Ch. Bansi Lal University, Bhiwani

STUDY AND EVALUATION OF SCHEME OF

FIVE YEARS INTEGRATED M.SC

IN

PHYSICS

SUMMARY

PROGRAMME : **Five Years Integrated M.Sc In Physics**
M.SC.(PHYSICS)

DURATION : **FIVE YEARS (FULL TIME)**

MEDIUM : **ENGLISH**

Minimum Required Attendance :**75%**

Total Credits :**241**

Assessment/Evaluation

	Internal Marks	Major Test(End Semester Exam)	Total
Theory	20	80	100
Practical	20	80	100

Internal Evaluation:

Minor Test	Attendance	Assignment	Total
10	05	05	20

Duration of Examinations:

Major Test(End Semester Examination	Internal(Minor Test)
3 HRS	1 Hr

To qualify the course, a student is required to secure a minimum of 40% marks in aggregate including the Major Test (End Semester Examination) and internal evaluation. A candidate who secures less than 40% of marks in a course shall be deemed to have failed in that course. The student should have obtained at least 40% marks in aggregate to qualify the semester.

QUESTION PAPER STRUCTURE

There shall be nine questions in all by covering the entire syllabus. Students will have to attempt five questions. Question No.1 shall be compulsory, consisting of ten short answer type questions covering the entire syllabus with an option to attempt any eight questions. Each question shall carry equal marks.

(Abbreviation: P = Physics; PL = Physics Laboratory: PPr = Physics Project, PE= Physics Elective B = Biology; BL = Biology Laboratory; C = Chemistry; CL = Chemistry Laboratory; GL = General Laboratory; H = Humanities and Social Sciences; M = Mathematics ;)

FIRST YEAR

(Common to all the students)

SEMESTER –I

Total credits for semester-I = 24

Subject Code	Subject	Nature of Course	Contact Hrs per week	Credits	Examination Scheme			
					Internal	Theory Exam	Practical/Project	Total
B-101#	Biology-I (Introductory Biology)	Core Course (CC)	3	3	20	80		100
C-101	Chemistry-I (Structures & Bonding)	Core Course (CC)	3	3	20	80		100
P-101	Physics-I (Classical Physics)	Core Course (CC)	3	3	20	80		100
M-100/ M-101*	Mathematics-I	Core Course (CC)	3	3	20	80		100
H-101	Communication Skills-I	Ability Enhancement Course (AEC)	3	3	20	80		100
GL-101	Computer Basics	Ability Enhancement Course (AEC)	3	2	20		80	100
BL-101#	Biology Laboratory-I		3	2	20		80	100
CL-101	Chemistry Laboratory-I		3	2	20		80	100
PL-101	Physics Laboratory-I		3	2	20		80	100
HO-101	Hobby Club		2	1	50			50
Total credits for Semester-I				**24**				**950**

SEMESTER –II

Total credits for semester-II = 24

Subject Code	Subject	Nature of Course	Contact Hrs per week	Credits	Examination Scheme			
					Internal	Theory Exam	Practical/Project	Total
B-201#	Biology-II(Introduction to Macromolecules)	Core Course (CC)	3	3	20	80		100
C-201	Chemistry-II(Chemical Thermodynamics)	Core Course (CC)	3	3	20	80		100
P-201	Physics-II (Modern Physics)	Core Course (CC)	3	3	20	80		100
M-200/M-201*	Mathematics-II	Core Course (CC	3	3	20	80		100
H-201	Communication Skills-II	Ability Enhancement Course (AEC)	3	3	20	80		100
BL-201#	Biology Laboratory-II		3	2	20		80	100
CL-201	Chemistry Laboratory-II		3	2	20		80	100
PL-201	Physics Laboratory-II		3	2	20		80	100
GL 201	Electronics Laboratory		3	2	20		80	100
HU-201	Hobby Club		2	1	50			50
Total credits for Semester-II				**24**				**950**

***M-100 and M-200 are for the students who did not have mathematics in 12th Standard and will be completely Internal, while M-101 and M-201 are for those who had mathematics in 12th Standard.**

#B-101,BL-101,B-201 and BL-201 will be completely Internal.

SECOND YEAR

SEMESTER-III

Total credits for semester-III = 23

Subject Code	**Subject/Course**	**Nature of Course**	**Credits**	**Contact Hrs per week**	**Examination Scheme**			
					Internal	Theory Exam	Practical/Project	Total
P301	Classical Mechanics-I	CC	4	4	20	80		100
P302	Mathematical Physics-I	CC	4	4	20	80		100
P303	Electromagnetism-I	CC	4	4	20	80		100
P304	Waves, Oscillations and Optics	CC	4	4	20	80		100
H301	Humanities and Social Science	AEC	3	3	20	80		100
PL301	Physics Laboratory		4	6	20		80	100
	Semester Credits		23					
	Subtotal		71 of 241					600

SEMESTER-IV

Total credits for semester-IV = 26

Subject Code	**Subject/Course**	**Nature of Course**	**Credits**	**Contact Hrs per week**	**Examination Scheme**			
					Internal	Theory Exam	Practical/Project	Total
P401	Mathematical Physics -II	CC	4	4	20	80		100
P402	Quantum Mechanics-I	CC	4	4	20	80		100
P403	Classical Mechanics-II	CC	4	4	20	80		100
PE401	Elective-I (Out of Stream Elective)	Generic Elective Course (GEC)	4	4	20	80		100
H401	Humanities and Social Science	AEC	3	3	20	80		100
PL401	Physics Laboratory		4	6	20		80	100
PL403	Statistical and Computational Techniques		3	3	20		80	100
	Semester Credits		26					
	Subtotal		97 of 241					700

THIRD YEAR

SEMESTER-V

Total credits for semester-V = 25

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hrs per week	Examination Scheme			
					Internal	Theory Exam	Practical/ Project	Total
P501	Electromagnetism-II	CC	4	4	20	80		100
P502	Quantum Mechanics-II	CC	4	4	20	80		100
P503	Statistical Physics-I	CC	4	4	20	80		100
H501	Humanities and Social Science	AEC	3	3	20	80		100
G501	Environmental Science	AEC	2	2	20	80		100
PL501	Physics Laboratory		4	6	20		80	100
PL502	Numerical Methods		4	5	20		80	100
	Semester Credits		25					
	Subtotal		122 of 241					700

SEMESTER-VI

Total credits for semester-VI = 23

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hrs per week	Examination Scheme			
					Internal	Theory Exam	Practical/ Project	Total
P601	Nuclear Physics	CC	4	4	20	80		100
P602	Condensed Matter Physics-I	CC	4	4	20	80		100
P603	Atomic & Molecular Physics	CC	4	4	20	80		100
H604	Mathematical Physics - III	CC	4	4	20	80		100
H601	Humanities and Social Science	AEC	3	3	20	80		100
PL601	Physics Laboratory		4	6	20		80	100
	Semester Credits		23					
	Subtotal		145 of 241					600

Fourth YEAR

SEMESTER-VII

Total credits for semester-VII = 26

Subject Code	**Subject/Course**	**Nature of Course**	**Credits**	**Contact Hrs per week**	**Examination Scheme**			
					Internal	Theory Exam	Practical/ Project	Total
P701	Fluid Mechanics	CC	4	4	20	80		100
P702	Statistical Physics-II	CC	4	4	20	80		100
P703	Condensed Matter Physics-II	CC	4	4	20	80		100
PE701	Elective-II	Disciple Specific Elective (DSE)	4	4	20	80		100
PPr701	Projects		4				100	100
PL701	Advanced Physics Laboratory		6	8	20		80	100
	Semester Credits		26					
	Subtotal		171 of 241					600

SEMESTER-VIII

Total credits for semester-VII = 26

Subject Code	**Subject/Course**	**Nature of Course**	**Credits**	**Contact Hrs per week**	**Examination Scheme**			
					Internal	Theory Exam	Practical/ Project	Total
P801	Astronomy & Astrophysics	CC	4	4	20	80		100
P802	Nonlinear Dynamics & Chaos	CC	4	4	20	80		100
P803	Computational Physics	CC	4	4	20	80		100
PE801	Elective-III	DSE	4	4	20	80		100
PPr801	Projects		6				100	100
PL801	Advanced Physics Laboratory		6.	8	20		80	100
	Semester Credits		28					
	Subtotal		199 of 241					600

FIFTH YEAR

SEMESTER-IX

Total credits for semester-IX = 24

Subject Code	**Subject/Course**	**Nature of Course**	**Credits**	**Contact Hrs per week**	**Examination Scheme**			
					Internal	Theory Exam	Practical/ Project	Total
PPr901	Project		24				600	600
	Semester Credits		24					
	Subtotal		223 of 241					600

SEMESTER-X

Total credits for semester-X = 18

Subject Code	**Subject/Course**	**Nature of Course**	**Credits**	**Contact Hrs per week**	**Examination Scheme**			
					Internal	Theory Exam	Practical/ Project	Total
PE1001	Elective IV	DSE	4	4	20	80		100
PE1002	Elective V	DSE	4	4	20	80		100
PE1003	Elective VI	DSE	4	4	20	80		100
PPr1001	Project		6				100	100
	Semester Credits		18					
	Subtotal		241 of 241					400

Ch. Bansi Lal University, Bhiwani

STUDY AND EVALUATION OF SCHEME OF

FIVE YEARS INTEGRATED M.Sc.

IN

CHEMISTRY

SUMMARY

PROGRAMME	**: Five Years Integrated M.Sc. in Chemistry**
DURATION	**: FIVE YEARS (FULL TIME)**
MEDIUM	**: ENGLISH**
Minimum Required Attendance	**:75%**
Total Credits	**:246**

Assessment/Evaluation

	Internal Marks	Major Test(End Semester Exam)	Total
Theory	20	80	100
Practical	20	80	100

Internal Evaluation:

Minor Test	Attendance	Assignment	Total
10	05	05	20

Duration of Examinations:

Major Test(End Semester Examination	Internal(Minor Test)
3 HRS	1 Hr

To qualify the course, a student is required to secure a minimum of 40% marks in aggregate including the Major Test (End Semester Examination) and internal evaluation. A candidate who secures less than 40% of marks in a course shall be deemed to have failed in that course. The student should have obtained at least 40% marks in aggregate to qualify the semester.

QUESTION PAPER STRUCTURE

There shall be nine questions in all by covering the entire syllabus. Students will have to attempt five questions. Question No.1 shall be compulsory, consisting of ten short answer type questions covering the entire syllabus with an option to attempt any eight questions. Each question shall carry equal marks.

(Abbreviation: P = Physics; PL = Physics Laboratory: PPr = Physics Project, PE= Physics Elective B = Biology; BL = Biology Laboratory; C = Chemistry; CL = Chemistry Laboratory; GL = General Laboratory; H = Humanities and Social Sciences; M = Mathematics ;)

Centre for Excellence in Basic Sciences

Outline and Credits of the course structure for 5-years integrated M.Sc. Degree

M.Sc.(CHEMISTRY)

- Minimum total credits for integrated M.Sc. degree is 246.
- 1st Year [Semester-I (24 credits) and semester-II (24 credits)] is common to all the students.
- Subject specific teaching and project begins from 2nd year (III-Semester onwards)
- IX-Semester (24 credits) is a full-time project work
- X-Semester is elective course
- 1st August to 30 November: Semesters-I, III, V, VII and IX

  1st January to 30 April: Semesters-II, IV, VI, VIII and X

(Abbreviation: B = Biology; BL = Biology Laboratory; BPr = Biology Project; C = Chemistry; CL = Chemistry Laboratory; CPr = Chemistry Project; GL = General Laboratory; H = Humanities and Social Sciences; M = Mathematics; MPr = Mathematics Project; P = Physics; PL = Physics Laboratory: PPr = Physics Project)

Course Structure for M.Sc. (Integrated) Chemistry

FIRST YEAR

(Common to all the students)

SEMESTER-I

Subject Code	**Subject/Course**	**Nature of Course**	**Credits**	**Contact Hours per week**	**Examination Scheme**			
					Internal	Theory Exam	Practical/Project	Total
B101	Biology-I		3	3	20	80		100
C101	Chemistry I	CC	3	3	20	80		100
M101/ 100*	Mathematics-I	CC	3	3	20	80		100
P101	Physics-I	CC	3	3	20	80		100
H101	Communication Skills-I	AEC	3	3	20	80		100
			Credits	**Practical/Laboratory contact Hours**				
BL101	Biology Lab.		2	3	20		80	100
PL101	Physics Lab.	**CC**	2	3	20		80	100
CL101	Chemistry Lab	**CC**	2	3	20		80	100
GL101	Computer Lab	**SEC**	2	3	20		80	100
HY101	Hobby Club		1	2	50			50
		Semester Credits	24					
		Subtotal	**24** of **246**					950

SEMESTER-II

Subject Code	**Subject/Course**	**Nature of Course**	**Credits**	**Contact Hours per week**	**Examination Scheme**			
					Internal	Theory	Practical/Project	Total
B201	Biology-II		3	3	20	80		100
C201	Chemistry II	CC	3	3	20	80		100
M201/200	Mathematics-II	CC	3	3	20	80		100
P201	Physics-II	CC	3	3	20	80		100
H201	Communication Skills-II	AEC	3	3	20	80		100
			Credits	**Practical/Laboratory contact Hours**				
BL201	Biology Lab.		2	3	20		80	100
PL201	Physics Lab.	**CC**	2	4	20		80	100
CL201	Chemistry Lab	**CC**	2	4	20		80	100
GL201	Electronics Lab		2	2	20		80	100
HO201	Hobby Club		1	2	50			50
	Semester Credits		24					
	Subtotal		**48** of **246**					950

M-100 and M-200 are for the students who did not have mathematics in 12th Standard and will be completely Internal, while M-101 and M-201 are for those who had mathematics in 12th Standard.

#B-101, BL-101, B-201 and BL-201 will be completely Internal.

All the laboratory courses in 1st year will run for two months for a given student.

SECOND YEAR

SEMESTER-III

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory	Practical/Project	Total
B301	Biochemistry-I	CC	4	4	20	80		100
C301	Mathematics for Chemists & Biologists	CC	4	4	20	80		100
C302	Organic Chemistry-I	CC	4	4	20	80		100
C303	Inorganic Chemistry-I	CC	4	4	20	80		100
H301	History and Philosophy of Science	AEC	2	2	20	80		100
OE301	Open Elective/Generic Elective/Swayam	AEC	2	2	20	80		100
CL 301	Chemistry Laboratory		3	6	20	80		100
	Semester Credits		**23**					
	Subtotal		**71 of 246**					700

SEMESTER-IV

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory	Practical/Project	Total
C401	Spectroscopy -I	CC	4	4	20	80		100
C402	Physical Chemistry-I	CC	4	4	20	80		100
C403	Physical Chemistry-II	CC	4	4	20	80		100
C404	Organic Chemistry-II	CC	4	4	20	80		100
H401	Humanities and Social Science	AEC	3	3	20	80		100
			Credits	**Practical/Laboratory contact Hours**				

CL-401	Chemistry Laboratory		4	8	20	80		100
PL-402	Computational Laboratory		3	3	20	80		100
	Semester Credits		**26**					
	Subtotal		**97 of 246**					700

THIRD YEAR

SEMESTER-V

Subject Code	**Subject/Course**	**Nature of Course**	**Credits**	**Contact Hours per week**	**Examination Scheme**			
					Internal	Theory	Practical/Project	Total
C501	Analytical Chemistry	CC	4	4	20	80		100
C502	Physical Chemistry-III	CC	4	4	20	80		100
C503	Inorganic Chemistry-II	CC	4	4	20	80		100
C504	Spectroscopy-II	CC	4	4	20	80		100
H501	Humanities and Social Science	AEC	3	3	20	80		100
G501	Environmental Science		2	2	20	80		100
			Credits	**Practical/Laboratory contact Hours**				
CL501	Chemistry Laboratory	**CC**	4	8	20	80		100
	Semester Credits		**25**					
	Subtotal		**122 of 246**					700

SEMESTER-VI

Subject Code	**Subject/Course**	**Nature of Course**	**Credits**	**Contact Hours per week**	**Examination Scheme**			
					Internal	Theory	Practical/Project	Total
C601	Biophysical Chemistry	CC	4	4	20	80		100
C602	Group Theory & Applications	CC	4	4	20	80		100
C603	Inorganic Chemistry-III	CC	4	4	20	80		100
C604	Organic Chemistry-III	CC	4	4	20	80		100

C605	Nuclear Chemistry	CC	4	4	20	80		100
H601	Humanities and Social Sciences	AEC	3	3	20	80		100
			Credits	**Practical/Laboratory contact Hours**				
CL601	Chemistry Laboratory	CC	4	8	20	80		100
	Semester Credits		**27**					
	Subtotal		**149 of 246**					700

FOURTH YEAR

SEMESTER-VII

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory	Practical/Project	Total
C701	Photochemistry	CC	4	4	20	80		100
C702	Molecular Thermodynamics	CC	4	4	20	80		100
C703	Organometallics and Bio-inorganic Chemistry	CC	4	4	20	80		100
C704	Physical Organic Chemistry	CC	4	4	20	80		100
CPr701	Project	-	4	-	20		80	100
CL701	Advanced Chemistry Laboratory I		6	12	20	80		100
	Semester Credits		**26**					
	Subtotal		**175** of **246**					
								600

SEMESTER-VIII

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory	Practical/Project	Total
C801	Materials Chemistry	CC	4	4	20	80		100
C802	Macro and supra-molecular Chemistry	CC	4	4	20	80		100

C803	Computational Chemistry	CC	4	4	20	80		100
C804/ C805	Lasers and its Applications / NMR in Chemistry	CC	4	4	20	80		100
CL801	Advanced Chemistry Laboratory II		6	12	20	80		100
CPr801	Project		6		20		80	100
	Semester Credits		**28**					
	Subtotal		**203** of **246**					600

FIFTH YEAR

SEMESTER-IX

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory	Practical/Project	Total
CPR901	Project	CC	25	25	100		400	500
	Semester Credits		**25**					
	Subtotal		**228** of **246**					500

SEMESTER-X

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory	Practical/Project	Total
	Elective I	DES	4	4	20	80		100
	Elective II	DES	4	4	20	80		100
	Elective III	DES	4	4	20	80		100
CPr1001	Project		6	6	20		80	100
20	Semester Credits		**18**					
	Subtotal		**246** of **246**					400

Ch. Bansi Lal University, Bhiwani

STATE INSTITUTE OF EXCELLENCE IN BASIC SCIENCES(SIBS)

STUDY AND EVALUATION OF SCHEME OF

FIVE YEARS INTEGRATED M.SC

IN

MATHEMATICS

SUMMARY

PROGRAMME	**: M.SC.(MATHEMATICS)**
DURATION	**: FIVE YEARS (FULL TIME)**
MEDIUM	**:ENGLISH**
Minimum Required Attendance	**:75%**
Total Credits	**:240**

Assessment/Evaluation

	Internal Marks	Major Test(End Semester Exam)	Total
Theory/Practical	20	80	100

Internal Evaluation:

Minor Test	Attendance	Assignment	Total
10	05	05	20

Duration of Examinations:

Major Test(End Semester Examination	Internal(Minor Test)
3 Hours	1*hour*

To qualify the course, a student is required to secure a minimum of 40% marks in aggregate including the Major Test(End Semester Examination) and internal evaluation. A candidate who secures less than 40% of marks in a course shall be deemed to have failed in that course. The student should have obtained at least 40% marks in aggregate to qualify the semester.

