an ubiquitous intracellular signaling molecule.	2
Concept of Protein phosphorylation and de-phosphorylation: Regulation by phosphorylation of proteins, proteins kinases and phosphatases, different modes of regulation of kinase and phosphatase functions, structural aspects of protein kinases and phosphatases, relevance in disease scenarios	3
NF-kB Signaling and Inflammation : Discovery of NF-kB, canonical and alternative pathways, relevance in immunity, regulation and disease-relevance	3
Signaling through Enzyme coupled receptors: Different classes of Enzyme-coupled receptors, Signaling by Receptor Tyrosine Kinases (RTKs), How phosphorylation of RTKs determines specificity and speed of signaling process, SH2- & SH3- domains, Adapter Proteins, Scaffold proteins, Molecular Switches and Small Monomeric GTPases, Rho-family of GTPases and how they maintain cellular architecture and motility. PI-3-AKT kinase signaling, How it controls survival and growth ? mTOR and its relation to cellular growth. Receptors associated with Tyrosine Kinases, Cytokine Signaling, JAK-STAT pathway, and how it controls inflammation. Serine Threonine Kinases, TGF-β signaling pathway, Smads, how TGF-β-Smad signaling regulates differentiation.	2
Alternative Signalling Pathways : Notch signaling pathway, Wnt signaling pathway, Sonic Hedgehog signaling, Nuclear Receptor Signaling	2
How Different Signaling Pathways control Vital Cellular Processes : Cellular Proliferation is regulated by different signaling pathways that ultimately affect the Cell Cycle; Cellular Growth is controlled by the PI3-Akt-mTOR pathway; Various signaling axes regulate Migration of cells; How Angiogenesis is modulated by various signaling cross talks ?	3

Signaling in Plants:	
Developmental signaling: Mode of action of Plant Growth Regulators - auxins, gibberellins, cytokinins, abscisic acid, Ethylene, Brassinosteroid, Jasmonic acid.	2
Plant Stress signalling: **Biotic stresses and signaling:** Stress physiology of virus, bacteria, fungus, Oomycete, nematode, insects pests infection/infestation. Mechanisms of natural resistance. Programmed cell death. **Abiotic stresses and signaling:** Stress physiology of drought, salinity, thermal, submergence, UV stress etc. Mechanisms of natural tolerance, Signaling crosstalk during stress.	6
Signaling during plant- beneficial microbe interaction: Importance, type of plant-microbe interactions (beneficial interactions and harmful interactions), Plant beneficial microbes: Plant growth promoting rhizobacteria, mechanism of root association and growth promotion; Mycorrhyzae and plant root endosymbiosis,	2

BS506 Biophysical chemistry-II

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Dr. Smarajit Polley**

Topic	Contact hrs.
Protein conformation and dynamics: Proteins as dynamic entities; translational and rotational motions of proteins; hydrodynamic properties of proteins and relationship with conformation; internal motions of proteins and its importance in protein function. Amyloids and prions. Intrinsically disordered proteins. LLPS (liquid liquid phase separation).	8
Nucleic acid conformation and dynamics: Forces behind association of DNA strands; RNA folding; melting of DNA and its kinetics, thermodynamics of DNA melting; base-mobility and base-flipping.	4
Macromolecular interactions: Protein-ligand interactions; entropy-enthalpy compensation; conformational pre-selection; induced-fit; thermodynamic origin of affinity and specificity; protein-protein, protein-small molecule, protein-nucleic acid interactions. Few cutting edge techniques to study such interactions.	8
Protein folding: Protein folding in vitro and in vivo, protein degradation and recycling mechanisms; role of chaperones,	5
Studying Biological molecules at Single-molecule resolution: Optical tweezers; fluorescence correlation spectroscopy.	5

BS507 Bioinformatics and Computational Biology

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Prof. Shubhra Ghosh Dastidar & Dr. Zhumur Ghosh**

Topic	Contact hrs.
Introduction to computational biology & bioinformatics. Branches of bioinformatics.	1
Biological Databases Nature of biological data. Biological data formats. Bioinformatics databases: Literature databases (PubMed), Primary nucleotide sequence databases (NCBI, EMBL, DDBJ), Secondary nucleotide sequence databases (UniGene, SGD etc.), Protein sequence databases (SwissProt/TrEMBL, PIR), Sequence motif databases (Pfam, PROSITE), Structure databases (PDB, NSD, SCOP, CATH), Gene Expression databases.	8