QUESTION PAPER STRUCTURE

There shall be nine questions in all by covering the entire syllabus. Students will have to attempt five questions. Question No.1 shall be compulsory, consisting of ten short answer type questions covering the entire syllabus with option to attempt any eight questions. Each question shall carry equal marks.

STATE INSTITUTE OF EXCELLENCE IN BASIC SCIENCES(SIBS)

Outline and Credits of the course structure for 5-years integrated M. Sc. Degree

M.SC.(MATHEMATICS)

- Minimum total credits for integrated M.Sc. degree is 240.
- 1st Year [semester-I (24 credits) and semester-II (24 credits)] is common to all the students
- Subject specific teaching and project begins from 2nd year (III-Semester onwards)
- IX-Semester (24 credits) is a full-time project work
- X-Semester is elective course
- 1st August to 30 November: Semesters-I, III, V, VII and IX

  1st January to 30 April: Semesters-II, IV, VI, VIII and X

(Abbreviation: B = Biology; BL = Biology Laboratory; BPr = Biology Project; C = Chemistry; CL = Chemistry Laboratory; CPr = Chemistry Project; GL = General Laboratory; H = Humanities and Social Sciences; M = Mathematics; MPr = Mathematics Project; P = Physics; PL = Physics Laboratory: PPr = Physics Project)

FIRST YEAR

(Common to all the students)

SEMESTER –I (August- November) **Total credits for semester-I = 24**

Subject Code	Subject	Contact Hrs / per week	Credits	Examination Scheme			
				Internal	Theory Exam	Practical /Project	Total
B-101#	Biology-I (Introductory Biology)	3	3	20	80		100
C-101	Chemistry-I (Structures & Bonding)	3	3	20	80		100
P-101	Physics-I (Classical Physics)	3	3	20	80		100
M-100/ M-101*	Mathematics-I	3	3	20	80		100
H-101	Communication Skills-I	3	3	20	80		100
BL-101#	Biology Laboratory-I	3	2	20		80	100
CL-101	Chemistry Laboratory-I	3	2	20		80	100
PL-101	Physics Laboratory-I	3	2	20		80	100
GL-101	Computer Basics	3	2	20		80	100
HO-101	HOBBY CLUB	2	1	50			50
Total credits for Semester-I			24				950

SEMESTER –II (January-April)

Total credits for semester-II = 24

Subject Code	Subject	Contact Hrs / per week	Credits	Examination Scheme			
				Internal	Theory Exam	Practical /Project	Total
B-201#	Biology-II (Introduction to Macromolecules)	3	3	20	80		100
C-201	Chemistry-II (Chemical Thermodynamics)	3	3	20	80		100
P-201	Physics-II (Modern Physics)	3	3	20	80		100
M-200/M-201*	Mathematics-II	3	3	20	80		100
H-201	Communication Skills-II	3	3	20	80		100
BL-201#	Biology Laboratory-II	3	2	20		80	100
CL-201	Chemistry Laboratory-II	3	2	20		80	100
PL-201	Physics Laboratory-II	3	2	20		80	100
GL 201	Electronics Laboratory	3	2	20		80	100
HU-201	HOBBY CLUB	2	1	50			50
Total credits for Semester-I			24				950

***M-100 and M-200 are for the students who did not have mathematics in 12th Standard and will be completely Internal, while M-101 and M-201 are for those who had mathematics in 12th Standard. #B-101,BL-101,B-201 and BL-201 will be completely Internal.All the laboratory courses in 1st year will run for two months for a given student.**

SEMESTER-III

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours	Examination Scheme			
					Internal	Theory Exam	Practical /Project	Total
M301	Foundations	CC	4	4	20	80		100
M302	Analysis-I (Single Variable Analysis)	CC	4	4	20	80		100
M303	Algebra-I (Groups and Rings)	CC	4	4	20	80		100
M304	Elementary Number Theory	CC	4	4	20	80		100
H301	Humanities and Social Science	CC	4	4	20	80		100
OE301	OPEN ELECTIVE/MOOCs (Non-Departmental)	AEC	2	2	20	80		100
P301	Classical Mechanics	**CC**	**2**	**2**	**20**	**80**		**100**
	Semester Credits		24					
	Subtotal		72 of 240					Total=700

SEMESTER-IV

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory Exam	Practical /Project	Total
M401	Analysis-II (Multivariate Analysis)	CC	4	4	20	80		100
M402	Algebra-II (Linear Algebra)	CC	4	4	20	80		100
M403	Topology-I	CC	4	4	20	80		100
M404	Discrete Mathematics	CC	4	4	20	80		100
M405	Complex Analysis	CC	4	4	20	80		100
PL403	Statistical and Computational Techniques	**CC**	3	6	20		80	100
	Semester Credits		23					
	Subtotal		95 of 240					Total=600

SEMESTER-V

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory Exam	Practical /Project	Total
M501	Analysis-III (Measure and Integration)	CC	5	5	20	80		100
M502	Algebra-III (Field Theory)	CC	5	5	20	80		100
M503	Topology-II	CC	5	5	20	80		100
M504	Graph Theory	CC	5	5	20	80		100
PL-502	Numerical Methods Laboratory	CC	5	L=2, P=3	20		80	100
G-501	Environmental Science	CC	2	2	20	80		100
	Semester Credits		27					
	Subtotal		122 of 240					Total= 600

SEMESTER-VI

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory Exam	Practical /Project	Total
M601	Analysis-IV (Fourier Analysis)	CC	5	5	20	80		100
M602	Algebra-IV(Module Theory)	CC	5	5	20	80		100
M603	Differential Equations and Special Functions	CC	6	6	20	80		100
M604	Probability Theory	CC	5	5	20	80		100
H601	Humanities and Social Sciences	**AEC**	**3**	3	20	80		100
	Semester Credits		24					Total=500

	Subtotal		146 of 240	

SEMESTER-VII

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory Exam	Practical/ Project	Total
M701	Functional Analysis	CC	5	5	20	80		100
M702	Commutative Algebra	CC	5	5	20	80		100
M703	Algebraic Topology	CC	5	5	20	80		100
M704	Differential Geometry and Applications	CC	5	5	20	80		100
MPr701	Project	CC	4	4	20		80	100
	Semester Credits		24					
	Subtotal		170 of 240					Total= 500

SEMESTER-VIII

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory Exam	Practical/ Project	Total
M801	Partial Differential Equations	CC	5	5	20	80		100
M802	Algebraic Number Theory	CC	5	5	20	80		100
M803	Differential Topology	CC	5	5	20	80		100
M804	Computational Mathematics	CC	5	5	20	80		100
MPr801	Project	CC	6	6	20		80	100
	Semester Credits		26					
	Subtotal		196 of 240					Total= 500

SEMESTER-IX

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory Exam	Practical/ Project	Total
MPr901	Project	CC	24	24	100		400	500
	Semester Credits		24					
	Subtotal		220 of 240					Total= 500

SEMESTER-X

Subject Code	Subject/Course	Nature of Course	Credits	Contact Hours per week	Examination Scheme			
					Internal	Theory Exam	Practical/ Project	Total
ME1001	Elective I	DES	5	5	20	80		100
ME1002	Elective II	DES	5	5	20	80		100
ME1003	Elective III	DES	5	5	20	80		100
ME1004	Elective IV	DES	5	5	20	80		100
	Semester Credits		20					
	Subtotal		240 of 240	Total=400				

Ch. Bansi Lal University, Bhiwani

State Institute of Excellence in Basic Sciences

Syllabus
for
5-years integrated M. Sc. Degree
Physics, Chemistry and Mathematics

(implemented from Academic year 2020-2021)

(Abbreviation: P = Physics; PL = Physics Laboratory: PPr = Physics Project, PE= Physics Elective B = Biology; BL = Biology Laboratory; BPr = Biology Project; C = Chemistry; CL = Chemistry Laboratory; GL = General Laboratory; H = Humanities and Social Sciences; M = Mathematics ;)

NOTE: This syllabus will be implemented from the batch admitted to SIBS from 2020-2021 Academic Year.

Code No	Syllabus
B-101	**Biology-I (Introductory Biology)** 1. **Life:** History and origin of life, Concepts of biological evolution, Darwinism, Lamarckism, Hardy-Weinberg equilibrium, natural selection, speciation. 2. **Classification of living things:** Classification and domains of life, Prokaryotes and Eukaryotes, Taxonomy of plants, animals and microorganisms. 3. **Ecology and Ecosystem:** Concept of ecology and ecosystem, ecological succession, ecosystem dynamics, flow of ecology and matter, biogeochemical cycling, ecosystem changes, biotic and biotic factors and stresses, food web, adaptation of individual organism to the environment through genetic changes. 4. **Cell Biology**: Discovery of cell, cell theory, classification of cell types, cell membrane, cell-cell interactions, energy and metabolism, respiration, photosynthesis, sexual reproduction. 5. Cell Division and System Development: cell cycle, mitosis, meiosis, mechanism of development (stem cells), formation of tissues. **References** 1. Biology with mastering Biology (8th Edition) by Neil A. Campbell and Jane B. Reece (Hardcover - Dec. 7, 2007). 2. Biology: Concepts and Connections with my biology" (6th Edition) by Neil A. Campbell, Jane B. Reece, Martha R. Taylor, and Eric J. Simon (Hardcover - Feb. 28, 2008). 3. On the Origin of Species by Charles Darwin (Kindle Edition - Mar. 3, 2008) - Kindle Book. 4. Essential Cell Biology by Bruce Alberts, Dennis Bray, Karen Hopkin, and Alexander D Johnson (Hardcover - Mar. 27, 2009). 5. Molecular and Cell Biology for Dummies by René Fester Kratz (Paperback - June 2, 2009). 6. Darwin's Black Box: The Biochemical Challenge to Evolution by Michael J. Behe (Paperback - Mar. 7, 2006). 7. Biology: A Self-Teaching Guide, 2nd edition by Steven D. Garber (Paperback - Aug. 15, 2002).
B-201	**Biology-II (Introduction to Macromolecules)** 1. Cell – Overview: Cellular organization, Bio-membranes, Nucleus, Cytoplasmic organelles, Bacteriophages. 2. Nucleic Acids, Genomes and Proteomics: Building blocks- nucleotides, DNA structure, RNA structure and function, chromatin structure, genome code, genes, repetitive DNA sequences. 3. Gene Transcription: Overview of gene expression, overview of transcription, gene's regulatory elements, transcription mechanisms in prokaryotes and eukaryotes (a comparison). 4. Protein Structure and Function: Building blocks- amino acids, peptides, secondary structure, three-dimensional structure, membrane proteins, miscellaneous proteins, enzymes. 5. Cell Signalling: Overview, signalling via hydrophobic molecules, signalling via ion channels, signalling via G-protein coupled receptors, signalling via cell surface enzymes, intracellular signalling. 6. Biotechnology: DNA cloning, Uses of recombinant DNA technology, Polymerase chain reaction (PCR), Production of recombinant proteins and SDS-PAGE. **References** 1. Molecular Biology of the Cell by Bruce Alberts, Alexander Johnson, Julian Lewis, and Martin Raff. 2. Molecular Biology of the Gene (6th Edition) by James D. Watson, Tania A. Baker, Stephen P. Bell, and Alexander Gann. 3. Molecular Biology of the Cell, Fifth Edition: The Problems Book by John Wilson and Tim Hunt (Paperback - Nov 28, 2007). 4. Genes IX (Lewin, Genes XI) by Benjamin Lewin (Hardcover - Mar 5, 2007).

BL-101	Biology Laboratory-I 1. Introduction to Biology laboratory 2. Introduction to Research Laboratory: Different kinds of microbial plates, liquid growth media for microbes, Laminar air flow system, stem cells laboratory, Centrifuges, Spectrophotometer, Sonicator, PCR and Real-time PCR, Gel Documentation system, Chlamydomonas and Drosophila incubation systems, Stereo-microscope and various Incubators 3. Introduction to Light Microscopy 4. Gram Staining: To differentiate bacteria cells by Gram staining. 5. Micrometry: Measuring size of a microscopic specimen. 6. Staining and Observing human cheek cells: To carry out staining of epithelial cells from the mouth using methylene blue stains. 7. Staining human blood cells: To observe human blood cell types by differential staining. 8. Haemocytometer 9. Dye exclusion method of differentiating dead v/s live cells: To use a vital stain to distinguish dead and live yeast cells. 10. Concept of pH & Buffers: Hydrogen ion concentration in solutions, Inorganic ion concentration in solutions, Inorganic Buffers and Biological fluids, Henderson- Hesselbach equation 11. Media Preparation: Preparing and inoculating solid and liquid nutrient media for culturing microorganisms, pouring nutrient agar plates and streaking bacterial culture on solid media, inoculating nutrient broth with bacterial culture, Preparing nutrient media 12. Taxonomy 13. Methods of Classification: Dichotomous key, Hierarchical Classification, Phylogenetic Classification 14. Phototaxis Growth Curve: Generating a bacterial growth curve under various pH and environmental conditions (steady and shaking), Calculations of Growth rate constant (μ), Calculation of generation time 16. Plant anatomy: Relationship between plant anatomy and habitat
BL-201	Biology Laboratory-II 1. Observing instruments to be used in Semester-II, their use and maintenance: (a) micro-pipettes, (b) tissue homogenizer, (c) electrophoresis apparatus, (d) centrifuges, (e) ultraviolet and visible (UV-Vis) absorption spectrophotometer 2. Centrifugation of the cell contents at varying speeds such that the subcellular fractions separate out based on their density differences 3. Nucleic acid extraction - from plant & animal tissue using ethanol precipitation 4. Agarose gel electrophoresis 5. Analysis of DNA under various conditions – pH and Temperature 6. Carbohydrate extraction & estimation - extraction of sugars from grapes & estimation of the same by DNSA method 7. Protein extraction & estimation determination of total protein content in microorganisms by Folin-Ciocalteu method 8. Protein extraction & separation using polyacrylamide gel electrophoresis (PAGE) 9. Photosynthesis - floating leaf disc experiment under various conditions (light, dark & light - dark) 10. Separation of biomolecules using: a) Adsorption chromatography b) Partitioning of indicators in various solvent systems. c) Separation of a mixture of solutes by partitioning d) Separation of leaf pigments by paper chromatography e) Separation of flower pigments by paper chromatography 11. Reverse phase thin layer chromatography (RPTLC) - Separation of photosynthetic

	pigments
C-101	Chemistry-I (Structure & Bonding) Part-1: Building Blocks: Atoms & Molecules (20 + 10 = 30 Hrs) **Atoms**: Hydrogen atom: Line spectra, Old quantum theory: Bohr's theory and beyond. Many-electron atoms: Electronic configuration, energy level sequence, Pauli exclusion principle, Hund's rule, concept of screening of charge. Properties of atoms: Size of atoms and ions, ionization energy, electron affinity, concept of electronegativity, its scales and applications, variable valency, oxidation states, position in the periodic table and periodic variation of properties. **Molecules**: Concept of chemical bond between atoms: Types of bonds: Ionic, covalent, and coordinate bond. The quantum chemical picture: Concept of atomic orbitals, Concept of hybridization. Molecular geometry: Bond length, bond angle & dihedral angle, d-orbital participation in molecular bonding, sigma and pi bonding. Shapes of the molecules: Valence shell electron pair repulsion (VSEPR) theory, effect of lone pair and electronegativity, isoelectronic principle, examples. Theory of bonding: Valence bond theory and molecular orbital theory. Molecular orbitals (MO) as linear combination of atomic orbitals (LCAO), MO treatment for di- and tri-atomic molecules and molecules involving delocalized pi-electron bonding. Basic concepts of resonance, conjugation, aromaticity, and hyperconjugation. **Bulk phase**: *Physical properties and molecular structures:* Polarizability and dipole moment, melting and boiling points, solubility and acid-base properties, Intermolecular forces (dipole-dipole interaction), Hydrogen bonding and van der Waals forces. **Spectroscopy:** *Interaction of molecular systems with light*: Introduction to spectroscopy of different types. **Part-2: Chemical Reactivity and Mechanism (10 + 5 = 15 h)** **Stability and Reactivity:** Polarization and polarizability effects, delocalization of electrons, resonance, hyperconjugation. Aromaticity: Criteria for aromaticity, Hückel theory, Benzenoid and non-benzenoid compounds, anti-aromaticity, homo-aromaticity. Acidity and basicity: Different concepts, hard and soft acid base. Hydrogen bonding and its effect on properties of molecular systems and chemical reactions. **Reactive intermediates**: Structure, generation, stability, and general reactions of carbocation, cation radicals, carbene, electrophile and nucleophile, ambident electrophile and nucleophile, Solvents and solvent effect. **Mechanism:** Guidelines for depicting mechanism. Thermodynamics and kinetic control of chemical reactions. **References** 1. J.D. Lee, Concise Inorganic Chemistry, 4th Edition, ELBS, 1991. 2. P.W. Atkins, Physical Chemistry, 7th Edition, Oxford University Press, 2006. 3. G.M. Barrow, Physical Chemistry, 5th Edition, Tata McGraw-Hill, New Delhi, 1992. 4. R.T. Morrison and R.N. Boyd, Organic Chemistry, 7^{th} Ed, Prentice Hall of India, 2010 G.W. Castellan, Physical Chemistry, 3rd Ed. Addison-Wesley / Narosa Pub. House, 1993.

C-201	**CHEMISTRY- II (Chemical Thermodynamics)** **Revisit to Thermodynamics & Kinetic theory:** Basic concepts, laws of thermodynamics, concepts of heat & energy, temperature, internal energy, work, state function, reversible & irreversible processes, isothermal & adiabatic processes, Carnot cycle, gas laws, van der Waals equation, Kinetic theory of gases, Maxwell Boltzmann velocity distribution. **Thermochemistry:** Enthalpy, heat of fusion & vaporisation, enthalpy of a chemical reaction (heat of combustion, solution, & neutralization), enthalpy of formation, standard reaction enthalpy, Hess's law, Kirchhoff's law, bond energy, dissociation energy. **Entropy:** Formulation of Second law (different statements), entropy change in a phase transition & other processes, entropy and Gibbs energy of mixing, Trouton's Rule, calculation of absolute (Third law) entropy, entropy change in a chemical reaction. **Free energy functions:** Criteria for spontaneity and equilibrium of closed systems, variation of Gibbs free energy with pressure and temperature, Gibbs Helmholtz equation, the concept of chemical potential, partial molar quantity, Gibbs Duhem equation. **Phase equilibrium:** Simple systems: Solid – liquid, liquid – vapour, vapour – solid transitions, phase diagrams: water, carbon dioxide, sulphur, phase equilibrium condition, Gibbs phase rule, Clapeyron & Clausius – Clapeyron equation. **Ideal Solutions:** Chemical potential of a solute in a binary ideal solution, Raoult's Law, colligative properties: vapour pressure lowering, freezing point depression, boiling point elevation, osmotic pressure, van't Hoff equation. **Chemical equilibrium**: Gibbs free energy change of a reaction, standard reaction Gibbs free energy, condition for chemical equilibrium, equilibrium constant, reactions involving gases and pure substances, effect of temperature, pressure on the equilibrium, Le Chatelier principle and applications. **Electrochemical systems**: Chemical potential of a charged species, electrochemical cell (galvanic and electrolytic). half-cell potential (electrode potential), relation with free energy, Nernst equation. **Molecular thermodynamics**: Concept of ensembles, partition function, evaluation of partition function for vibrational, rotational, electronic energies, evaluation of free energy, entropy and equilibrium constants from partition functions. References 1. P.W. Atkins, Physical Chemistry, 7th Ed, Oxford University Press, 2006. 2. G.W. Castellan, Physical Chemistry, 3rd Ed. Wesley/Narosa Publishing House, 1993. 3. G.N. Lewis and M. Randall, Thermodynamics, (Revised by K.S. Pitzer and L. Brewer), International Students Edition, McGraw Hill, 1961. 4. K.G. Denbigh, The principles of Chemical Equilibrium: With Applications in Chemistry and Chemical Engineering, 4th Ed., Cambridge University Press, 1981
CL-101	**Chemistry Laboratory** **Objectives of the Experiments**: To familiarise the students with chemistry laboratory and basic experiments involving simple chemical reactions and physical processes. Details of Safety requirement and practice in laboratory will be emphasised. **Topics to be covered**: Calibrations of pipette, burette, standard flasks etc., acid base titrations, recrystallization, thin layer chromatography, identification of organic functional groups, complexometric titrations based on EDTA complexation with metal ions, Synthesis of benzoic acid, diazotization etc. **References** 1. Vogel's Textbook of Quantitative Chemical Analysis (5th Edition; Longman) 2. Vogel's Qualitative Inorganic Analysis (7th Edition) 3. Various relevant articles in Journal of Chemical Education, American Chemical Society

CL-201	**Chemistry Laboratory** Objectives of the Experiments: To familiarise the students with various analytical procedures and use of a few equipments. Topics to be covered: Use of colorimeter for quantitative estimation, determination of equilibrium constant of complexation reactions, use of conductometry, and pH meter for determination of concentration of acids and bases, their dissociation constants, and critical micelle concentration of surfactants and identification of functional groups/ inorganic ions. **References** 1. Vogel's Textbook of Quantitative Chemical Analysis, 5th Edition 2. Vogel's Qualitative Inorganic Analysis, 7th Edition, **3.** Various relevant articles in Journal of Chemical Education, American Chemical Society

GL-101	Computer Basics
	History of Computers: A brief outline of the history of computing machines and processes. The first modern mechanical computers. The generation of electronic computers. General understanding of the computer architecture of the different generations. The different classes of computers. **Current Trends in Computation Industry:** General introduction of the current computer hardware and software. The basic building blocks of a modern hardware, viz. 1) processing unit, 2) graphical processing unit, 3) memory and storage, 4) input and output devices and their ports. The basic building blocks of software, viz. 1) the concept of Operating System and their different types, 2) the file system for different operating systems, 3) concept of programs and scripts. Trends in current computing industry: viz. parallel processing, virtualization, cloud computing, etc. Binary Logic and Logic Gates Introduction to binary arithmetic. Introduction to logic gates and logic operations. **Introduction to Linux Operating System:** The structure of the OS. The file system. Introduction to the shell (BASH) and the GUI. Introduction to Office applications (word processor, spreadsheet, etc.). Basic commands of the shell. Some aspects of system administration. Usage of plotting software to plot graphs, viz. GNUPLOT. **Introduction to Programming:** Fortran (using the GNU Fortran compiler "GFORTRAN" for Linux kernel). The concept of compiling and running a program. The structure of a computer program. The concept and purpose of syntax. Use of editors in writing a program and the use of a command line / shell in compiling and running a program. The Novice's Programming Techniques in Fortran: The data types. Reading and writing of data (input and output). Basic arithmetic operations. Formatting of input and output. Conditional statements. **The Beginner's Programming Techniques in Fortran:** Complex conditional statements. Different types of loops. Applications of conditional branching and loops for scientific, statistical and other applications. **The Intermediate Programming Techniques in Fortran:** Concept of arrays. Application of one dimensional arrays in manipulation of data. Sorting of data and its application. Two dimensional arrays. Matrix manipulation. Application in vector analysis. **The Advanced Programming Techniques in Fortran:** Usage of subroutines and functions. The structure of a complex Fortran programme. The dummy and global variables. **Applications of Fortran Programming:** Numerical computation of series, sequence. Interpolation and extrapolation. Finding the roots of functions. Testing the convergence and divergence of a series. Introduction to numerical differentiation and integration.

	Applications of numerical methods in physical problems. Vector manipulation. (including other interesting problems, viz., inverting an integer number, finding the factors of a number, HCF and LCM, prime numbers, etc.) **Project:** Web programming – Rudimentary web page, Computer graphics – GIMP.
GL-201	**Electronics Laboratory** Analogue electronics: Introduction to passive electronic components -resistance, capacitance, inductance; Circuit theorems: Thevenin's theorem, Norton's theorem and Maximum power transfer theorem; basic concepts of semiconductor diode and transistor; Principle of DC power supply; half and full wave bridge rectifier, capacitor filter – ripple factor, concept of load and line regulation, concept of constant voltage source and constant current source; concept of short circuit protection and current limit protection; Zener regulator; concept of Switch Mode Power Supply (SMPS), power supply ICs, charge pump ICs for stepping up voltage and for bipolar supply; application of Bipolar Junction Transistor (BJT) - biasing circuits: The CE configuration, fixed base bias, emitter bias, and potential-divider or voltage divider bias; CE amplifier, amplifier as a switch, concept of negative feedback, differential amplifier; Operational Amplifier (OPAMP): principle, basic characteristics and parameters relevant for general use; non-inverting and inverting amplifier, voltage follower, difference amplifier, summing amplifier, voltage controlled current source; OPAMP comparator, Schmidt trigger; Digital to Analogue Converter (DAC) with weighted resistance and R-2R ladder network; Analogue to Digital Converter (ADC); filters: low pass, high pass; band pass; Butterworth filter. Digital electronics: Review of basic logic gates; DeMorgan's theorem, Use of NAND / NOR as universal building blocks; arithmetic circuits; binary addition, half adder, full adder, binary subtraction - 1s and 2s complement, controlled inverter, adder / subtracter, parity checker; Flip-Flops (FF): RS-FF, D-FF, JK-FF; counters and shift registers: binary counter, ripple counter. **References** 1. Electronic Principles, 7th Edition, A. Malvino and D.J. Bates, Tata McGraw–Hill Education 2006. 2. Electronic Devices and Circuits, 5th Edition, David A. Bell, Oxford University Press 2008. 3. Digital Principles and Applications, 7th Edition, D. Leach, A. Malvino and G. Saha, McGraw- Hill Education (India), 2010.
H-101	**Communication Skills-I** 1. **Listening and comprehending Scientific Speeches, Lectures, Discussions** – Students would listen to passages of different kinds (lectures/speeches, discussions), graded for competence levels, on different scientific subjects. These passages would be both audio and video. They would then be given work sheets to evaluate their comprehension of these passages. The passage would then be repeated so that students could identify their own shortcomings in the comprehension of the passage. At the end of each session there would be an open discussion session between the teacher and the students to rationalize and overcome their problems in listening comprehension. 2. **Speaking Skills for Scientists** - As scientists, students would have to make

	classroom presentations, participate in debates and group discussions. This section of the course would break up the class into smaller groups and assign specific speaking tasks to them in the context of group discussions, debates and scientific presentations. At the end of each session there would be an open discussion on the mistakes made by the students and tasks assigned as homework for the rectification of such errors. These errors could be more centrally taken up in parallel Remedial Courses. 3. **Remedial Grammar** – Additionally some sessions would be reserved for remedial grammar exercises based on the felt needs of the students.
H-201	**Communication Skills-II** 1. **Reading Skills for Scientists** – As students of science reading would be an important skill. This section of the course would focus on different kinds of reading skills such as skimming, scanning and detailed reading. This would enable students to process texts as chunks of language (discourse) rather than single words, thus making their comprehension more complete. The passages selected for this section would again be graded for linguistic competence. The teacher would also use the passages to show students how language is structured in different rhetorical patterns such as narrative, analytical, argumentative and interpretative. This kind of reading sessions would thus enable students to actually understand and internalize texts rather than merely learn them by rote. 2. **Writing for Science** - This section of the course would teach students how to write scientific material in a coherent and readable style. This would involve the right choices in vocabulary, phrasing and sentence structures. The actual writing tasks would be preceded by short workshops on style (descriptive, explanatory, argumentative, analytical, interpretative) complexity of sentences, specialist vocabulary, nouns (abstractions and nominalizations), verbs (tense and voice), verbs (first person and third person constructions). Students would be given practice in different kinds of writing (reports, papers, summaries, synopses). At the end of each session the students would be broken up into groups and peer- evaluate their own work. Each group would then report on the learning experience from the session. Errors in writing could also be taken up for further remediation in parallel Remedial Courses. 3. **Remedial Grammar** – Additionally some sessions would be reserved for remedial grammar exercises based on the felt needs of the students.
H-301	**Humanities and Social Sciences** **History and Philosophy of Science** History of World Science up to the Scientific Revolution: Introduction about stone age, beginning of agriculture, urban civilization and science. Science in Samaria, Babylonia and Egypt. Natural philosophy of pre-Socratic Greece. Natural philosophy in Athens. Greek science in the Alexandrian period. Rome and decline of Ancient European science. Science and technology in China. Science and technology in the Muslim world. Technology and the craft tradition in medieval Europe. The scholarly tradition during the middle ages. Renaissance, the Copernican system of the world. Gilbert, Bacon and the experimental method. Galileo and the science of mechanics. Descartes – the mathematical method and the mechanical philosophy. The Protestant reformation and the scientific revolution. Newton –the theory of universal gravitation and optics. Alchemy and iatrochemistry. Medicine, theory of circulation of blood. Growth and characteristics of the scientific revolution. **History of Ancient Indian Science:** Indian civilization from pre-historic times to the Indus Valley Civilization. Ancient Indian mathematics and astronomy. Ancient

Indian medicine and biology. Chemistry, metallurgy and technology in general in ancient India. Strengths, weaknesses and potentialities of ancient Indian science.

Introduction to Philosophy of Science: What is science? Scientific reasoning; Explanation in science; Realism and instrumentalism; Scientific change and scientific revolutions.

Great Scientific Experiments: Group wise study and presentations by students of historically significant experiments in science.

References

1. A History of the Sciences, Stephen F. Mason, Collier Books, Macmillan Pub. Co. (1962)
2. A Concise History of Science in India, D. M. Bose, S. N. Sen, B. V. Subbarayappa, INSA (1971)
3. Philosophy of Science – A Very Short Introduction, Samir Okasha, Oxford Univ Press (2002)
4. Great Scientific Experiments – Ron Harre, Oxford University Press (1983)
5. The Story of Physics, Lloyd Motz and Jefferson Hane Weaver, Avon Books (1992)
6. The Cambridge Illustrated History of World Science, Colin A. Ronan, Cambridge-Newnes (1982)
7. Encyclopaedia of Classical Indian Sciences, Ed. Helaine Selin and Roddam Narasimha, University Press (2007)
8. Articles from Wikipedia on History and philosophy of science

H-401

Humanities and Social Sciences

World Literature

World Literature and Cinema are today interlinked as literature metamorphoses into cinema and films inspire literature. The concept of world literature has also changed with time. Classical Greek and Roman drama and poetry alone were originally considered to be worthy of this tag. Then gradually literatures of modern European languages were included in this category, followed by the literature of the USA and Latin America. Literatures of Asia and Africa, as well as texts written by women and the socially marginalized found no place in this construct of world literature. However, by the end of the 20th century and the beginning of the 21st century, the category of world literature has become more inclusive of people of colour, women, the socially marginalized, aboriginals and citizens of the developing world. This is also reflected in the major Western literary awards as well as global cinematic awards which are today won regularly by non-European and Northern American writers.

Background

Literary traditions in different parts of the world, Literary techniques and style, Contemporary writers and their works, Global trends in Cinema, The language of cinema, Global Film makers and their work

Literature

1. "Buying a Fishing Rod for My Grandfather", Gao Xingjian (China)
2. "Cities of Salt", Abdul Rahman Munif (Saudi Arabia)
3. "Fire and the Rain", Girish Karnad (India)
4. "The Lion and the Jewel", Wole Soyinka (Nigeria)
5. "Beloved", Toni Morrison (USA)
6. Selected Poems from around the world

Cinema

1. "Children of Heaven", Director: Majid Majidi, 1997 (Iran)
2. "Rashoman", Director: Akira Kurosawa, 1950 (Japan)
3. "The Bicycle Thieves", 1948, Director: Vittorio de Sica (Italy)
4. "The Apu Trilogy", Director: Satyajit Ray, 1955-1959 (India)

	5. "The Battleship Potemkin", Director: Sergei Eisenstein, 1925 (Russia) 6. "The Godfather", Director: Francis Ford Coppola, 1972 (USA)
H-501	**Humanities and Social Sciences: Psychology** **Positive psychology** is "the scientific study of what makes life most worth living", or "the scientific study of positive human functioning and flourishing on multiple levels that include the biological, personal, relational, institutional, cultural, and global dimensions of life". Positive psychology is concerned with eudaimonia, "the good life", reflection about what holds the greatest value in life – the factors that contribute the most to a well-lived and fulfilling life. Positive psychology began as a new domain of psychology in 1998 when Martin Seligman chose it as the theme for his term as president of the American Psychological Association. Mihaly-Csikszentmihalyi and Christoph are regarded as co-initiators of this development. It is a reaction against psycho-analysis and be, which have focused on "mental illness", meanwhile emphasizing maladaptive behavior and negative thinking. It builds further on the humanistic movement, which encouraged an emphasis on happiness, well-being, and positivity, thus creating the foundation for what is now known as positive psychology.
H-601	**Humanities and Social Sciences** **Ethics of Science and IPR** Introduction to a Collective, Participatory Teaching-learning Program: A Science of Our own. Science Stands the Test of Ethics: Some indicators. Levels of Moral Development - Does it mean anything? Medical Ethics: Different themes pertaining to medical ethics including ethical issues in public health. History, Philosophy and Psychology of Ethics: History of Political Economy and Modern Ethics. Environmental Ethics. Intellectual Property Rights and Associated Issues: History of Patenting. Digitalizing Culture-I: Free Software and Free Culture. Digitalizing Culture-II: Concentration and appropriation of Power by the few as well as Possibility of Distributive Justice. Journals and Publishers: Monopolistic practices by Academic Publishers. Quest for Determining what is Virtuous: Ethics in Practice. Collaborative Projects by the Class. Teaching the Teachers and other Virtuous Inquiries.
M-100	**Remedial Mathematics-I** **Trigonometry and Vectors:** arc lengths and areas of sector, polar coordinates, relations between different trigonometric functions, periodicity, graphical representation, fundamental identities, addition formulae, multiple angles, factorization formulae, Scalers and vectors, norm of a vector, dot product, projections, cross product. (3 weeks) **Sets and Functions:** Sets, Functions, Inequalities, graphical representation. (1 week) **Numbers:** Numbers of Different Types ($\mathbb{N}$, $\mathbb{Z}$, $\mathbb{Q}$, $\mathbb{R}$, $\mathbb{R} \setminus \mathbb{Q}$), Algebraic Properties, Factorial notation, Mathematical Induction, Division Algorithm, Divisibility, Prime Numbers, Fundamental Theorem of Arithmetic, Order Properties and Completeness Property of $\mathbb{R}$, concept of congruences. (3 weeks) **Series:** AP, GP and HP and inequalities of the mean, Sum of a series, Sigma notation,

Convergence, Limit Theorems, Divergence Tests for Convergence (Absolute Convergence and Non-absolute Convergence), Series of Functions, Taylor's Series, Power Series. (2 weeks)

Limits and Continuity: Limits of Functions, Convergence and Divergence, Boundedness, Squeeze Theorem. Graphical idea of monotonic function and Continuity, Continuous Functions, Continuous Functions on Intervals, Uniform Continuity. (2 weeks)

Derivatives and Differentiation: Definition and Graphical Representation of Derivatives, Differentiability and Continuity, Chain Rule, Product and quotient rules, Higher Derivatives. Derivatives of e^x, $\log x$, Trigonometric and Inverse Trigonometric Functions, derivatives of inverse functions, Derivatives of Power Series. Mean Value Theorem, Derivatives and Extrema, L'Hospital's Rule. (3 weeks)

References

1. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, John Wiley and Sons Inc., 1994.
2. T. M. Apostol, Mathematical Analysis, Pearson Education, 2004.
3. G. S. Strang, Calculus, Wellesley-Cambridge Press, 1991.
4. D. M. Burton, Elementary Number Theory, McGraw-Hill Education, 2010

M-101

Mathematics-I

Introduction (1 week)

Reading and Writing Mathematics: Illustration of mathematical proofs via examples, Illustration of Conjunction, Disjunction, Negation of Statements and Conditional Statements via examples. (1 week)

Functions and Relations: Sets, De Morgan’s Laws, Relations, Cartesian Products, Functions and Graphical Representation, Injective and Surjective functions, Composition and Inverse of Functions, Level Sets, Equivalence Relations and Equivalence Classes. (3 weeks)

Numbers: Natural Numbers, Algebraic Properties, Mathematical Induction. Real Numbers, Order Properties and Completeness Property of $\mathbb{R}$, Intervals on $\mathbb{R}$, Infinity, Infinite Sets and Cardinality. (3 weeks)

Sequences: Sequences, Convergence, Limit Theorems, Divergence, Cauchy Sequences. (3 weeks)

Infinite Series: Convergence and Divergence of Series, Geometric Series, Tests for Convergence. (1 week)

Limits: Limits of Functions, Boundedness, Squeeze Theorem, Limits at Infinity. (2 weeks)

References

1. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, John Wiley and Sons Inc., 1994.
2. P. D. Lax and M. S. Terell, Calculus with Applications, Springer, 2014.
3. K. A. Ross, Elementary Analysis, UTM, Springer, 2013.
4. G. S. Strang, Calculus, Wellesley-Cambridge Press, 1991.
5. T. M. Apostol, Mathematical Analysis, Pearson Education, 2004.
6. J. P. D’Angelo and D. B. West, Mathematical Thinking - Problem Solving and Proofs, Second Edition, Prentice Hall, 2000.