Basics of algorithms and bio-tools Basics of sequence alignment. Scoring matrix, BLAST series, FASTA. Pairwise Sequence Alignments and Multiple sequence alignments (ClustalW). Global Alignments – Needleman Wunsch Algorithm, Local Alignments – Smith Waterman Algorithm. Multiple sequence alignments (ClustalW). Basic concepts on phylogenetic markers and molecular phylogeny. Comparative genomics and gene prediction tools.	7
Basics of molecular modelling Conformational states and concept of population distributions of various states. Conformational ensemble and its dynamic equilibrium. Methods of mimicking atoms and molecules in computer, empirical estimation of stabilities (or energy) of macromolecular conformations using molecular mechanical force-field, potential energy landscape, simple methods of searching stable conformations (energy minimization) and its limitations. Solvent models, use of periodic boundaries, implicit solvent techniques. Methods of quantifying protein-ligand interactions. Notes on the degree of accuracy of the models. Advantages and common pitfalls.	4
Practical implications of molecular models Qualitative understanding of the link between microscopic world (molecular model) and macroscopic events (experiments) and the principles to correlate them, Ergodic Hypothesis. Ideas of conformational sampling to predict macroscopic behaviour of the molecular systems. Elementary concepts of the deterministic and stochastic methods of sampling (without much theoretical details): Molecular dynamics and monte-carlo methods. Basic methods of analysing conformational ensemble. Exposure to the domain of applications, including their usage to narrow down an investigation to fewer and focused experiments. Applications in drug design ligand design. Understanding the limitations.	3
Application of Bioinformatics Basics of omics data in biomedical sciences, omics data handling and analysis (Genomics, Transcriptomics, Proteomics, Metabolomics), Microbiome data analysis, usage of machine learning tools for multi-omics data analysis and integration, interaction networks and analysis.	7

BS510 Practicals-II

Credit:6 Contact hrs: 180 Marks: 75

Course Coordinator: **Prof. Atin K. Mandal, Dr. Smarajit Polley, Dr. Nirmalya Sen, Dr. Subhash Halder**

Topic	**Contact hrs.**
Enzyme kinetics Enzyme activity of alkaline phosphatase; Determine the optimum pH of ALP; Estimate Km and Vmax of ALP, determination of IC50 / IS50 of ALP, reversible and irreversible type of binding of inhibitor to enzyme.	35
Biophysical chemistry Spectroscopic and interaction techniques	35
Cell signaling and Immunology	40
Bioinformatics Practicals Visualizing and understanding biological data formats, such as genbank flat file, fasta, nexus, pdb etc. Exploring nucleotide and protein databases. Basics of Molecular modelling and simulation. Hands on transcriptomics, Proteomics, metabolomics data analysis, machine learning modules and biological network visualization	30
Genetics and Genomics	40

SEMESTER - III

BS601 Advanced Methods in Structural Biology

Credit:2 Lecture hours: 30 Marks: 25
Course Coordinator: **Prof. Ajit Bikram Datta & Prof. Anirban Bhunia**

Topic	Contact hrs.
Macromolecular X-ray crystallography:	
Understanding crystal lattice, symmetry, Crystal systems and Bravais Lattices	3
Crystal growth, sample preparation, limitations	2
Basics of diffraction and reciprocal lattice, Bragg's law, Ewald sphere, differentiating crystals on the basis of diffraction, systematic absences	4
Crystal data collection and processing, unit cell determination, integration, scaling and merging of datasets	1
Introduction to phase problem, MR, MIR and MAD methods of phase determination, advantages and drawbacks of each method, Patterson function	3
Cryo-electron Microscopy:	
Fundamentals of Cryo-EM, Sample preparation and practical considerations in cryo-EM, Image formation, aberrations, and beam-induced motion, Classification, refinement, and reconstruction of 3D models, Introduction to CryoET and CLEM	8
Model building and structure refinement in crystallography and Cryo-EM:	
Introduction to structure solution, refinement and validation. Calculation of electron density maps and model building, automated and manual building procedures using available tools, refinement strategies, optimum model refinement and validation of the structure.	2
NMR Spectroscopy:	
Basic NMR phenomenon; rotating frame description; pulse Fourier transform NMR; chemical shift; scalar coupling. Relaxation and relationship with motion; Nuclear Overhauser Effect and distance determination. Polarization transfer; selective excitation; spin-echo. Important NMR experiments: two-dimensional NMR, COSY, NOESY, TOCSY, heteronuclear shift-correlation. Some examples of Protein and Nucleic acids NMR.	7