M-200	**Remedial Mathematics-II** **Integration:** Notion of an integral, integral as limit of sums, anti-derivatives, area under a curve, Fundamental theorem of calculus, definite integrals, indefinite integrals, Rules of integration: integration by parts, integration by substitution, Properties of definite integrals, Application of integrals (path lengths, areas, volumes, etc.) (3 weeks) **Complex Numbers:** real and imaginary parts, the complex plane, complex algebra (complex conjugate, absolute value, complex equations, graphs, physical applications). Consequences of Euler's formula. (2 weeks) **Matrices and Linear Equations:** System of linear equations, notion of a matrix, determinant. Row and Column Operations, Gauss Elimination, Simple properties of matrices and their inverses. (2 weeks) **Combinatorics and Probability:** Permutations and combinations, Binomial theorem for integral and non-integral powers, Pascal's triangle, Introductory probability theory, Conditional probability, Binomial probability distribution. (3 weeks) **Coordinate Geometry:** Introduction to coordinate geometry. Concept of a Locus, Equation of a straight line, circle, parabola, ellipse and hyperbola. Basic properties, slope and tangent line, (2 weeks) **Curvilinear coordinates:** Spherical and cylindrical coordinates, area and volume elements, illustrations, unit vectors, coordinate conversion matrices (1 week) **Basic Statistics:** frequency tables, mean, median, mode, standard deviation. (1 week) **Additional Topics:** Scalar functions of several variables, partial derivatives, properties of partial derivatives, chain rule, applications. Gradient of a function, geometric interpretation, properties and applications, Vector functions. Derivatives of a vector function, divergence and curl, geometric interpretation, properties and applications. **References** 1. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, John Wiley and Sons Inc., 1994. 2. T. M. Apostol, Mathematical Analysis, Pearson Education, 2004. 3. G. S. Strang, Calculus, Wellesley-Cambridge Press, 1991.
M-201	**Mathematics-II** **Continuity:** Continuous Functions, Graphical Representation, Composition and Inverse of Continuous Functions, Continuous Functions on Intervals. (2 weeks) **Differentiation:** Definition and Graphical Representation of Derivatives, Differentiability and Continuity, Chain Rule, Higher Derivatives. Mean Value Theorems, Derivatives and Extrema, L'Hospital's Rule, Taylor's Theorem and Applications. (4 weeks) **Integration:** Riemann Integral and its Properties, Statement of Fundamental Theorem of Calculus. (3 weeks) **Complex Numbers:** Complex Numbers, Statement of Fundamental Theorem of Algebra, Polar Coordinates, Euler's and de Moivre's Formulae, Formulae for Sine and Cosine, Roots of a Complex Number. (1 week)

	Vector Spaces: Vector Spaces (finite dimensional, over ℝ or ℂ. Illustrate concepts with 2- or 3-dimensional examples), Linear Independence, Basis, Dimension, Rank of a Matrix,Span. Linear Transformations, Matrix Representation of a Linear Transformation, Kernel and Image, Change of Bases, Invertibility and Rank. (4 weeks) **References** 1. M. Artin, Algebra, Prentice Hall, 1991. 2. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, John Wiley and Sons Inc., 1994. 3. P. D. Lax and M. S. Terell, Calculus with Applications, Springer, 2014. 4. K. A. Ross, Elementary Analysis, UTM, Springer, 2013. 5. T. M. Apostol, Mathematical Analysis, Pearson Education, 2004. 6. G. S. Strang, Calculus, Wellesley-Cambridge Press, 1991.
P-101	**PHYSICS-I (Classical Physics)** **Mechanics:** Review of concepts of energy, mass, momentum; Newton's laws - illustrations from real life; Conservative forces, Friction; One-dimensional random walk and locomotion of micro-organisms. (**6 hours**) **Electricity and magnetism:** Electrostatics, electric fields for various charge configurations, Gauss' law for electric fields; Moving charges, magnetic field, Gauss' law for magnetic fields; Faraday's law; The Ampere-Maxwell law. (**8 hours**) **Electromagnetism and Optics:** Fermat's principle of least time; Electromagnetic waves and dipole radiation – qualitative ideas without using calculus; Interference of two dipole radiators (qualitative discussion); Diffraction, diffraction grating, resolving power of grating, coloured films, crystals, opaque screen; Origin of refractive index, energy carried by an electric wave; Scattering of light; Polarization; Colour vision and its mechanism. **(14 hours)** **References** 1. The Feynman Lectures on Physics, vol. I, R. P. Feynman, R. B. Leighton, and Matthew Sands (Pearson, 2012). 2. Electricity and Magnetism (Berkeley Physics Course volume 2), E. M. Purcell (McGraw Hill, 2017). 3. Mechanics, waves, and thermodynamics: an example-based approach, Sudhir R. Jain (Cambridge Univ. Press, 2016). 4. Physics – Structure and Meaning, Leon N. Cooper (Brown Univ. Press, 1992). 5. Principles and Practice of Physics, Eric Mazur (Pearson, 2015).
P-201	**PHYSICS-II (Modern Physics)** **Review of classical physics and its limits**: the equipartition theorem, degrees of freedom, specific heat, Blackbody radiation, Photoelectric effect, Compton effect, Electron interference and diffraction (double slit experiment with electrons and Davisson-Germier experiment). Wavelike properties of particles, de Broglie hypothesis,

wave packets, uncertainty relation, bedarken experiment with Heisenberg microscope for measurement of electron position **(5 hours**)

Elementary Quantum Mechanics: Schrödinger wave equation and its heuristic derivation, operators, eigenvalues and eigen-functions, wave function and its probabilistic interpretation, superposition of eigenstates, collapse of wave function.
Simple one-dimensional problems: Particle in a box, finite square well, bound and unbound states, potential step, transmission and reflection coefficients, Potential barrier, tunneling phenomena with examples (alpha decay, scanning tunneling microscope), 1 dimensional harmonic oscillator, estimate of ground state energy using uncertainty principle, generalization to 2 and 3 dimensions, concept of degeneracy. Brief overview of hydrogen atom problem, Bohr's model of atom and atomic spectra, intrinsic spin. Franck-Hertz experiment, energy levels and spectroscopic notation, hydrogen fine structure and Zeeman effect (no detailed derivation) **(10 hours**)

Elements of Statistical Physics: Microscopic and macroscopic variables, classical phase space, distribution of molecular velocities, Maxwell-Boltzmann statistics, indistinguishable particles, Fermi Dirac and Bose Einstein statistics, applications of quantum statistics (**4 hours**)

Elements of Solid State Physics: Free electron theory, Drude and Sommerfeld models of specific heat, introduction to Fermi energy, Fermi velocity, Fermi temperature, concepts of density of states, electrons in periodic potential, Bloch theorem, Krönig-Penny model (no derivation), Band theory of solids, metals, semiconductors and insulators, intrinsic and extrinsic semiconductors, concept of holes, elementary semiconductor devices. (**5 hours**)

Nuclear Physics: Structure of nuclei and their stability, Binding energy curve, Shell model, Nuclear transformations (alpha, beta and gamma decay, nuclear reactions, cross sections, Fusion and Fission, Energy of stars. (**4 hours**)

References

1. H. S. Mani and G. K. Mehta, Introduction to Modern Physics, Affiliated East-West Press (2000).
2. R. Eisberg and R. Resnick, "Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles", Wiley (2nd Edition, 2006).
3. Arthur Beiser, Shobit Mahajan and S. Rai Chaudhury, "Concepts in Modern Physics", McGraw Hill Education (7th Edition, 2017).
4. P. A Tipler and R. Liewellyn, "Modern Physics", W. H. Freeman & Co. (6th Edition2012).
5. K. S. Krane, "Introductory Modern Physics", Wiley (2008).

P-301

Classical Mechanics-I

Recap: Newton's laws, vector algebra, gradient; momentum, energy, constraints, conservative forces, potential energy, angular momentum. Inertial and non - inertial frames, fictitious forces, Foucault pendulum, effects of Coriolis force. Central forces, conservation of energy and angular momentum, trajectories, orbits, 1/r potential (quadrature), classical scattering, two body problem, centre of mass and relative motions. Rigid body motion, moment of inertia tensor, energy and angular momentum, Euler's theorem, motion of tops, gyroscope, motion of the Earth. Introduction to Lagrangian through variational principle, applications of variational principle.

Relativity: Historical background, inconsistency of electrodynamics with Galilean relativity. Einstein's hypothesis and Lorentz transformation formula, length contraction, time dilation, Doppler shift. Energy, momentum and mass, mass - energy

	equivalence. Four vector notations, consistency of electrodynamics with relativity. **References** [1] An Introduction to Mechanics, 1st Edition, D. Kleppner and R. J. Kolenkow, Tata McGraw - Hill Education, 2007 [2] Classical Mechanics, 5th Edition, T. W. B. Kibble, F. Berkshire, World Scientific 2004. [3] Introduction to Special Relativity, R. Resnik, Wiley (India), 2012 [4] Spacetime Physics, 2nd Edition, E. F. Taylor, J. A. Wheeler, W. H. Freeman and Co. 1992. Classical mechanics, N. C. Rana, P. S. Joag, Tata McGraw-Hill Education, 2001.
P-302	**Mathematical Physics-I** **Vector Analysis**: Vector algebra, Basis vectors, Linear independence, Scalar product, Cross product, Triple products Partial derivatives, Curvilinear coordinates (cylindrical and spherical polar), Vectors as derivatives, Gradient, Divergence, Curl, Laplacian – all in Cartesian, cylindrical and spherical polar coordinates Vector integration, line, surface, volume integrals, Green's theorem, Stokes' theorem, Gauss divergence theorem **Differential equations:** Real analytic functions, Revision of first-order differential equations, Ordinary differential equations with constant coefficients, equidimensional equations, Riccati equations, Applications **Tensors:** Coordinate system transformations, Basis-vector transformations, Basis- vector vs. component transformations, Non-orthogonal coordinate systems, Dual basis vectors, finding covariant and contravariant components, Index notation, quantities that transform covariantly or contravariantly **References** 1. "About vectors", Banesh Hoffmann (Dover, London, 1975) 2. "Vector analysis", Second Edition, M. R. Spiegel, S. Lipschutz, D. Spellman (Tata McGraw- Hill, New Delhi, 2010). 3. "A Student's Guide to Vectors and Tensors", D. Fleisch (Cambridge Univ. Press, New Delhi, 2013). 4. "Differential equations with applications and historical notes", G. F. Simmons (McGraw-Hill, New Delhi, 1980).
P-303	**Electromagnetism-I** **Review of Vector calculus:** gradient, curl, divergence and Laplacian; Cartesian, spherical polar and cylindrical coordinates; volume and surface integrals, divergence theorem, Stoke's theorem. **Electrostatics:** superposition principle for continuous charge distribution, Gauss's law in integral and differential form, electric potential, energy of electrostatic field, Poisson's and Laplace's equations, properties of conductors, method of images, polarization and bound charges, vectors **D** and **P**. **Magnetostatics:** Lorentz force, Ampere's and Biot-Savart's law, divergence and curl of **B**, vector potential and concept of gauge, charged particle in electromagnetic field; magnetism in matter, volume and surface currents, magnetization vector **M** and vector **H**. Faraday's law in integral and differential forms; displacement current, Maxwell's

equations.
Electromagnetic waves, Poynting vector, radiation pressure.

References

1. “Introduction to Electrodynamics”, D. J. Griffiths, 4th Edition, Pearson India (2017).
2. “Foundations of Electromagnetic Theory”, J. Reitz, F. J. Milford and R. W. Christie, 4th Edition, Addison Wesley (2008).
3. “Electricity and Magnetism: Berkeley Physics Course, Vol. II”, Edward Purcell, McGraw Hill (2011).

P-304 Waves, Oscillations and Optics

Free oscillations, Simple harmonic motion, damped and forced oscillations; Coupled oscillators, normal modes, beats, infinite coupled oscillators and dispersion relation of sound; vibrating string; travelling and stationary waves; Amplitude, phase and energy. Derivation of wave equation for a string; Longitudinal and transverse waves. Waves in two and three dimensions, the wave vector, wave equation, linearity, superposition, Fourier decomposition of a wave, notion of wave packets, phase and group velocity. Example of mechanical waves (sound waves), speed of sound in air, effect of bubbles, natural observations and qualitative explanations, string and wind instruments. Chaldni plates. Propagation in changing media, continuity conditions, characteristic impedance. Snell's laws and translation invariant boundary, prism, total internal reflection, evanescent waves. Water waves, ocean waves, Tsunami. Electromagnetic waves, polarisation, interference, Fraunhofer diffraction. Shocks waves, boat wakes, linear analysis of the Kelvin wake. Alfven waves (qualitative).

References

1. Waves, Berkeley Physics Course Vol. 3, Frank S. Crawford, Tata McGraw – Hill Education, 2011
2. Introduction to the Physics of Waves, Tim Freegarde, Cambridge Univ. Press 2012
3. The Physics of Waves, Howard Georgi (http://www.people.fas.harvard.edu/~hgeorgi/new.htm)

P-401 Mathematical Physics-II

Linear vector space: Definition, Scalar product, Dual vectors and Cauchy - Schwarz inequality, Real and complex vector spaces, Metric spaces, linear operators, Algebra of linear operators, Some special operators (adjoint, Hermitian, unitary etc.), Eigenvalues and eigenvectors, Orthogonalization theorem, N-dimensional vector space, Matrix algebra, Inverse of a matrix, Change of basis in N-dimensional vector space, Orthogonal bases and some special matrices, Introduction to tensor calculus, Invariant subspaces, The characteristic equation and Hamilton-Cayley theorem, The decomposition of an N-dimensional space, The canonical form of a matrix, Hermitian matrices and quadratic forms

Differential equations: Second-order Differential equations, classification of singularities, Series solution, Frobenius method with all cases studied, local analysis, applications to equations leading to Special functions (Airy function, Bessel functions), Introduction to asymptotic methods for the case of equations with irregular singular points

Partial differential equations: General theory for the first-order equation, classification of second-order equations, method of characteristics, Fundamental solutions of Laplace equation, Helmholtz equation, and heat equation, Boundary-value problems, Green functions

References

	1. "Advanced mathematical methods for scientists and engineers", C. M. Bender and S. A. Orszag (Springer, Heidelberg, 1978). 2. "Mathematical methods for physicists", G. B. Arfken, H. J. Weber, F. E. Harris (Academic Press, New Delhi, 2013). 3. "Special functions", G. E. Andrews, R. Askey, R. Roy (Cambridge Univ. Press, New Delhi, 2000). 4. "Mathematics for Physicists", Philippe Dennery and Andre Krzywicki (Dover, London, 1996). 5. "Mathematics for Quantum Mechanics: An introductory Survey of Operators, Eigenvalues and Linear Vector Spaces", J. D. Jackson (Dover, London, 1990). 6. "Methods in Theoretical Physics", vols 1 and 2, P. M. Morse and H. Feshbach (McGraw-Hill, New York, 1953). 7. "Introduction to Matrices and Linear Transformations", D. T. Finkbeiner (W. H. Freeman, 1978).
P-402	**Quantum Mechanics-I** Review of introductory wave mechanical formalism, simple one-dimensional potential problems: particle in an infinite potential well, delta function potential, a finite potential well, potential barrier and tunneling, motion of a wave packet. Mathematical preliminaries, linear algebra, Hilbert space, observables, Dirac notation, Schrödinger and Heisenberg pictures. Linear harmonic oscillator, wave mechanical solution, Hermite polynomials, algebraic method, ladder operators. Central force, orbital angular momentum, intrinsic spin angular momentum, angular momentum algebra, raising and lowering operators. Hydrogen atom, reduction to one body problem, reduced mass, energy spectrum and wavefunctions. Addition of angular momenta, Clebsch Gordan coefficients, spherical tensors, Wigner- Eckart Theorem. **References** 1. "Introduction to Quantum Mechanics" D. J. Griffiths, 2nd Edition, Pearson Education (2005). 2. "Principles of Quantum Mechanics", R. Shankar, 2nd Edition, Springer (2010).
P-403	**Classical Mechanics-II** Principle of virtual work, d'Alembert's principle, Degrees of freedom, Generalized coordinates, Lagrange's equation of motion, Ignorable coordinates. Principle of least action and Hamilton's principle, Derivation of Euler Lagrange equation. Symmetry and conservation laws, Noether's theorem, generalized momenta, energy function, gauge freedom of Lagrangian. Systems with constraints, Lagrange multipliers, generalized forces. Electromagnetic Lagrangian. Small oscillations and normal modes, matrix formulation of coupled oscillator problems, damped and forced oscillations, Rayleigh's dissipation function. Hamiltonian formalism, derivation of Hamilton's equations motion, particle in an electromagnetic field.

	Phase space flow in second order autonomous systems, special case of Hamiltonian systems, comparison to incompressible fluids, examples of Hamiltonian phase space flows, elliptic and hyperbolic fixed points. Canonical transformations, different types of generating functions, simplectic criterion, infinitesimal canonical transformations, generators, Poisson's brackets, Jacobi identity, phase space volume conservation, Liouville's theorem. Hamilton Jacobi equation, discussion of quantum to classical limit. **References** 1. "A course in Theoretical Physics, Vol. 1, Mechanics", L. D. Landau and E. M. Lifshitz, Elsevier (Indian Reprint, 2010) 2. "Classical Mechanics", H. Goldstein, C. Poole and J. Safco, 3rd Edition, Addition Wesley (Pearson Edition, 2011). 3. "Classical Mechanics", N. C. Rana and P. S. Jog, Tata McGraw Hill (1991).
P-501	**Electromagnetism-II** Topics in Electrostatics: Solutions of Poisson and Laplace's equations, Uniqueness theorem, formal solution of boundary value problems with Green's function, method of images with conducting sphere, solution of Laplace's equation in Cartesian, spherical and cylindrical coordinates using separation of variables, Multipole expansion of potential due to a charge distribution, boundary value problems with dielectrics, molecular polarizability, Clausius-Mossotti relation. Maxwell's equations, scalar and vector potentials, gauge transformations, Lorentz and Coulomb gauge, Stress tensor and conservation laws, Electromagnetic waves, reflection and refraction of electromagnetic waves at interface between dielectrics, Fresnel equations; electromagnetic waves in conductors, skin depth. Rectangular Wave Guides, TE and TM modes; resonant cavity. Radiation theory: electric and magnetic dipole radiation, power radiated by a point charge, radiation reaction. Electrodynamics and relativity, transformation of electromagnetic fields, field tensors, relativistic potentials, field of a moving charge, retarded and advanced potentials. **References** 1. "Introduction to Electrodynamics", D. J. Griffiths, 4th Edition, Pearson India (2017). 2. "Classical Electrodynamics", J. D. Jackson, 3rd Edition, Wiley (2016). 3. "Classical Electricity and Magnetism", W. K. H. Panofsky and M. Phillips, 2nd Edition, Sarat Book House (2006).
P-502	**Quantum Mechanics-II** Approximation methods in quantum mechanics : Time independent perturbation theory, non-degenerate and degenerate perturbation, fine structure of hydrogen atom;, Zeeman effect, Stark effect; Time dependent perturbation theory, Schrödinger, Heisenberg and interaction pictures, harmonic perturbations, sudden approximations, Fermi's Golden rule, second order transitions, two level systems, Rabi oscillation, semi-classical radiation theory; Variational principle, ground state of helium atom, adiabatic approximation, Berry's phase, Aharonov Bohm effect; WKB approximation. Identical Particles, classical case, symmetric and antisymmetric states, bosons and

	fermions. Scattering theory, Green's function, Born approximation. Density matrix formulation of quantum mechanics. EPR paradox, Bell's inequalities. Dirac equation: free particle Dirac equation, negative energy solutions, antiparticles, Dirac equation for hydrogen atom, hydrogen fine structure (qualitative). **References** 1. "Introduction to Quantum Mechanics", D. J. Griffiths, 2nd Edition, Pearson Education (2005). 2. "Principles of Quantum Mechanics", R. Shankar, 2nd Edition, Springer (2010). 3. "Quantum Mechanics", E. Merzbacher, 3rd Edition, John Wiley (2003).
P-503	**Statistical Physics-I** Elementary probability theory; random walk; binomial, Poisson, log-normal distributions; the Gaussian. Brief Review of the Laws of Thermodynamics. Kinetic theory of dilute gases in equilibrium. Introduction to Ensembles; micro-canonical ensemble; canonical ensemble, grand canonical ensemble. Canonical Ensemble. calculation of thermodynamic quantities; Gibbs paradox; the equipartition theorem; Harmonic Oscillator, two level system and paramagnetism. Energy, density fluctuations, Validity of the classical approximation. Identical particles and symmetry; quantum distribution functions; Bose-Einstein statistics; Fermi-Dirac statistics. The free electron gas – heat capacity and Pauli paramagnetism; Bose Einstein Condensation. Interacting systems: Equation of State of the non-ideal gas and virial coefficients; Weiss molecular field approximation. Black body radiation and the Planck radiation law **References** 1. "Fundamentals of Statistical and Thermal Physics", F. Reif, Sarat Book Distributors (2010) 2. "Statistical Mechanics", 3rd Edition, by R. K. Pathria and Paul D. Beale, Elsevier (2011) 3. "Elementary Statistical Physics", C. Kittel, Dover publications (2004) 4. "Thermodynamics and an Introduction to Thermo-statistics", 2nd Edition, H. B. Callen, Wiley (2006)
P-601	**Nuclear Physics** **Nuclear Properties:** Size – nuclear radius, charge distribution, matter distribution. Mass-binding energy, liquid drop model/mass formula. Spin, Parity, isospin. Electromagnetic moments- magnetic dipole and electric quadrupole moments/nuclear shapes. Nuclear stability, alpha, beta, gamma decays, fission. Experimental methods for size, mass, spin, moments to be included. **Nuclear Forces:** Nuclear interaction, saturation of nuclear density, constancy of binding energy per nucleon. Bound two nucleon system, Deuteron problem, absence of bound pp, nn. N-N scattering – as a function of energy, phase shift, cross section. Salient features of nuclear force. Yukawa's theory of nuclear interaction (basics). **Nuclear Structure:** Magic numbers, shell model, spin orbit interaction, deformed shell model. Nuclear excited states vibration, rotation, Collective model. Electromagnetic interactions in nuclei: multipole transitions, selection rules, life times, electron capture, internal conversion, isomers, Coulomb excitation.