BS602 Ecology and Evolutionary Biology

Credit:2 Lecture hours: 30 Marks: 25
Course Coordinator: **Dr. Anupama Ghosh**

Topic	Contact hrs.
ECOLOGY	
Habitat and Niche: Concept of habitat and niche; niche width and overlap; fundamental and realized niche; resource partitioning; character displacement.	2
Population Ecology: Characteristics of a population; population growth curves; population regulation; life history strategies (r and K selection); concept of meta-population – demes and dispersal, inter-demic extinctions, age structured populations.	3
Species Interactions: Types of interactions, inter-specific competition.	2
Ecological Succession: Types; mechanisms; changes involved in succession; concept of climax.	2
Applied Ecology:	3

Environmental pollution; global environmental change; biodiversity: status, monitoring and documentation; major drivers of biodiversity change; biodiversity management approaches.	
Evolutionary Biology	
Emergence of evolutionary thoughts: Lamarck; Darwin–concepts of variation, adaptation, struggle, fitness and natural selection; Mendelism; Spontaneity of mutations; The evolutionary synthesis.	6
Molecular Evolution: Concepts of neutral evolution, molecular divergence and molecular clocks; Molecular tools in phylogeny, classification and identification; Protein and nucleotide sequence analysis; origin of new genes and proteins; Gene duplication and divergence.	5
The Mechanisms: Population genetics – Populations, Gene pool, Gene frequency; Hardy-Weinberg Law; concepts and rate of change in gene frequency through natural selection, migration and random genetic drift; Adaptive radiation; Isolating mechanisms; Speciation; Allopatricity and Sympatricity; Convergent evolution; Sexual selection; Co-evolution.	7

BS603 Disease etiology in animals

Credit:2 Lecture hours: 30 Marks: 25

Course Coordinator: **Dr. Abhrajyoti Ghosh & Dr. Basudeb Maji**

Topic	Contact hrs.
Classification of Diseases : Infectious versus Non-infectious Diseases, Chronic and Acute Diseases, Genetic Diseases, Metabolic Diseases and De-generative Diseases and their examples. **Disease epidemiology:** Steps involved in epidemiology, purpose of infection control, regulations, policy and practice, risk assessments, Principles of infection control procedures.	2
Infectious Diseases: Concept, Origin and Evolution of Infection; Immune surveillance and Immune Escape, Virulence and pathogenesis.	2
Bacterial Infectious Diseases: Pathogens versus non-pathogens; Common bacterial diseases in humans; Basic mechanism of bacterial pathogenesis; Bacterial survival in host cells-Quorum sensing; Microbial structures and Toxins. **Tuberculosis:** Primary tuberculosis and Post-primary tuberculosis, tuberculosis in immunocompromised individuals, Diagnosis, treatment, Host-Pathogen Interaction: Immunity and Resistance, Drug target, Drug Resistance. Multi drug resistant tuberculosis **Cholera:** Pathogenesis and epidemiology of cholera, virulence factors, Evolution and transmission of virulence factors, molecular mechanisms of V. cholerae infections, Role of changes in the *V. cholerae* c-di-GMP pool and Type III secretion system during infection, treatment and prevention.	3
Viral Diseases: Viral pathogenesis and life cycle; genomes and structure of few pathogenic Viruses; Host–virus interactions; Mechanisms of Immune Evasion; Viral diseases and antibody response; Antivirals compounds, mutations and anti-viral resistance. **Biochemistry of Influenza and COVID-19**: Causative agents, and biochemical features of influenza (including Avian-Flu, H1N1, SARS, MERS) and COVID-19. Understanding of terms such as epidemic, pandemic, endemic, mode of transmission, outbreak, quarantine, isolation, incubation period, contact tracing, morbidity, and mortality.	3

Protozoan & Fungal Diseases: Different protozoan diseases, General mode of action and Pathogenesis protozoan diseases; Host response to Protozoans; Molecular signaling against Protozoa; Hypersensitivity and autoimmunity associated with Protozoan infections. **Malaria:** Plasmodium Life Cycle and General Morphology, Vertebrate Phases and Invertebrate stages, Classification of Plasmodium, Disease Pathogenesis, Host-Pathogen Interaction: Immunity and Resistance, Control and treatment, Metabolism, Drug target, Action and Drug Resistance. **Fungal diseases:** Mode of action of fungal diseases; Immune response against fungal infection; Candidiasis; Infection caused by Yeast; Mode of action of Yeast infection.	3
Non-Infectious Diseases: Genetic Diseases; Classification of genetic diseases; Metabolic Disorders; Classification of Metabolic Disorders; De-generative Diseases.	1
Cancer: Cancer as a microevolutionary disease, Hallmarks of Cancer, Uncontrolled Proliferation, Altered Metabolism and Warburg's Hypothesis, Metastasis, Cancer Critical Genes, Oncogenes and Tumor-suppressor genes, Mutations – Driver and Passenger Mutations, Examples of Mutations leading to altered phenotype, Cellular Heterogeneity in Cancer, Cancer Stem cells, Cancer Prevention & Treatment, Cancer Epidemiology, Preventable Causes of Cancer, Viral Causes of Cancer and their Treatment, Chemo-therapeutic Drugs, their anti-cancer mechanisms, Immuno-therapy, Mechanisms of anti-cancer resistance	6
Diabetes as a Metabolic Disorder: History of Diabetes, Diabetes as a metabolic as well as a life-style disorder; Types of Diabetes mellitus; Biochemistry of the maintenance of Blood Glucose, Hormones affecting Blood Glucose level: Insulin, glucagon and others, their sources, structures and functions-hyper & hypo activities, Insulin receptor and its role (brief structure, function & desensitization-insulin resistance); Causes of the disease: genetic (metabolic disorder) & environmental (Life Style); Biochemical changes in lipid metabolism in diabetes - causes and molecular mechanisms, Role of gut derived hormones and microbiome in diabetes; Associated Pancreatic disorders, different molecular mechanisms of beta-cell loss; Brief clinical aspect of this disease (symptoms, management & precautions).	4
Neurodegenerative Diseases: Basic concept of aging and neurodegenerative disorders. Protein mis-folding as a basis for Neurodegenerative disorders; Molecular mechanisms leading to Parkinson's (PD), Alzheimer's (AD), Huntington's diseases (HD) and Frontotemporal dementia (FTD) pathogenesis and pathophysiology. Overview of therapeutic approaches for neurodegenerative diseases.	6

BS604 Pathophysiology in Plants & Crop Improvement

Credit:2 Lecture hours: 30 Marks: 25
Course Coordinator: **Prof. Anupama Ghosh**

Topic	Contact hrs.
Plant beneficial microbes interaction: Types of association with a plant and biochemical/genetic aspect of mutual exchange **Plant stress response:** Plants' response to abiotic and biotic stresses; Disease concept; disease cycle and control measures - Blast disease of rice, brown spot of rice, black stem rust of wheat, early blight of potato, late blight of potato, wilt of pigeon pea, stem rot of jute, red rot of sugarcane.	6
Plants growth and microbes: Importance, type of plant-microbe interactions (beneficial interactions and harmful interactions), Plant beneficial microbes: Plant growth promoting rhizobacteria, mechanism of root association and growth promotion; Mycorrhyzae and plant root endosymbiosis, Plant phyllosphere, rhizosphere and endosphere as microbial habitat, examples of microbial species commonly associated with phyllosphere, rhizosphere and endosphere, Conditions regulating the composition of host plant associated microbial population. Techniques to identify plant associated microbial population and assess growth promotion activities, PGPRs as biofertilizers.	6
Plant mineral nutrition and utilization mechanisms: Molecular mechanism of ion uptake, ion transporters, specific examples of transporters for Nitrate, Phosphate, Potassium and other nutrients. Physiological and molecular mechanisms underlying differential nutrient efficiency in crop genotypes, Phosphorous, Iron and Zinc efficient crop varieties. Plant responses to mineral toxicity. Source-sink relationship, Factors influencing seed development, seed quality. Seed storage proteins	4
Molecular Breeding approaches in crop improvement Linkage maps, Tetrad analysis, Development of mapping population. Molecular marker assisted approach: RAPD, RFLP, SSR library preparation, ISSR, SNPs, SNP detection using TaqMan/molecular Beacon tools. Plant phenomics in marker assisted breeding. Marker assisted breeding for quality improvement.	4
Agrobiology and Direct gene transfer: Agrobacterium plant interaction; Virulence; Ti and Ri plasmids; Opines and their significance; T-DNA transfer; Disarming the Ti plasmid. Genetic Transformation: Cointegrate and binary Vectors and their utility; Agrobacterium mediated gene delivery; characterization of transgenics PEG-mediated, electroporation, particle bombardment and other alternative methods Screenable and selectable markers, Marker– free transgenics methodologies, Chloroplast transformation	5
Genetic Engineering for Plant Architecture and Metabolism: Vitamins and other value addition compounds; Source-sink relationships for yield increase; Post-harvest bioengineering; Plant architecture; Flowering behavior. Phytoremediation	5