	Nuclear Reactions: Kinematics, Q value, excitation energy, conservation laws, cross section, mean free path. Types of nuclear reactions, experimental observables, excitation function, angular distribution, spectra. Compound nuclear reactions, Resonances, level density, temperature, Bohr model. Direct nuclear reactions, optical model, pick up and stripping reactions, spectroscopic factor Nuclear fission and fusion reactions. **References** 1. Introductory Nuclear Physics, K.S. Krane, Wiley 2008. 2. Concepts of Nuclear Physics, B. L. Cohen, McGraw Hill 1971. 3. Introductory Nuclear Physics, S. S. M. Wong, Prentice – Hall 2010. 4. Introduction to Nuclear and Particle Physics, 2nd Edition, A. Das and T. Ferbel, World Scientific 2004.
P-602	**Condensed Matter Physics-I** **Crystal Structure and X-ray diffraction:** Bravais lattices, space groups, reciprocal space, Brillouin zones, X-ray diffraction, structure factor, Diffraction of waves in periodic structures. **Lattice Vibrations:** Thermal properties: Einstein's and Debye's theories of specific heats of solids, thermal expansion and thermal conductivity, quantization of lattice vibrations, phonons. **The Free Electron Theory:** Drude Model: Electron conductivity, Heat capacity, Somerfield model: Thermal conductivity, AC conductivity and optical properties. **Band theory of solids**: Bloch theorem, Kronig-Penny model, Nearly Free electron model, effective mass, Tight binding model, Density of states, Fermi surface; Metals, insulators and semiconductors, Intrinsic and extrinsic semiconductors, energy gap, mobility, electrons and holes, Hall effect and cyclotron resonance, carrier lifetime, semiconductor devices. **Magnetic properties of materials:** dia, para and ferromagnetism. Quantum theory of paramagnetism, Curie's law. Ferromagnetism, exchange interactions, Heisenberg and Ising models, magnetic ordering and spin waves, anti-ferromagnets. **Superconductivity:** Introduction and important properties, Type-I and type-II superconductors, Electrodynamics of superconductivity: London's equation, Thermodynamics of the transition, Flux Quantization, Cooper pairs, BCS theory (qualitative), Josephson effect. **References** 1. Introduction to Solid State Physics, 8th edition, C. Kittel, Wiley (2012). 2. Solid State Physics, N. W. Ashcroft and N. D. Mermin, Cengage (2003).
P-603	**Atomic and Molecular Physics** **Many – electron atoms:** One – electron wavefunctions and energies in Coulomb potential (revision); Atomic orbitals, spin – orbit coupling, Thomas precession, fine structure; Alkali atoms; Helium ground state and excited states, direct and exchange integrals; Many – electron atoms: LS and jj coupling schemes; Hartree – Fock method; Pauli's principle and the Periodic Table; Nuclear spin and hyperfine structure. **Atoms in External Fields:** Quantum theory of normal and anomalous Zeeman

	effect, Linear and quadratic Start effect; Semi – classical theory of radiation; Absorption and induced emission; Einstein's A and B coefficients, dipole approximation, intensity of radiation, selection rules. Two level atoms in a coherent radiation field, Rabi frequency, radiative damping, optical Bloch equation, Broadening of spectral lines (Doppler, pressure and power broadening). **Lasers:** Basic concepts, rate equation and lasing conditions, working of some common lasers. Doppler free laser spectroscopy; Crossed – beam method, saturated absorption spectroscopy, two photon spectroscopy, Laser cooling and trapping (descriptive); Atom interferometry (descriptive). **Molecules:** Ionic and covalent bonding, Hydrogen molecular ion (H_2^+), Born – Oppenheimer approximation; Bonding and anti – bonding orbitals, Hydrogen molecule; Heitler – London method, Molecular orbital method, hybridisation, quantum mechanical treatment of rotational and vibrational spectra (diatomic and polyatomic molecules); Electronic spectra, Raman effect (classical and quantum theory); Vibrational and rotational Raman spectra; Electron spin resonance. **References** 1. Atomic Physics, Christopher Foot, Oxford University Press, 2005. 2. Intermediate Quantum Mechanics, 3rd Edition, H. A. Bethe and R. W.Jackiew, Persius 1997 3. The Physics of Atoms and Quanta: Introduction to Experiments and Theory, H. Haken, H. C. Wolf and W. D. Brewer, Springer 2005 4. Molecular Physics and Elements of Quantum Chemistry: Introduction to Experiments and Theory, H. Haken, H. C. Wolf and W. D. Brewer, Springer 2010.
P-604	**Mathematical Physics-III** **Complex analysis**: Elementary functions, stereographic projection, limits, continuity, complex differentiation, Analytic functions, Cauchy-Riemann equations, Multi-valued functions and Riemann surfaces, Complex integration, Cauchy's theorem, Cauchy's integral formula, Liouville theorem, Morera theorem, Maximum-modulus theorem, singularities of complex functions, Cauchy residue theorem, Principal value integrals, Rouché's theorem, Contour integration, Fourier and Laplace transforms **Fourier series** and its applications **Calculus of variations:** Fundamental ideas illustrated by problems involving shortest distances, brachistochrone, surfaces of revolution of minimum area, Weierstrass, Legendre, and Jacobi conditions, Envelope theorem, Euler-Lagrange equations, Connection of eigenvalue problems and Calculus of variations, Functional derivative **References** 1. "Complex variables: Introduction and applications", M. J. Ablowitz and A. S. Fokas (Cambridge University Press, New Delhi, 1997). 2. "Complex analysis", L. V. Ahlfors (McGraw-Hill, New Delhi, 2013). 3. "Integral transforms in mathematical physics", C. J. Tranter (Metheun, London, 1966). 4. "An elementary treatise on Fourier series", W. E. Byerley (Ginn and company, Boston, 1893). 5. "Calculus of variations", G. A. Bliss (Carus monographs, Mathematical Association of America, 1978). 6. "Mathematical methods of Physics", J. Mathew and R. L. Walker (Benjamin Cummings, Mumbai, 1979).
P-701	**Fluid Mechanics**

	Validity of hydrodynamical description. Kinematics of the flow field. Stress-strain relationship. Basic equations governing conservation of mass, momentum & energy. Navier-Stokes equation for viscous flows. Shear and bulk viscosity and radiative diffusivity in fluids. Viscous and thermal boundary layers. Potential flows. Water waves. Kelvin's circulation theorem. Stokes's flow Lubrication theory. Virial theorem in the tensor form. Magnetohydrodynamic flows. Generalized Ohm's law in the presence of Hall current &Ambipolar diffusion. Magneto-gravity-acoustic modes. Classical hydrodynamic and hydromagnetic linear stability problems: Rayleigh-Taylor and Kelvin-Helmholtz instabilities. Jeans' gravitational instability; Benard convection. Parker instability and magnetic buoyancy. Thermal instability. Non-linear Benard problem. Spherical accretion flows onto compact objects and accretion disks. High Speed flow of gases. Shock waves and blast waves. Supernova hydrodynamics. Physiological hydrodynamics. Blood flow in human heart. **References** 1. Hydrodynamics, 6th Edition, H. Lamb, Dover 1945. 2. An Introduction to Fluid Dynamics, G.K. Batchelor, Cambridge University Press, 2000. 3. Fluid Mechanics, 2nd Edition, L.D. Landau and E.M. Lifshitz, Elsevier 1987. 4. Magnetohydrodynamics, 2nd Edition, T.G. Cowling, Hilger 1976. 5. Introduction to Physics of Fluids and Solids, J. Trefil, Dover 1975.
P-702	**Statistical Physics-II** **Critical Phenomena:** Phase transitions in different systems, First and second order transitions, Lattice models to describe phase transitions such as Ising Models, X-Y and Heisenberg models, critical exponents. **Techniques**: 1) Mean Field Theory: Mean Field Theory for Ising model, Landau theory of second order phase transitions, Correlation functionsp; 2) Transfer matrix: Setting up the transfer matrix, Calculation of free energy and correlation functions Transport theory using the relaxation time approximation; Boltzmann differential equation formulation; examples of the Boltzmann equation method Diffusion equation; Einstein relation and the Langevin derivation. Fluctuation- Dissipation theorem. Semiconductor Statistics **Optional**: Renormalization Group: Scale invariance and scaling hypothesis. universality, scaling and critical exponents. Block spins and the Kadanoff construction, Application to 1D Ising model. 2D Ising model, Peierls criterion. Introduction to Monte- Carlo Methods in statistical mechanics; Metropolis algorithm; Gilespie method. **References** 1. "Fundamentals of Statistical and Thermal Physics", F. Reif, Sarat Book Distributors (2010). 2. "Statistical Physics part 1", 3rd Edition, L. D. Landau and E. M. Lifshitz, Elsevier (2008). 3. "Statistical Mechanics", K. Huang, John Wiley & Sons (1987). 4. "A Modern Course in Statistical Physics", L. E. Reichl, Wiley (2009).
P-703	**Condensed Matter Physics-II** **Introduction to many-body theory:** Second quantization and its application to free particle theory. **Correlated systems and interactions*:*** The electron gas: Hartree-Fock and Random

phase approximation, Hubbard model: basic features, The Mott transition.

Response theory: Fluctuation-dissipation theorem, Linear response, Kubo formula

Superconductivity and superfluidity: Ginzburg Landau theory, BCS theory, Bogoliubov transformation, Boundary between normal metal and superconductor, Andreev Reflection and Proximity effect.
Magnetism: Quantum theory of magnetism: Rationalization of the Heisenberg Hamiltonian, Hubbard model: Derivation of susceptibility, Origin of exchange, Spin wave, Band Magnetism and Stoner Theory

Integer and Fractional Quantum Hall effect: Landau levels, Disorder, localized and extended states, Edge states, introduction to FQHE

Kondo Physics: Magnetic impurities and their interactions, Anderson model, s-d exchange model, Kondo effect and RKKY Interactions, spin glasses.

Graphene physics: Crystal structure, properties and applications, band structure by Tight Binding, Dirac fermions, pseudospin, Berry phase - Blocking of backscattering, weak anti-localization

Plasmonics and photonic band gap materials: Electromagnetics of metals, surface plasmons at metal-insulator interfaces, waveguides and excitation of surface plasmons, transmission and detection

References

1. Many-Particle Physics, by Gerald D. Mahan, Springer Verlag, 3rd edition 2000.
2. The Physics of Solids by J. B. Ketterson.
3. Principles of Condensed Matter Physics by P. M. Chaikin & T. C. Lubensky.
4. Introduction to Superconductivity by M. Tinkham.
5. Quantum theory of Magnetism by R. M. White.
6. Plasmonics: Fundamentals and Applications by S. A. Maier.

P-801 Astronomy and Astrophysics

Stellar Physics: Equations governing the structure of stars: Mechanical & Thermal equilibrium. Virial theorem. Modes of energy transfer in stars: radiative & convective transport of energy. Auxiliary input: equation of state, opacity and energy generation by thermonuclear processes. Boundary conditions at the stellar surface & at the centre. Models with linear & quadratic density profiles. Polytropic models. Mass-luminosity- radius relations for low, intermediate & high mass stars. Sources of opacity and nucleosynthesis in stars. Manufacturing of iron-peak and heavier elements by rapid neutron capture processes. Mixing length theory of convective transport of hear. Completely convective stars. Hertzsprung-Russel diagram. Pre-main sequence contraction and the Hayashi phase. Zero-age main sequence. Stellar evolution: main sequence, red giant and asymptotic giant branch. Advanced stages of stellar evolution: white dwarfs, neutron stars & black holes. Physics and astrophysics of collapsed objects: pulsars, X-ray &gamma ray sources. Spherical accretion and Bondi solution. Physics of accretion discs. Stellar rotation and magnetism.

Galactic Physics: Units in astronomy, co-ordinate system, multi-wavelength sky (radio, IR, Optical, UV, X-ray, Gamma ray), distance ladder, Milkyway Galaxy, interstellar medium, basics of star formation, spiral and elliptical galaxies (morphology, content and kinematics), evidences for dark matter, AGNs, evidences for
supermassive black holes, M-sigma and similar correlations, radio galaxies, synchrotron radiation, accretion onto black hole, physical processes behind black hole-

galaxy co-evolution (merger, infall and feedback), clusters of galaxies (contents and kinematics), high redshift galaxies, cosmic evolution of galaxies and black holes, hierarchical structure formation, cosmic-web, GMRT, astronomy and society (including citizen science), constraints and prospects of astronomy and astrophysics research in India.

References

1. The Internal Constitution of Stars, A. S. Eddington, Cambridge University Press, 1988.
2. An Introduction to the Study of Stellar Structure, S. Chandrasekhar, Dover Publications, 2003.
3. The structure & Evolution of the Stars, M. Schwarzschild, Dover Publications, 1962.
4. Cox and Giuli's Principles of Stellar Structure, 2nd Ed., A. Weiss et al., Cambridge, 2003.
5. The Physical Universe: An Introducing to Astronomy, F. H. Shu, University Science Books, 1982.
6. Galactic Astronomy, James Binny and Michael Merrifield, Princeton University Press, 1998.
7. An Introduction to Active Galactic Nuclei, B. M. Peterson, Cambridge University Press, 1997.
8. Extragalactic Astronomy and Cosmology: An Introduction, Peter Schneider, Springer, 2006.
9. Physics of the Interstellar & Intergalactic Medium, Bruce T. Draine, Princeton Univ. Press, 2011.

P-802

Nonlinear Dynamics and Chaos

Dynamical Systems, phase portraits, vector fields, nullclines, flows, discrete dynamical systems, 1-d maps. Fixed points, linearization of vector fields, canonical forms, generalized eigenvectors, semisimple – nilpotent decomposition, Jordan canonical form, classification of fixed points. Hartman-Grobman theorem, homeomorphism, Stable Manifold Theorem, Centre Manifold Theorem, examples of manifolds. Index theory, Lyapunov functions and stability analysis, Limit cycles, Poincare-Benedixon Theorem. Gronwall's inequality, the Variational Equation, exploring neighbourhoods, Lyapunov exponents, Monodromy matrix, Floquet exponents. Bifurcations: Saddle- Node, Transcritical, Pitchfork and Hopf Bifurcation. 1-d maps, linear stability of fixed points and higher order fixed points, chain rule, lyapunov exponent, bifurcation diagram, finding period-n orbits in 1-d maps. 2-d maps, Linearization, the Henon map, Poincare surface of section. Symbolic dynamics, Sensitivity to initial conditions, Chaos, Partitions, Transition matrix, Entropies, Smale Horseshoe. Invariant density, the Perron-Frobenius operator. Fractals. Hamiltonian Dynamics.

References

1. Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering, S. Strogatz, Addison-Wesley 2001
2. Chaos: An Introduction to Dynamical Systems, K.T. Aligood, T.D. Sauer, J.A. Yorke, Springer, 2000.
3. Differential Equations, Dynamical Systems and an Introduction to Chaos, M. Hirsh, S. Smale and R. Devaney, Elsevier Academic Press, 2012
4. Chaos and Integrability in Nonlinear Dynamics: An Introduction, M. Tabor, John Wiley & Sons, 1989.
5. Classical and Quantum, P. Cvitanovic *et al.,* ChaosBook.org, Neils Bohr Institute, Copenhagen 2016

P-803

Computational Physics

Ordinary Differential Equations: Brief review of methods covered, Stiff equations, Numerov Method and its applications to Schrodinger Equation.

Root finding: Brief review of methods covered, System involving many variables, Brayden and the complementary Brayden method.

	Matrix Diagonalization: The Lanczos approach, Davidson method Fourier Analysis: Discrete and Fast Fourier Transform, Spectrum Analysis, Chaos in non-linear differential equations, Computerized Tomography Partial Differential Equations: the vibrating string, the steady state heat equation, the pseudo spectral method, the potential step problem, wave packets in two dimensions. Optimization: Constrained and Unconstrained minimization, Penalty function methods, Metropolis algorithm and its applications to calculation of partition function and path integrals, Gillespie algorithm. Treatment of integral equations and nearly singular integrals. **References** 1. Computational Physics, P. L. DeVries and J. E. Hasbun, Jones and Bartlett, Sudbury, Massachusetts, 2011. 2. Numerical Methods that Work, F. Acton, F. S. Acton, Harper and Row, New York, 1970. 3. Introduction to Non-Linear Optimization, D. A. Wismer and R. Chatterggy, North Holland, N. Y. 1978. 4. Numerical Recipes in Fortran, 2nd Edition, W.H. Press *et al.*, Cambridge University Press 2000. 5. Number Crunching, P. Nahin, Princeton University Press, Princeton, 2011. 6. For Brayden method: "New Method for Self-Consistency in Disordered Systems", Vijay A. Singh and Paul Bendt, *Phys. Rev.*, B 27 (1983) 6464-6468. 7. For nearly singular integrals: "A Simple Scheme for the Numerical Evaluation of Nearly Singular Integrals", G. C. John, J. E. Hasbun, and Vijay A. Singh, *Computers in Physics*, **11** (1997) 293-298.
PL-101	**Physics Laboratory-I** Introduction to experimental physics – conceptual and procedural understanding, planning of experiments; Plots (normal, semi-log, log-log); uncertainty / error in measurements and uncertainty / error analysis. Introduction to measuring instruments – concepts of standards and calibration; determination of time periods in simple pendulum and coupled strip oscillator system with emphasis on uncertainty in the measurements and accuracy requirements; study of projectile motion – understand the timing requirements; determination of surface tension of a liquid from the study of liquid drops formed under the surface of a glass surface; determination of Young's modulus of a strip of metal by double cantilever method (use of travelling microscope); study of combination of lenses and nodal points and correspondence to a thick lens; study of thermal expansion of metal – use of thermistor as a thermometer; measurement of small resistance of a wire using Carey-Foster-bridge and determine electrical resistivity of the wire; study of time dependence of charging and discharging of capacitor using digital multimeter – use of semi-log plot. **References** 1. Advanced Practical Physics for Students, B. L. Worsnop and H. T. Flint, Methuen and Co. Ltd., London
PL-201	**Physics Laboratory** Review of uncertainty / error analysis; least squares fit method; introduction to sensors / transducers; determination of 'g' (acceleration due to gravity) by free fall method; study of physical pendulum using a PC interfaced apparatus – study variation of effective 'g ' with change of angle of plane of oscillation - investigation of effect of large

	angle of oscillation on the motion; study of Newton's laws of motion using a PC interfaced apparatus; study of conservation of linear and angular momentum using 'Maxwell's Wheel' apparatus; study of vibrations of soft massive spring; study of torsional oscillatory system; study of refraction in a prism - double refraction in calcite and quartz; study of equipotential surface using different electrode shapes in a minimal conducting liquid medium; determination of electrical inductance by vector method and study effect of ferromagnetic core and study the effect of non-linearity of inductance with current. **Suggested Texts and References:** 1. Advanced Practical Physics for Students, B. L. Worsnop and H. T. Flint, Methuen and Co. Ltd., London
PL-301	**Physics Laboratory** Frequency response of R-C circuit (concept of cut-off freq and filter) and frequency response of L-C circuit; concepts of phase difference between voltage and current in these circuits, phase factor for appliances using AC mains supply; R-L-C (series / parallel) resonance; transient response in R-L-C series circuit; study of Newton's rings and interference in wedge shaped films; study of double refraction in calcite / quartz prisms, polarisation of the refracted light rays, optical activity in dextrose and fructose; soldering experience – make a gated timer with indicator; measurement of heat capacity of air; Use of thermocouple / platinum resistance thermometer, use of instrumentation amplifier in amplifying signal from thermocouple; study of the laws of a gyroscope; determination of the charge of an electron by Millikan's oil drop experiment. **Reference** 1. Advanced Practical Physics for Students, B. L. Worsnop and H. T. Flint, Methuen and Co. Ltd., London
PL-401	**Physics Laboratory** Application of PHOENIX (IUAC, New Delhi) microcontroller system for automation in experiments (six sessions); study of acoustic resonance in Helmholtz resonator using PHOENIX system; Resolving power of optical grating; study of atomic spectra in hydrogen, helium, mercury; Application of gamma counts from detected by G.M. counter for study of Poisson and Gaussian distributions; study of black body radiation by optical and thermal radiations; study of electrically coupled oscillators – normal and transient response. Assembling components for an experiment on thermal and electrical conductivity of metals and making of measurements. **References** 1. Phoenix: Computer Interfaced Science Experiments – http://www.iuac.res.in/~elab/phoenix/ 2. The Art of Experimental Physics, D. W. Preston and D. R. Dietz, Wiley 1991 3. Manual of Experimental Physics with Indian Academy of Sciences, Bangalore kit, R. Srinivasan and K.R.S. Priolkar
PL-402	**Computational Laboratory** Computing special functions (using recurrence relations, Attn: loss of accuracy and its effects), making subroutines/functions for these. Computing derivatives numerically. Zeros (roots) of functions (single variable, multivariable). Solving differential equations (single variable, any order), Euler and Runge-Kutta, initial and boundary value problems. Numerical integration: trapezoidal and Simpson rules, Gaussian quadrature

rules. Linear equations, inverse of a matrix, determinant using Gauss elimination. Matrix eigenvalue problems (Power method and recursive QR decomposition), principal component analysis and Singular Value Decomposition by taking examples from biological systems. Data fitting, least square method. Random number generators, Monte-Carlo methods, Gillespie Algorithm.

References

1. Gillespie, Daniel T. (1977). "Exact Stochastic Simulation of Coupled Chemical Reactions". *The Journal of Physical Chemistry*. 81 (25): 2340–2361.
2. W. H. Press *et al*., Numerical recipes in FORTRAN (2nd ed.): the art of scientific computing

PL-403 Statistical and Computational Techniques

Basic tools for numerical analysis in science: Solution of algebraic functions – Fixed point method, Newton-Raphson method, Secant method. Numerical Integration – Rectangular method, trapezoidal method. Lagrange's interpolation.

Matrix Algebra: Approximate solution of a set of linear simultaneous equations by Gauss-Sidel iteration method. Exact solution by Gaussian elimination. Inversion of a matrix by Gaussian elimination. Determining all the eigenvalues of a real symmetric matrix by Householder's method of tridiagonalization followed by QR factorization of the tridiagonalized matrix.

Purpose of Statistics, Events and Probabilities, Assignments of probabilities to events, Random events and variables, Probability Axioms and Theorems. Probability distributions and properties: Discrete, Continuous and Empirical distributions. Expected values: Mean, Variance, Skewness, Kurtosis, Moments and Characteristics Functions. Types of probability distributions: Binomial, Poisson, Normal, Gamma, Exponential, Chi-squared, Log-Normal, Student's t, F distributions, Central Limit Theorem. Monte Carlo techniques: Methods of generating statistical distributions: Pseudorandom numbers from computers and from probability distributions, Applications. Error Analysis: Statistical and Systematic Errors, Reporting and using uncertainties, Propagation of errors, Statistical analysis of random uncertainties, Averaging Correlated/ Uncorrelated Measurements. Least-squares fitting: Linear, Polynomial, arbitrary functions: with descriptions of specific methods; Fitting composite curves. Covariance and Correlation, Analysis of Variance and Covariance.

References

1. Statistics: A Guide to the Use of Statistical Methods in the Physical Sciences, R.J. Barlow, John Wiley 1989
2. The Statistical Analysis of Experimental Data, John Mandel, Dover Publications 1984
3. Data Reduction and Error Analysis for the Physical Sciences, 3rd Edition, Philip Bevington and Keith Robinson, McGraw Hill 2003

PL-501 Physics Laboratory

Study of diffraction by single slit, double slit and multiple slits leading to grating, quantitative determination and compare with simulation; Study of Michelson interferometer and determination of refractive index of air; study of Fabry-Perot interferometer; Study of Zeeman effect using Fabry-Perot Interferometer; study of characteristics of scintillation counter used in nuclear radiation detection; study of Hall effect in semiconductors; Introduction to Labview software for automation and use of

	NI data acquisition card in PC (six sessions). **Reference** 1. The Art of Experimental Physics, D. W. Preston and D. R. Dietz, Wiley 1991.
PL-502	**Numerical Methods Laboratory** Error, its sources, propagation and analysis; Errors in summation, stability in numerical analysis. Linear algebraic equations: Gaussian elimination, direct triangular decomposition, matrix inversion, SVD. Root-finding: review of bisection method, Newton's method and secant method; real roots of polynomials, Laguerre's method. Matrix eigenvalue problems: Power method, eigenvalues of real symmetric matrices using Jacobi method, applications. Interpolation theory: Polynomial interpolation, Newton's divided differences, forward differences, interpolation errors, Hermite interpolation, cubic splines. Approximation of functions: Taylor's theorem, remainder term; Least squares approximation problem, Orthogonal polynomials, Near minimax approximation. Numerical integration: review of trapezoidal and Simpson's rules, Newton – Cotes integration formulas, Gaussian quadrature; Error estimation. Numerical differentiation. Random numbers; Monte Carlo methods, Metropolis algorithm. Least squares problems: Linear least squares, examples; Ordinary differential equations: predictor – corrector method, Runge – Kutta methods. **References** 1. An introduction to Numerical Analysis, 2nd Edition, Kendall Atkinson, Wiley 2012 2. Numerical Methods for Scientists and Engineers, H. M. Antia, Hindustan Book Agency 2012. 3. Numerical Recipes in Fortran, 2nd Edition, W. H. Press *et al.*, Cambridge University Press 2000
PL-601	**Physics Laboratory** Study of quantum mechanics through acoustic analogue (four sessions); Fourier analysis / synthesis – use of simulation; Study of characteristics of a coaxial cable and determination of speed of electromagnetic waves in the coaxial cable; determination of specific charge (e/m) of electron; Study of Faraday rotation and determination of Verdit's constant in a glass material; investigation of chaos in a spring based coupled oscillator system; Introduction to workshop practice (two sessions); Introduction to vacuum practice (two sessions). **References** 1. The Art of Experimental Physics, D. W. Preston and D. R. Dietz, Wiley 1991.
PL-701	**Advanced Physics Laboratory** **Nuclear Physics** Spectral features of photoelectric absorption and Compton scattering with scintillation detectors (i) Inorganic: NaI(Tl), BaF2 (ii) Organic: BC501A and plastic. Energy calibration, energy resolution, photopeak and total efficiency, relative intensity, photoelectric and Compton cross-sections, radiation shielding. Alpha spectroscopy with a silicon surface barrier detector. Fine structure of alpha spectrum and determination of age of source. Fast timing and coincidence measurements using BaF2 and BC501A detectors. Angular correlation of gamma rays using NaI(Tl) detectors. High resolution, low-energy photon measurements with a silicon drift detector: Internal conversion studies, elemental composition through X-Ray Fluorescence (XRF) analysis. Geiger-Muller counter: operating characteristics, dead time measurement, determination of mass absorption coefficient, verification of inverse

	square law. Lifetime measurements: from nanoseconds through minutes using fast coincidence and decay studies. High-resolution gamma ray measurements with high- purity germanium detectors. Classic experiments: Rutherford scattering, cloud chamber, beta spectrometer. Spectrum analysis techniques and fitting routines: data/peak fitting, energy and efficiency calibration, 1D and 2D histograms. (Selected experiments from the above list are performed based on number of contact hours prescribed) **Condense Matter Physics** Growth of metallic thin films by physical vapor deposition techniques like thermal evaporation and DC magnetron sputtering. Tuning of growth parameters to change the deposition rate and hence thickness of the films. Introduction to vacuum techniques: vacuum pumps, rotary pump, diffusion pump and turbo molecular pumps. Measurement of vacuum: thermocouple gauges, hot and cold cathode gauges. Thickness measurement of thin films by quartz crystal monitor. Structural characterization of materials (some known and some unknown) by X-ray diffraction (XRD) and X-ray fluorescence (XRF) (a) Phase identification (b) Chemical composition (c) difference between powder diffraction pattern of single and polycrystalline systems (d) Reasons for line broadening in XRD: Rachinger correction and estimation of particle size from Debye-Scherer formula. (e) Identifying crystal structure and determination of lattice constant. Introduction to low temperature measurements: operation of a closed cycle cryostat, low temperature thermometers, controlling temperatures using PID feedback using temperature controllers, making electrical contacts on thin films and measuring DC resistance with sourcemeter using four probe method-advantages and disadvantages of the technique, temperature dependent (300-20K) measurement of electrical resistivity of metallic thin films and comparing the room temperature value with the standard. Determination of superconducting transition temperature of a high temperature superconductor using electrical transport measurements. Determination of band gap of a semiconductor: highly doped Si by fitting the temperature dependent resistance to the standard variation in semiconductors. Concepts of measuring electrical resistance in labs: from metals to dielectrics. Introducing GPIB interfacing of electronic instruments with the computer and writing LABVIEW programs to interface temperature controller and sourcemeter. Introduction to phase sensitive measurements: using of a dual phase lock-in amplifier. Measurement of the superconducting transition temperature of a superconducting thin film using a mutual inductance technique down to 2.6K (working of a cryogen free system). Measuring AC resistance of a milliohm resistor using phase sensitive detection and studying the frequency and amplitude variation of the resistance: introduction to noise, White noise and 1/f noise. **References** 1. Radiation Detection and Measurement, Glenn F. Knoll, John Wiley 2010. 2. Techniques for Nuclear and Particle Physics Experiments: William R. Leo, Springer 1995. 3. Basic Vacuum technology, 2nd Edition, A. Chambers, R. K. Fitch and B. S. Halliday, IOP 1998. 4. Physical Vapor Deposition, R. J. Hill, McGraw-Hill 2005. 5. Elements of X-ray Diffraction, 3rd Edition, B. D. Cullity and S. R. Stock, Prentice Hall 2001. 6. Introduction to Solid State Physics, 8th Edition, C. Kittel, Wiley 2012.
PL-801	**Advanced Physics Laboratory**

	Introduction to Observational Astronomy: Transmission of radiation through atmosphere in different bands, need for space platforms for invisible astronomies, Introduction to Optical, Infrared, Ultra-violet, X-ray and Gamma-ray astronomy, what do me measure and learn from different wavebands. **Introductory Astronomy and Different types of Optical Telescopes**: Astronomical parameters like Apparent and Absolute magnitude, Flux, Luminosity and its dependence on size and temperature of stars, Atmospheric Extinction, Coordinate System in Astronomy Refracting and Reflecting telescopes, different focal plane configurations, their applications and relative merits and demerits. Reflectivity and its wavelength dependence, "seeing" and factors affecting it, use of active and adaptive optics in modern telescopes to overcome atmospheric and thermal effects, calculation of focal length, focal ratio, magnification, field of view, plate scale, diffraction limit of telescopes. **Introduction to Focal Plane Detectors for Optical, infrared and UV astronomy:** Developments and evolution of modern Optical and Infrared imaging detectors: Photographic Plates, Phototubes, Image Intensifiers, Charge Coupled Devices (CCDs), Bolometers and how they work, their characterization and parameters (charge transfer efficiency, quantum efficiency, flat fielding etc.). CCDs uses in Imaging, morphological and Spectroscopic studies, Infrared Detectors and IR Arrays, UV Imaging and Photon Counting Detectors. **Different types of Focal Plane Instruments**: Imagers, Photometers, Fast Photometers for photon counting, limitations of PMT and CCD bases photometers, Importance of spectroscopy, Design and description of Low and High-resolution Spectrometers and their applications, Polarimeters and their applications. **Interaction of radiation with matter**: (a) Passage of charged and neutral particles through matter, Ionization loss formulae and dependence on different parameters, relativistic rise in ionization loss, detection of neutrons, Bremsstrahlung process, Cerenkov radiation and its application (b) Interaction of photons with matter: Photoelectric interaction, mass absorption formula and dependence on energy, atomic number etc., Thompson scattering, Compton scattering, Pair production process, formula and dependence on energy, atomic number, radiation length, critical energy **Introduction to Different Types of Gas-Filled Radiation Detectors:** Role of development of new detection techniques in new discoveries in high energy physics and astrophysics, different kind of detection techniques for charged and neutral radiation Dependence of charge multiplication on high voltage and pressure, Townsend coefficient, need for use of inert gases, quench gas, mobility of electrons and ions (a) Ionization Chamber (IC), description of a typical IC, its characteristics, application of IC in physics (b) Proportional Counters (PC): Single and multi-cell PCs, filling gases, Penning effect, charge multiplication process, energy resolution of PC, Fano factor, use of PCs in high energy physics, and astronomy especially in X-ray astronomy (c) Geiger Mueller (GM)Counter: Typical GM counter, its characteristics, applications of GM counter **Scintillation Counters, Cerenkov Detectors and other Solid State Detectors:** Scintillation processes, dependence on energy, charge and atomic number, Photomultiplier (PMT) for detection of light, PMT characteristics, charge multiplication and use of PMTs with scintillators (a) Organic Scintillation Counters:

	Plastic Scintillators and light yield, their use in charged particle detection, a typical PS detector and its characteristics (b) Inorganic Scintillation Counters: Scintillation medium and need for activators, Sodium Iodide (NaI) and Caesium Iodide detectors, their light output, application of these detectors in physics and astrophysics (c) Silicon detectors and their applications in X-ray Astronomy, Germanium Detectors, Cadmium - Telluride devices and their arrays **Observational X-ray Astronomy:** Birth and evolution of X-ray Astronomy, different types of X-ray sources, Discovery of X-ray Binaries, their broad properties, optical identification, classification in Low Mass X-ray binaries (LMXBs) and High Mass X-ray Binaries (HMXBs), their unique characteristics, estimation of mass of the compact star in X-ray binaries from the binary parameters (a) Neutron Star Binaries (NSB): X-ray Pulsars in Binaries, Rotation powered pulsars in SNRs, detailed discussion of their timing and spectral properties, New physics and astrophysics learnt from their studies (b) Black Hole Binaries (BHB): Inference about black hole nature, time variability, spectral measurements, mass of black hole **X-ray Radiation Processes:** (a) Thermal Emission, Black Body emission, Thermal Bremstrahlung (free-free emission),spectral line formation in thermal plasma, examples of thermal spectra, measurement of temperature and elemental abundances from spectral data (b) Non-thermal Emission: Synchrotron mechanism (magnetic bremstrahlung), spectral shape, polarized emission, Inverse Compton Scattering, spectrum of radiation, examples of non-thermal spectra, Cyclotron process in strongly magnetized stars and formation of cyclotron lines, determination of magnetic field of the stars **Experiments to be performed:** 1.Measuring energy resolution (R) of a Cadmium Telluride Detector using X-rays of different energies (E) from radioactive sources and deriving expression for variation of R with E. 2. Solar Constant measurement. 3. Measurement of Solar Limb Darkening. 4. Observing an Optical Binary Star and deriving its light curve. 5. Determine Pulsation period and binary light curve of an accreting Neutron star from X-ray data. 6. Measuring X-ray Energy Spectrum of a Black Hole Binary and fit it with different spectral models. 7. Characteristics of a Proportional Counter and dependence of its energy resolution on different parameters of the PC.
PPr-701	To be assigned by the Supervisor
PPr-801	To be assigned by the Supervisor
PPr-901	To be assigned by the Supervisor
PPr-1001	To be assigned by the Supervisor

C-301	Mathematics for Chemists and Biologists
	Series: Taylor series and its applications **Differential equations:** Review of first order ordinary differential equations (ODE), Linear ODEs with constant coefficients, Linear ODEs with variable coefficients: solutions by series expansion methods, introduction to partial differential equations, Laplace's equation, separation of variables. **Special functions/orthogonal polynomials:** Legendre differential equation and Legendre polynomials, important properties of Legendre polynomials, Hermite polynomials, Laguerre polynomials, and applications. **Integral Transforms:** Fourier series and Fourier transform, Laplace transform and applications, convolution and applications. **Vectors and Matrices: Vector calculus:** Concept of gradient, divergence and curl, determinant and inversion of a matrix, Eigen value problems, Secular determinants, Characteristics polynomials, Eigen values of real symmetric matrices; Eigen values and Eigen functions, important properties and examples. **Basics of complex variables:** Complex numbers, Analytic functions, Cauchy Riemann equations, Cauchy's integral formula, Residue theorem and simple applications. Concept of contour integration and its application. **References** M.R. Spiegel, Schaum's Outline of Advanced Mathematics for Engineers and Scientists, McGraw-Hill, 2009. 1. E. Kreyszig, Advanced Engineering Mathematics, 10^{th} Ed., John Wiley & Sons, 2010.

C-302	Organic Chemistry –I
	Part-1: Chemistry of Aliphatic compounds **Systematic naming of organic compounds:** acyclic, alicyclic, polycyclic, aromatic, spiro compounds. **Sources of organic compounds:** Coal, natural gas, petroleum, C_1 compounds.

Alkanes as cycloalkanes: As fuel (calorific value, isomerization of alkenes to better fuel, octane number, improvements in hydrocarbon fuels, environmental effect) mechanism of halogenation of alkanes, strains in cycloalkane/cycloalkene

Alkenes and cycloalkenes: Preparation: cracking of petroleum, Elimination reaction E1 and E2, Saytzeff and Hoffman elimination, Reactivity of C=C bond, electrophilic and radical reaction and selectivity therein, epoxidation and reactions of epoxides, hydroboration, oxidation; polymerization: Mechanism, important monomers, structures of poly-olefins and properties, conjugate addition: 1,2- and 1,4- addition, Diels Alder reaction Kinetic and thermodynamic control, Cumulene, catalytic hydrogenation of alkenes.

Alkynes: Nature of C=bond, Methods of preparation, Electrophilic addition, acidity, metal acetylides and their reactions, reductions.

Alkyl halides: Nucleophilic substitution reaction, SN1, SN2, SNcA, SN'reactions, metalation reaction and utility of organometallics.

Alcohols and thiols: Acidity, H-Bonding, polyhydric alcohols, preparation and properties of thiols.

Ethers and thioethers: Methods of preparation, reactions, applications.

Aliphatic and aromatic Aldehydes and ketones: Methods of preparations, carbonylation, Tetrahedral mechanism of nucleophilic addition, aldol and related reactions; Cannizzaro's reaction, Reductions, Oximes and their reactions, Baeyer Villiger and Wittig reaction, conjugate addition, acetals and ketals, α-halogenation, reductive amination.