BS605 Fundamentals of Systems Biology

Credit: 1 Lecture hours: 15 Marks: 15

Course Coordinator: **Prof. Suman K. Banik**

Topic	**Contact hrs.**
Modeling biological systems:	
Building blocks of biochemical networks (motifs and switches), Boolean representations, graphical analysis.	3
Transcription regulatory networks: Simple gene regulation, auto regulation, identification of motifs from network analysis, feed-forward loop	5
Robustness and Optimal designs:	
Kinetic proof reading and Robustness	2
Optimal designs in biological systems & pareto-optimality.	3
Signal transduction networks:	
Two component system; MAP kinase cascades, cross talk	2

BS606 Product development and Entrepreneurship

Credit: 1 Lecture hours: 15 Marks: 15

Course Coordinator: **Prof. Ajit Bikram Datta & Dr. Nirmalya Sen**

Topic	**Contact hrs.**
Laboratory Record keeping, GLP and GMP:	
Proper documentation of research findings for future verification and IPR requirements.	1
Good laboratory practices and Good manufacturing practices. CFR 21 compliance.	1
Development of products for human consumption/use:	
Safety requirements, rules and regulations	1
Different phases of drug development, phase 1, phase 2 and phase 3 trials.	2
Efficacy, pharmacokinetic and pharmacodynamic studies.	1
Funds, IPR, Revenues and Industry: pillars of Entrepreneurship	
Why Take our science from Lab to Industry? Reasons to start an entrepreneurship	1
Funding agency, Venture capitalists, Crowd funding and Industrial research wings	3
Patent rules, IPR, Revenue/financial gains: How scientists team up with Industry	2
Presentation skills: how to sale your science	2
Start up: Indian Business policies, Types of ventures (MSMEs, BPOs), legal compliances	1

BS607A CBCS-A Stochastic Processes in Biology

Credit:4 Contact hr: 60 Marks: 40

Course Coordinator: Prof. Atin Kumar Mandal

Topic	**Contact hrs.**
Elements of Stochastic Processes:	
Brownian motion, Langevin equation, master equation, Fokker Planck equation	4
Elements of Dynamical Systems:	
Fixed points, linear stability analysis, two-dimensional systems	4
Elements of Chemical Kinetics:	
Mass action kinetics, Michaelis-Menten Enzyme Kinetics, Zero order ultrasensitivity	4
Elements of gene expression:	
DNA-protein interaction, Hill function, transcription, translation	4
Noise in gene expression:	
Intrinsic and extrinsic noise, phenotypic heterogeneity	3
Information theory:	
Entropy and mutual information	3

Signal transduction and information processing:	
TNF signaling pathway	4
Numerical simulation:	
Stochastic differential equation and stochastic simulation algorithm	4