Aliphatic and aromatic carboxylic acids and their derivatives: Mono- and poly-carboxylic acids, acidity, salt formation. Preparations and reactions of esters, amides, imides, anhydrides. Hoffmann rearrangement, oils, fats and waxes

Aliphatic and aromatic amines: Nitroalkanes and nitroaromatics, Methods of preparation of ammines, Basicity, Alkylation, Reaction with aldehydes and ketones, Chemistry of aromatic diazonium salts.

Aliphatic and aromatic sulfonic acids: Methods of preparation, acidity and applications.

Part-2: Aromatic electrophilic substitution reaction

General mechanism: Energy profile diagram, effect of substituents on the rate and orientations in substituted arenes-charge distribution method and stability of intermediate methods, Hammonds postulate.

Aromatic nucleophilic substitution reaction: General addition-elimination reaction with energy profile diagram, benzyne mechanism. Hydrolysis and amination of haloarenes, metalation of haloarenes.

Friedel Crafts and related reactions: Mechanism and synthetic applications of Friedel Craft alkylation and acylation, Formylation reaction.

References

1. I. L. Finar, Organic Chemistry, Vol. 1 & 2, Pearson., 2012,
2. R.T. Morrison and R. N. Boyd, Organic Chemistry, Prentice Hall of India, 2010.
3. L.G. Wade, Organic Chemistry, Pearson Education, 2012.
4. G. Solomons and C. Fryhle, Organic Chemistry, 10^{th} Ed., John Wiley & Sons (Asia) Pte Ltd., 2009.
5. P. Bruce. Organic chemistry; 8^{th} Ed., Pearson, 2016.

C-303 Inorganic Chemistry-I

Hydrogen: Preparation of hydrogen, Isotopes, ortho and para hydrogen, hydrides.

Rare gases: Occurrence and recovery of the elements, physical and chemical properties, Clathrate compounds, chemistry of Xenon and xenon fluoride complexes.

	Chemistry of s-block elements: a) alkali and alkaline earth metals: Extraction, general physical properties, flame colours and spectra, Reaction with water, air and nitrogen, oxides, hydroxides, peroxides and superoxide, sulfides, oxy salts, halides and hydrides, organic and organometallic compounds. b) *Group IIB elements:* Zn, Cd, Hg **Chemistry of p-block elements:** i) Group IIIA elements: Boron, aluminium, gallium, indium and thallium ii) Group IVA elements: carbon, silicon, germanium, tin and lead – physical properties, allotropes of carbon, graphite compounds, carbides, carbonates, carbon cycle, silicates, organosilicons, hydrides, halides and cyanides, cluster compounds. iii) Group VA elements: Nitrogen, phosphorous, Arsenic, antimony and bismuth – general properties, hydrides, azides, oxides and oxy-acids, sulphides and organometallics, fertilizers. iv) Group VIA elements: oxygen, sulphur, selenium, tellurium and polonium – general properties, structure and allotropy of the elements, chemistry of ozone, oxides, oxy-acids, oxo-halides, hydrides and halides, organo- derivatives. e) Group VIIA elements: Fluorine, chlorine, bromine, iodine and Astatine- general properties, oxidizing power, hydrogen halides, ionic and molecular halides, bridging halides, halogen oxides, oxoacids, interhalogen compounds, poly-halides, pseudo-halogens and pseudo-halides. **References** 1. J.E. Huheey, 'Inorganic Chemistry - Principles of Structure and Reactivity', 4th Ed. Dorling Kindersley Pvt. Ltd., 2008. 2. D.F. Shriver, P.W. Atkins and C.H. Langford, 'Inorganic Chemistry', Oxford University Press, 1991. 3. F.A. Cotton and G. Wilkinson, 'Basic Inorganic Chemistry', Wiley Easter, 1978. 4. J.D. Lee, 'Concise Inorganic Chemistry', 5th Ed. Wiley-Blackwell, 1999.
C-401	**Spectroscopy-I** **Introduction:** Failures of Classical mechanics, wave-particle duality of matter and the de Broglie equation, quantization of energy levels, Heisenberg Uncertainty principle and natural broadening of energy levels, light absorption and electric dipole - dipole interaction, transition probability and the basis of selection rules for transition between energy levels, absorption coefficient and transition moment integral, Lambert – Beer's law, mechanism of broadening and the width of spectral lines. **Rotational or Microwave Spectroscopy:** Rotation of molecules and moment of inertia, classification of molecules, rotational spectra of diatomic molecules as rigid and non-rigid rotator, Effect of isotopic substitution and isotopic abundance, non-rigid rotator and rotational spectra. Rotational spectra of polyatomic molecules – linear, symmetric top (prolate and oblate) and asymmetric top. Techniques and instrumentation. **Infrared or vibrational spectroscopy:** One dimensional harmonic oscillator, shape of vibrational wave functions and energy levels. Anharmonic oscillator - Oscillation frequency and anhrmonicity constant, Fundamental, overtone and hot vibrational bands. Diatomic vibrating rotator, vibration-rotation spectra of CO and rotational constant from the maxima of P and R branch lines. Breakdown of B-O approximation – interaction of rotations and vibrations. Vibrations of polyatomic molecules – Fundamental vibrations and their symmetry, parallel and perpendicular vibrations. Identifying the organic molecules from IR spectra, Techniques and instrumentation, FTIR spectroscopy. **Raman Spectroscopy:** Classical and quantum theories of Raman effect, Raleigh scattering, Stokes and Antistokes Raman lines, molecular polarizability and

	polarizability ellipsoid. Pure rotational Raman spectra of linear, spherical top and asymmetric top molecules. Change of polarizability ellipsoid with vibration and Raman activity of vibrations, rotational fine structure. Polarized Raman spectrum. Influence of nuclear spin on the intensities of rotational lines. Structure determination from Raman and infrared spectroscopy as complementary techniques, Techniques and Instrumentation. **Electronic spectroscopy of atoms and molecules:** Electronic orbital (i) and spin (s) angular momenta, l-s coupling and total angular momenta (j). Fine structure of hydrogen atom spectrum, Spectrum of Li and other H-like atoms, Na-D lines. Spectrum of He and the alkaline earth atoms. Atomic energy levels of atoms in the ground and excited states with equivalent and non-equivalent electrons and term symbols. Zeeman effect and determination of L, S and J values. Vibrational coarse structure of electronic spectrum of diatomic molecules, Franck–Condon Principle and intensities of vibrionic lines. Dissociation of diatomic molecules, determination of dissociation energy, Berge-Sponer extrapolation method. Rotational fine structure of electronic and vibration transitions and pre-dissociation. MO diagram of hydrogen and other diatomic molecules and their electronic properties. MO diagram of formaldehyde molecule and n-π* and π -π* transitions. Techniques and instrumentation. Molecular photoelectron spectroscopy. **Nuclear Magnetic Resonance (NMR) Spectroscopy:** Introduction to Nuclear Magnetic Resonance (NMR) spectroscopy. 1H and 13C NMR, number of signals, integration, chemical shift, splitting of signals. Principles and instrumentation of NMR spectroscopy. Nuclear spin and nuclear magnetism. Energies of nuclear spin states in a magnetic field. Boltzmann population of nuclear spin states and the origin of NMR signals. Applications: Interpretation of simple 1H NMR spectra. Information from: chemical shifts and delta values, peak areas and integration, splitting patterns and spin-spin coupling constants. (n+1) rule and Pascal's triangle, Nuclear Overhauser enhancement, J values, T1 relaxation, sensitivity, analysis of NMR spectra. **References** 1. G.M. Barrow, Introduction to Molecular spectroscopy, McGraw-Hill, 1962 2. C. N. Banwell and E. M. McCash, Fundamentals of Molecular spectroscopy, Tata McGraw Hill Pub. Co., New Delhi, 2017. 3. J. D. Graybeal, Molecular Spectroscopy, McGraw Hill International Book Co. N.Y., 1988. 4. Peter F. Bernath, Spectra of atoms and molecules, 3rd Ed., Oxford University Press, 2016. 5. J. Michael Hollas, Modern Spectroscopy, 4th Ed. Wiley, 2004 6.. Andrew E. Derome, Editor, Modern NMR Techniques for Chemistry Research, Pergamon press, 1997.
C-402	**Physical Chemistry-I (Chemical Kinetics and States of Matter)** **Part 1: Chemical Kinetics** **Basic Concepts:** Review of order and molecularity of a reaction, first, second and third order reactions, pseudo-unimolecular and autocatalytic reactions, effect of temperature on reaction rate, Arrhenius equation and concept of activation energy and transition state. **Complex Reactions:** Parallel and consecutive first order reactions, competitive, consecutive second order reactions, reversible reactions, complex mechanisms involving equilibria. **Reactions in Solutions***:* Theory of reaction rates, diffusion limited reactions, effect of ionic strength on reactions between ions, linear free energy relationships, relaxation methods for fast reactions.

	Catalysis: Homogeneous catalysis, acid base catalysis, Bronsted catalysis law, general and specific catalysis, heterogeneous catalysis: adsorption on surfaces, different isotherms for gas adsorption, negative catalysis and inhibition, surface reactions, effect of temperature and nature of surface, industrial catalysis. Oscillating chemical reactions. **Transition state Theory**: Collision theory, transition state theory, derivation of expression of rate constant. **Part 2: States of matter** **Gaseous State:** Ideal gases and gas laws, kinetic theory of gases, Derivation of Maxwell's law of distribution of molecular velocities, heat capacity of gases, equipartition of energy, collision frequency and mean free path. Transport properties: viscosity, thermal conductivity and diffusivity of gases. **Real gases*:*** Deviations of behaviour of real gases from ideal gas laws, collision diameter, equation of state, van der Waals equation, reduced equation of state, Dieterici equation, Berthelot's equation, equation of Kammerling-Onnes, Virial Theorem and equation of state, compressibility factors, continuity of state and critical phenomena, derivation of critical constants for van der Waals equation of state. **Liquid State:** Intermolecular forces – dipole-dipole London forces, hydrogen bonding. vapour pressure and its measurement, Clausius Clapeyron equation, boiling point. Surface tension: angle of contact, wetting phenomena, capillary rise, measurement, temperature dependence, parachor. Viscosity: definition, measurement, temperature dependence, molecular weight from viscosity. Refractive index: molar refraction and chemical constitution, optical activity and specific rotation. Ideal solutions and colligative properties. **Soft mater and colloids***:* Concept of soft matter, examples, colloidal system: preparation, classification, optical and electrical properties, effect of electrolytes, zeta potential, electrophoresis, electro-osmosis. Origin of charge and the mechanism of flocculation, stability and kinetic properties of sols. Brownian motion, Tyndall effect, determination of Avogadro's number. Macromolecules: viscosity and molecular weight of polymers, osmotic pressure. **Solid State**: Introduction to solids, crystalline and amorphous solids, glass transition **References** 1. P. L. Houston, Chemical Kinetics and reaction dynamics., Dover Publ., 2001. 2. K. J. Laidler, Chemical Kinetics, 3rd ed. Harper and Row, 1987. 3. P. W. Atkins, Physical Chemistry, 7^{th} Ed., Oxford University Press, 2006. 4. G. M. Barrow, Physical Chemistry, 5th Edition, Tata McGraw-Hill, New Delhi, 1992. 5.
C-403	**Physical Chemistry-II** **Foundations of quantum mechanics:** Review of old quantum theory, wave particle duality, concept of matter wave, concept of wavefunction, Schrodinger equation for time-dependent and time-independent potentials, postulates of quantum mechanics, concept of operators, eigenfunctions and eigenvalues, wave function for a free particle, physical interpretation of the wave function, expectation value of a dynamical quantity, wave packets and the uncertainty principle, Ehrenfest theorem. **Solution of Schrodinger's equation for exactly solvable systems:** *One-dimensional problems:* Constant potential: particle in one-, two- and three-dimensional boxes, particle in a rectangular well, electron in a ring, rectangular potential barrier penetration, concept of tunnelling, WKB approximation, variable potential: one-

dimensional harmonic oscillator.

Three-dimensional problems: Angular momentum, rigid rotator, particle in a sphere, hydrogen-like atoms, atomic orbitals and their shapes.

Approximate methods in quantum chemistry: Basics of variational principle and time-independent perturbation theory.

Many electron systems: Orbital approximation, helium atom, variational and perturbation theory treatment of helium atom. Aufbau principle, Pauli exclusion principle, Slater determinant form of the wave function.

Atoms to molecules: Hydrogen molecule ion and hydrogen molecule, basics of molecular orbital and valence bond methods. Simple diatomic molecules.

References

1. I.N. Levine, Quantum Chemistry, 5th Ed., Prentice Hall, India, 2012.
2. P.W. Atkins, R. Friedman*, Molecular Quantum Mechanics, 4th Ed., Oxford University Press, 2005.*
3. A.K. Chandra, Introductory Quantum Chemistry, 4th Ed., Tata McGraw-Hill Publishing, 2001.

C-404

Organic Chemistry – II

Part I: Stereochemistry

Stereochemistry of Organic compounds: Chirality, stereogenic elements, elements of symmetry, Stereochemistry of compounds with two or more chiral centres. Stereochemistry of 3,4,5, 6 membered ring compounds; mono and di substituted cyclohexanes; strains in cycloalkanes, fused ring compounds – decalins. Stereochemistry of N, S, Si, P, As compounds. Stereochemistry of allenes, spiranes, biphenyls, ansa compounds, paracyclophanes, alkylidene cycloalkanes Racemates: types, resolution of racemates. Conformations and conformational analysis, trans annular effects

Topocity and prostereoisomerism: Homotopic ligands and faces, enantiotropic ligands and faces, diastereotopic ligands and faces.

Stereoselective synthesis: Additions, elimination, dihydroxylation, addition to carbonyl group Felkin-Anh model.

Chiral synthesis: Different approaches. Chiral reagents and Chiral auxiliaries. Diastereoselective synthesis of alkenes, stereoselective alkylation of enolates. Asymmetric reactions: aldol reaction, Michael reaction, Sharpless epoxidation, dihydroxylation, oxidations and reductions aminohydroxylation; Jakobson epoxidation, Hydrogenation, Diels-Alder reaction. Chiral borane reagents. Asymmetric catalysis-Grubb's catalyst, Wilkinson's catalyst. Cram and Felkin models

Part II: Organic Synthesis

Functional groups: Their reactivity profile, interconversions and protection.

Ylides and Enamines: Ylides of P and S. Synthesis and reactivity, Wittig reaction and its modification.

Reduction*:* Catalytic hydrogenation. Dissolving metal reductions. Hydride transfer reagents. Complex hydrides including nucleophilic, electrophilic and radical reducing agents. Organo boranes. MVP reduction.

Oxidation: Cr, Os, Ti, Fe and Mn reagents, per acids and peroxides, oxidation by ozone and oxygen, Swern oxidation. Bayer Viliger oxidation

Selected organic reagents: TMSC/I, TBTH, DCC, DDQ, TCQ, CAN, NBS, DIBAL, PTC, Crown ethers, SmI_2, SeO_2 Corey- Chaykowsky reagent, DABCO, Gilman's reagent, Lawesson reagent, Simmon Smith reagent.

	Selected name reactions: Hoffmann-Loffler-Fritag reaction, Sharp reaction, Paterson reaction, Heck reaction, McMurry coupling reaction, Suzuki reaction, Birch reduction, Woodward-Prevost reaction, Mukaiyama esterification, Mitsunobu reaction. Finkelstein reaction, Buchwald-Hartwig amination, McMurry coupling, Baylis-Hilman reaction, Corey-Fuchs reaction, Ritter reaction, Tsuji-Trost allylic alkylation. **Rearrangements:** Favorskii reaction, Curtius Lossen, Benzil-Benzilic acid rearrangement, Steven, Shapiro, Tiffenev-Demyanov, Benzidine rearrangement, Baker-Venkatraman rearrangement, Ireland-Claisen rearrangement, Wittig rearrangements. **Disconnection approach and retrosynthetic analysis:** Planning of multistep synthesis. Concepts of synthons, retrones and synthetic equivalents. Generation of structural complexity using tandem and cascade processes. **References** 1. I. L. Finar, Organic Chemistry, Vol. 1 & 2, Pearson., 2012. 2. R. T. Morrison and R. N. Boyd, Organic Chemistry, 7^{th} Ed, Prentice Hall of India, 2010 3. Emest Eliel, Stereochemistry of Carbon Compounds, Tata-McGraw Hill Edition, 2001. 4. P.S. Kalsi, Stereochemistry Conformation and Mechanism, New Age International, 2005. 5. F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Part A and B, Springer International Edition, 2007. 6. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, Oxford Edition, 2014. 7. V. K. Ahluwalia, R.K. Parasher, Organic Reaction Mechanisms, Narosa Publishing House, 2011.
C-501	**Analytical Chemistry** **Error analysis**: Methods of sampling and associated errors, Classification of errors, Propagation of errors, treatment of errors, Normal distribution, Tests of Significance and Confidence Limits. **Separation techniques**: Solvent Extraction Technique: Conventional, Liquid Membranes – Bulk, Supported and Emulsified, Solid Phase Extraction (SPE). Ion Exchange: Conventional, Membranes. Chromatography: Gas chromatography (GC), High Performance Liquid Chromatography (HPLC), Ion chromatography (IC). **Mass Spectrometry**: Mass Analysers – Magnetic, Quadrupole, Time of Flight (TOF), Features – Resolution, Dispersion, Abundance, Sensitivity, Detectors, Ion Sources – Thermal Ionisation (TI), Electron Impact, ICP, GD, Laser Ablation (LA-ICP), Secondary Ionisation (SI), Matrix Assisted Laser Desorption and Ionisation (MALDI), IC-MS, HPLC-MS, GC-MS. **Thermal Methods**: Thermogravimetric Analysis (TGA), Derivative Thermogravimetric Analysis (DTG), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC), Evolved Gas Analysis (EGA). **Electrochemical Methods**: Introduction, Potentiometry, Ion Selective Electrodes (ISE), Voltammetry & Polarography, Cyclic, Pulse and Stripping Voltammetry, Coulometry and Amperometry, AC Electrochemical Techniques, Scanning Electrochemical Microscopy. **Detectors**: Photomultiplier Tube (PMT), Charge Coupled Device (CCD), Charge Injection Device (CID), Spectrometers – Czerny Turner, Echelle, Sample Introduction Devices – Flame, Electrothermal, Laser Ablation, Direct Sample Insertion Devices, Interferences, detection limits, sensitivity. **Conductance of solutions and electrochemistry**: Faraday's laws of electrolysis, Electrolytic conduction- Arrhenius theory of electrolytic dissociation, strong and weak electrolytes. Migration of ions – transference numbers, Determination of transference

	number using Hittrof's rule and moving boundary method. Conductance of solutions – electrolytic conductance, determination of conductance, equivalent conductance and concentration, Kohlrausch's law of independent migration of ions, ionic mobilities, temperature dependence. Hydration of ions, the interionic attraction theory. Applications of conductance measurements – degree of dissociation of weak electrolytes, dissociation constants of weak acids, degree of dissociation of water, basicity of organic acids, determination of solubilities of sparingly soluble salts, conductometric titrations, activities of electrolytic solutions, ionic strength. The Debye-Hückel theory of dilute ionic solutions. **References** 1. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 8th Ed. Thomson, 2004. 2. A. I. Vogel, A text book of Quantitative Analysis, 5th Ed. Revised by G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, ELBS, 1989. 3. A. K. De, S. M. Khopkar and R.A. Chalmers, Solvent Extraction of Metals, Van Nostrand, Reinhold, 1970. 4. L. R. Snyder and J. J. Kirkland, Introduction to Modern Liquid Chromatography, 2nd Ed., Wiley, 1979. 5. J. A. C. Broekaert, Analytical Atomic Spectrometry with flames and Plasmas, Wiley-VCH, 2002. 6. S.K. Aggarwal and H.C. Jain, Editors, Introduction to Mass Spectrometry.
C-502	**Physical Chemistry-III** **Revisit to one-electron atoms:** Review of hydrogenic atoms, energy levels, orbitals, their shapes, electronic transitions, Stark and Zeeman effect. **Approximate methods in quantum chemistry***:* Review of Variational principle and time-independent perturbation theory. Time-dependent perturbation theory: Application to interaction of radiation with matter, derivation of spectroscopic selection rules. **Many electron systems*:*** Orbital approximation, Slater determinant; Hartree and Hartree-Fock self-consistent field theory; Concept of electron correlation and post Hartree Fock methods. **Angular momentum of many-particle systems:** Spin orbit interaction; LS and JJ coupling. Spectroscopic term symbols for atoms and diatomic molecules. **Molecular Electronic Structure:** Born-Oppenheimer approximation, Molecular orbital and valence bond theories. Concept of LCAO approximation and introduction to *ab-initio* molecular orbital calculations for molecules. Application to homonuclear and heteronuclear diatomic molecules. Electronic structure and Chemical bonding, Directed valence and concept of hybridization in simple polyatomic molecules. Group theory-based symmetry adapted LCAO approach. **Semiempirical methods:** Huckel theory for conjugated systems, Parisar Parr Pople approximation and several approximate semiempirical methods of electronic structure calculations. **Miscellaneous topics:** Concept of basis sets and Slater and Gaussian type orbitals, virial theorem and Hellmann Feynman theorem, introduction to density functional methods, Molecules to solids and bonds to bands for extended systems. **References** 1. I. N. Levine, Quantum Chemistry, 6^{th} Ed., Prentice Hall, India, 2012. 2. *P*. W. Atkins, R. Friedman, Molecular Quantum Mechanics, 4^{th} Ed., Oxford University

Press, 2005.
3. A. K. Chandra, Introductory Quantum Chemistry, 4th Ed., Tata McGraw-Hill Publishing, 2001.
4. A. Szabo and N.S. Ostlund, Modern Quantum Chemistry, Dover, 1996
5. F. L. Pilar, Elementary Quantum Chemistry, McGraw Hill, 1968.