BS607B CBCS-B Experimental techniques in biology

Credit:4 Duration: 60 hrs Marks: 40

Course Coordinator: Prof. Ajit B. Datta

Topic	**Contact hrs.**
Introduction to separation techniques for Biomolecules: Electrophoresis, centrifugation, chromatography: Principles and applications	6
Introduction to Biomolecular spectroscopy: Spectroscopic properties of various biomolecules, principles and applications	6
Absorption spectrometry: Molecular basis for the absorption of biomolecules in the UV-Visible range its usage in quantification and detection.	4
Polarization and Circular dichroism spectroscopy: Differential absorption of polarized light by biomolecules and its application in understanding protein and DNA structures	4
Fluorescence Spectroscopy: Intrinsic and extrinsic fluorophores of biomolecules, linking techniques, applications. FRET and Flurorescence anisotropy	10
IR and Raman Spectroscopy:	10
Probing interactions in biomolecules: Isothermal titration calorimetry, surface plasmon resonance (SPR) and their applications in drug-discovery	4
Structural studies of biomolecules: X-ray crystallography: Understanding crystal lattice, symmetry, Crystal systems and Bravais Lattices, crystal growth and limitations, data collection and processing, introduction to phase problem, MR, MIR and MAD methods of phase determination, advantages and drawbacks of each method, Patterson function, model building and refinement of the structure.	6
Cryo electron microscopy: Principles of Cryo-EM, Sample preparation and practical considerations in cryo-EM, Image formation, aberrations, and beam-induced motion, Classification, refinement, and reconstruction of 3D models, Introduction to CryoET and CLEM.	5
NMR spectroscopy: Rotating frame description; pulse Fourier transform NMR; chemical shift; scalar coupling. Nuclear Overhauser Effect and distance determination, multidimensional NMR experiments: COSY, NOESY, and TOCSY. Some examples of Protein and Nucleic acids NMR.	5

BS607C CBCS-C Biostatistics

Course Coordinator: Dr. Atin Kumar Mandal

Topic	**Contact hrs.**
Introduction to Biostatistics:	8
Definition and importance; Applications in life sciences; Types of data: qualitative vs quantitative; Scales of measurement: nominal, ordinal, interval, ratio	
Data Collection and Presentation:	8
Methods of data collection; Sampling techniques; Frequency distribution; Graphical representation: bar charts, histograms, pie charts, box plots, scatter plots	
Descriptive Statistics:	8
Measures of central tendency: mean, median, mode; Measures of dispersion: range, variance, standard deviation, coefficient of variation; Skewness and kurtosis	

Probability and Probability Distributions:	10
Basics of probability theory; Rules of probability; Conditional probability and Bayes' Theorem; Probability distributions: Binomial, Poisson, Normal distribution; Standard normal distribution and z-scores	
Statistical Inference:	6
Population vs sample; Sampling distributions; Central Limit Theorem; Estimation: point and interval estimation; Confidence intervals	
Hypothesis Testing:	10
Null and alternative hypotheses; p-value and level of significance; t-test (one sample, two sample); Chi-square test for independence and goodness-of-fit; ANOVA (Analysis of Variance)	
Correlation and Regression:	10
Pearson and Spearman correlation; Simple linear regression; Least squares method; Interpretation of regression coefficients; Coefficient of determination (R^2)	

BS610A Choice Based Laboratory Practical

Credit:1 Contact hr: 45 Marks: 20
Course Coordinator:

SEMESTER - IV

BS701 Term Paper

(Research Methodology and Ethics)
Course Coordinator: **Prof. Debaraj Mukherjee/Dr. Basudeb Maji**
Credit:1 Marks: 20
Student shall choose a topic for term paper and prepare presentation not related to the labs he/she is attending.

BS702 Project, Dissertation and Seminar

Credit: 17 Marks: 180
Each student is required to undertake a research project on an advanced topic to be chosen in consultation with a supervisor. The topic will be usually centered on the research activities carried out in the respective laboratory. The progress of the student will be examined in the mid-semester and in the end-semester examinations. At the end of the project the students have to submit a detailed project report (dissertation) and deliver a seminar in support of their work. Submission of the dissertation has to be done ten days before (excluding) the seminar date.

BS703 Comprehensive Viva

Credit: 2 Marks: 40
Each student is required to develop an overall understanding of various aspects of biological sciences as well as acquire knowledge about advanced research topics, as much as possible. Comprehensive Viva aims to examine the student's overall understanding and grasp of basic and advanced (as applicable) topics in biological sciences and his/her research topic. The student will be required to answer conceptual questions.

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