C-503 Inorganic Chemistry-II

Coordination compounds: Werner's theory, effective atomic number, coordination number, shapes of d-orbitals and bonding in transition metal complexes, stability of complexes, the chelates and macrocyclic effects, types of classification of ligands, second sphere of coordination, -complexes, -acid ligands, multiple bonds from ligands to metals.

Crystal Field theory: Crystal field splitting and elementary treatment of the electronic spectra, Jahn-Teller distortion of octahedral complexes, square planar complexes, tetrahedral complexes, magnetic properties of 3*d* compounds.

Molecular Orbital theory*:* Nomenclature of coordination compounds, d-orbital splitting in various fields - Spectroscopic states - Tanabe-Sugano and Orgel diagrams - Derivation of Ligand field parameters (Dq. B) from electronic spectra - Magnetic moments - Orbital contribution, spin-orbit coupling and covalency - Molecular orbitals and energy level diagrams for common symmetries.
Bonding involving-donor ligands: Back-bonding - f-orbital splitting - Spectral and magnetic properties of f-block elements.

Reaction mechanisms*:* Substitution reactions - Dissociative and associative interchange - trans-effect, Linear free energy relations. Rearrangements - Berry pseudo rotation, Electron transfer reactions. Photo-dissociation, substitution and redox reactions, Fluxional molecules.

References

1. F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann, Advanced Inorganic Chemistry, 6th Ed., Wiley Eastern, John Wiley, 1999.
2. J. E. Huheey, E. Keiter and R. Keiter, Inorganic Chemistry, 4th Ed., Harper Collins College Publisher, 1993.
3. D. Banerjea, Inorganic Chemistry Principles, Books Syndicate Pvt. Ltd., 2000.
4. N. N. Greenwood and E. A. Earnshaw, Chemistry of Elements, Pergamon Press, 1989.

C-504 Spectroscopy-II

Electronic Spin Resonance (ESR) Spectroscopy: The Zeeman effect; Magnetic moment of an electron due its spin and orbital angular momenta; Magnetic moment in a magnetic field; magnetic resonance spectroscopy; Resonance condition; Field-swept vs frequency-swept ESR spectra; Observation of hyperfine lines in several molecular systems and the existence of electron-nuclear hyperfine interaction. EPR spectra of benzosemiquinone anion radical, methyl radical; Pascal triangle for several equivalent spin-½ nuclei; Hyperfine lines due to nuclear spin $I = 1$ and $I > ½$; Linewidths and intensities of various hyperfine lines; ESR spectrum of singlet oxygen molecule; splitting due to coupling of orbital angular momentum with rotational angular momentum.

Determination of structures of molecules using Spectroscopic Techniques: Use in Determining Molecular Structures from uv-vis, IR and NMR Spectra, Use in Investigating Reaction Mechanisms, Use in Protein Structure Determination. ^{13}C NMR spectra and sensitivity issues. Interpretation of NMR spectra using examples of organic compounds.

References

1. L. D. Field, S. Sternhell and J. R. Kalman. Organic Structures from Spectra, 5^{th} Ed., John Wiley and Sons, 2013
2. R. M. Silverstein, F. X. Webster, Spectrometric Identification of Organic Compounds, 6^{th} Ed., Wiley, 2006.
3. P.S. Kalsi, Spectroscopy of organic compounds, 6^{th} Ed., New Age International, 2006.
4. J. E. Wertz and J. R. Bolton, Electron spin resonance: Elementary theory and practical applications, McGraw-Hill, New York, 1972.
5. C. P. Poole, Jr., Electron Spin Resonance: A Comprehensive Treatise on Experimental Techniques, 2nd Ed., John Wiley and Sons, New York, 1983.

C-601 Biophysical Chemistry

The Chemistry of Life: An introduction*:* Physical properties of water: Structure, water as solvent, The hydrophobic effect, osmosis and diffusion. Introduction to Biomolecules: Nucleic Acid, Protein - Polymer Description of Macromolecular Structure, Intermolecular and Intramolecular forces, Non-Covalent Interaction.

General principles of Biophysical chemistry I: Hydrodynamic properties: Diffusion and sedimentation, determination of molecular weight from sedimentation and diffusion; Introduction of Ultra Centrifugation, Dynamic Light Scattering and Electrophoresis. Spectroscopic properties of proteins and nucleic acid: UV/Vis, Intrinsic fluorescence, Circular dichroism, Introduction to single molecule spectroscopy

General principles of Biophysical chemistry II: The concept and application of Chemical and Physical equilibria in Biological system, Double Strand formation in nucleic acid, Ligand-protein binding, Protein denaturation and stability, Introduction of DSC and ITC.

Molecular self-assembly and Molecular medicine: Protein folding kinetics and Biophysical methods, Misfolding and aggregation; Physical basis of conformation diseases, Therapeutic approaches to protein misfolding diseases**.**

Introduction to structural biology: Introduction to basic principles of protein X-ray crystallography, protein NMR, Small Angle X-ray scattering (SAXS), and Electron microscopy (EM).

References

1. Tinoco, Sauer, Wang, and Puglisi, Physical Chemistry: Principles and Applications in the Biological Sciences, Prentice Hall, Inc., 2003.
2. Peter Atkins and Julio de Paula, Physical Chemistry for the Life Sciences,
3. Dobson CM. General review papers: Principles of protein folding, misfolding and aggregation. Semin Cell Dev Biol. 2004 Feb;15(1):3-16.

C-602 Group Theory and Applications (Symmetry in Chemistry)

Group Theory: Machinery

Introduction: Symmetry in everyday life and chemistry

Symmetry Operations*:* Qualitative concept to quantitative definition, Symmetry Elements and operations (Identity, rotation, reflection, inversion, rotation-reflection), their algebra, role of symmetry in determining dipole moment and optical activity of molecules.

Basics of Group theory: Definition of a group, concept of subgroup, group multiplication table, concept of classes, symmetry operations forming a group, concept and classification of Point groups, Schoenflies notation, determination of point groups for molecules.

The matrix machinery: Matrix representation of symmetry operations, similarity transformations, concepts of equivalent, non-equivalent, reducible and irreducible representations, The Great Orthogonality theorem: Original form recast in terms of the traces of the representative matrices, Character Tables: their construction and content.

Group Theory: Applications

The Approach: Choice of basis set, forming characters of the reducible representations, decomposing into irreducible representations, concept of direct product representation, Projection Operators.

Application to spectroscopy & quantum chemistry: Prediction **of v**anishing of matrix elements for transition to excited states, Symmetry Adapted Linear Combinations for the LCAO approach to the construction of molecular orbitals, vanishing of matrix elements and simplifications thereby, Application to coordination chemistry, crystal field splitting and the resulting spectral properties.

References

1. F.A. Cotton, Chemical Applications of Group Theory, 3^{rd} Ed., John Wiley, 2003
2. D.M Bishop, Group Theory and Chemistry, Dover Publication, 1993.
3. C.N. Banwell and E.M. McCash, Fundamentals of Molecular spectroscopy, Tata McGraw Hill, 1995.

C-603

Inorganic Chemistry-III

Chemistry of *d*-block elements

General introduction to transition elements*:* Electronic structure, Metallic character, variable oxidation state, complexes, magnetic and catalytic properties.

Elements of the first transition series: Occurrence, separation, extraction and chemistry of the scandium group (IIIB), titanium Group (IVB) , vanadium group (VB), chromium group (VIB), Manganese group (VIIB), Iron group (VIIIB(8)), Nickel group (VIII(9)) and Copper group (VIIIB(10)).

Chemistry of the elements of the second and third transition elements*:* **Ha**fnium group (Group IVB), Niobium and Tantalum (Group VB), Molybdenum and Tungsten (Group VIB); Technetium and Rhenium (Group VIIB), The Platinum group Metals, Ruthenium and Osmium (Group VIII(8)); Rhodium and Iridium (Group VIII(9)), Palladium and Platinum (Group VIII(10), Silver and gold Group (1B(11)).

Chemistry of f-block elements*:* The lanthanide and actinide elements.

Reference

1. F. Albert Cotton and G. Wilkinson, Advanced Inorganic Chemistry, John Wiley & Sons, 1988.

C-604

Organic Chemistry-III

Chemistry of Natural Products:

Terpenoids: Occurrence, isolation, classification, structure, chemistry and biogenesis of some important mono; sesqui-, di-, and tri-terpenes.
Steroids*:* Occurrence, isolation, structure, classification, biological role. Important structural and stereochemical features of cholesterol, ergosterols, bile acids, steroidal hormones. Synthesis of 16-DPA from cholesterol, synthesis of commercially important steroids from 16-DPA, synthesis of Taxol. Sterols and bile acids, estrogens, androgens, gestogens and adrenocortical hormones.
Alkaloids: Occurrence, characteristic reactions, general methods of degradation, structure and chemistry of some well-known alkaloids.
Natural Pigments: Occurrence, isolation, anthocyanines, flavones, flavanones, isoflavones, xanthones, quinones, carotenoids, chlorophyll and haemin.
Insect pheromones*:* Prostaglandins- Classification and biological importance, Plant growth regulators
Antibiotics*:* Classification. B-lactam antibiotics. Penicillins and cephalosporins. en-dyne-antibiotic.

Chemistry of heterocyclic compounds

Nomenclature: Nomenclature of heterocyclic compounds- Trivial, Hantzch-Widman, Replacement. Nomenclature of mono and polycyclic compounds. Polarity, tautomerism, aromaticity, electrophilic substitution.
Reactivity, *preparation and reactions of the following:*
Small rings: Aziridines, thiirane, azetidine, oxetane, thietanes
Five membered: Diazoles, oxazoles and thiazoles.
Six membered: Diazines, triazenes, pyranes and pyrones
Seven membered: Diazepines
Fused ring: Benzofurans, benzopyrones, benzodiazepines, indole, quinolines and isoquinolines, purines

References

1. I. L. Finar, Organic Chemistry, Vol. 1 & 2, Pearson., 2012.
2. R. K. Bansal, Heterocyclic Chemistry, New Age International Publisher, 2014.
3. J. A. Joule, K. Mills and G. F. Smith, Heterocyclic Chemistry, 3rd Ed., Springer, 1995.
4. L. A. Paquette, Principles of Modern Heterocyclic Chemistry, W.B. Benjamin, Inc., 1978.
5. R. T. Morrison and R. N. Boyd, Organic Chemistry, 7th Ed, Prentice Hall of India, 2010.

C-605

Nuclear Chemistry

Nuclear Stability*:* Concept of nucleus and properties, nuclear mass and binding energy, elemental abundance, radioactive decay laws and equilibria**.** Nuclear Models: Liquid drop model, Shell model, Fermi gas model, collective model, optical model, concept of spin, parity electric and magnetic moments, isomerism.

Modes of Decay*:* □ decay, □ decay, electron captures, □ de-excitation, internal conversion, artificial radioactivity.

Nuclear reactions*:* Energetics, cross-section, centre of mass system, angular momentum, compound nucleus, statistical model, nuclear fission and fusion, nuclear reactors, Heavy ion induced reactions, Accelerators.

Applications of radioactivity*:* Probing by isotopes, preparation of radioisotopes**,** **Szilard**-Chamers' reaction, Concept of tracers, chemical yield, radiochemical purity, Application of radiotracers in Chemical Sciences, uses of nuclear radiations, radioisotopes as a source of electricity.

Elements of Radiation Chemistry*:* Interaction of radiation with matter, radiation

	dosimetry, radiolysis of water and some aqueous solutions, other radiolytic events.

Nuclear Methods*:* Activation Analysis – Neutron Activation Analysis (NAA), Charged Particle Activation Analysis (CPAA)**,** X-ray fluorescence (XRF) spectrometry**,** Ion Beam Analysis– Backscattering Spectrometry (BS), Particle Induced γ-ray Emission (PIGE), Nuclear Reaction Analysis (NRA), Elastic Recoil Detection Analysis (ERDA), Particle Induced X-ray Emission (PIXE).

Mossbauer spectroscopy: Introduction and applications

References

1. G. Friedlander, J. Kennedy, Nuclear and Radiochemistry –J. M. Miller and J. W. Macias, 1981.
2. R.D. Evans, Atomic Nucleus, 1955.
3. S. Glasstone, Source book of Atomic Energy, 1969.
4. G.T. Seaborg, Manmade elements, 1963.
5. H. J. Arnikar, Essentials of Nuclear Chemistry, 1982.
6. C. Keller, The Chemistry of Trans-uranium Elements, 1971.
7. J. C. Bailar, H. J. Emelius, R. S. Nyholm and A. F. Trotman-Dickenson; *Comprehensive Inorganic Chemistry,* Vol. 5, Pergamon Press, Oxford, 1973.

C-701 Photochemistry

Part 1: Basic Principles of photochemistry

Photophysical processes: Properties of the excited states*:* Einstein theory of induced absorption and emission processes, laws of photochemistry, Lambert – Beer's law, absorption coefficient and transition moment integral, Jablonski diagram, De-excitation processes of the excited molecules (radiative and non-radiative processes, radiative lifetime, delayed emission, nonradiative relaxation, excimer and exciplex formation, heavy atom effect, etc.). Kinetics of excited state processes and quantum yields of different processes. Acid-base properties, redox potential, geometry, dipole moment, dynamic properties of the excited states.

Photoinduced chemical processes*:* Photo-dissociation, photo-ionization, intramolecular charge and proton transfer processes, intermolecular electron and proton transfer reactions, conformational relaxations, intra and intermolecular energy transfer processes and other important photochemical reactions. Kinetics and mechanism of photochemical reactions.

Applications of photochemistry*:* Photosynthesis, vision, solar energy conversion, atmospheric photochemistry, single molecule spectroscopy, Photon-up-conversion process, absorption properties of nanoparticles and nanoaggregates.

Techniques and Studies on ultrafast processes*:* Nanosecond laser flash photolysis, Single photon counting technique, picosecond and femtosecond Pump- probe transient absorption and fluorescence up conversion techniques. Singlet and triplet state properties, solvation dynamics and studies on other excited state properties.

Part 2: Organic Photochemistry

Distinctive features of photochemical reactions, methods of preparative photochemistry, Photochemistry of alkenes, alkynes and related compounds – geometrical isomerism, electrocyclic processes, sigmatropic shifts, di-π methane reactions, addition, cycloaddition and oxidative reactions. Photochemistry of aromatic compounds – bond cleavage and hydrogen abstraction reactions, cycloaddition reactions, rearrangements of cyclo-hexenones and cyclo-hexadienones, thiocarbonyl compounds. Photochemistry of other organic compounds – imines, imminium salts, nitriles and nitro compounds, azo and diazo compounds, diazonium salts, sulphur and halogenated compounds, photohalogenation and photonitrosation reactions.

	Photooxidation of alkanes. **Part 3: Inorganic Photochemistry** Introduction, Photophysical processes, electronic absorption spectra and characteristics of the electronically excited states of inorganic compounds. Photo-electro-chemistry of excited state redox reactions: Photosensitization. Photochemical reactions: substitution, decomposition and fragmentation, rearrangement, and redox reactions. Selective inorganic photochemistry using laser beams. Inorganic photochemistry in biological processes and their model studies. Ligand field photochemistry of d_n complexes, photochemistry of carbonyl compounds, energy conversion (solar) and photodecomposition of water. **References** 1. K. K.Rohatagi-Mukherjee, Fundamentals of Photochemistry, Wiley Eastern, 1978. 2. M. S.Wrighton, Inorganic and Organometallic photochemistry, ACS Pub.,1978. 3. V. Balzani and V. Carasiti, Photochemistry of Co-ordination compounds, Academic Press,1970. 4. J. D. Coyle, Introduction to Organic Photochemistry.
C-702	**Molecular Thermodynamics** **Introduction:** Review of Basics of Thermodynamics and scope of Statistical Mechanics as a route for bridging the microscopic and macroscopic description. Concept of probability distribution, correlation functions and their application in determining the structure and dynamics in chemistry. **Ensembles and Averages**: Concept of ensembles and averages: micro-canonical; canonical and grand canonical ensembles. Interconnection and equivalence of ensembles. **Partition Functions**: Concept of partition function, evaluation of thermodynamic quantities from partition functions for ideal gas, classical systems as well as simple quantum systems, evaluation of equilibrium constants of chemical reactions in terms of partition functions. **Theory of Simple liquids**: Application of classical statistical mechanics to simple liquids, radial distribution function, integral equation theories and density functional theories for equilibrium systems. Brief introduction to computer simulation methods such as Monte Carlo and molecular dynamics simulation. **Miscellaneous topics**: Concept of time-correlation functions and their applications, Linear response theory, Jarzynski equality, phase transitions, thermodynamics of small systems: nano-thermodynamics, Basic concepts of nonequilibrium thermodynamics and applications of chemical significance, relaxation processes, diffusion process. Illustration with simple examples. **References** 1. D.A. Mcquarrie, Molecular Thermodynamics, Viva Books, 2010 2. D.A. Mcquarrie, Statistical Mechanics, Viva Books, 2011. 3. H.B. Callen, Thermodynamics and an Introduction to Thermostatics, 2^{nd} Ed., John Wiley, 1985. 4. R K Pathria and Paul D. Beale, Statistical Mechanics, 3^{rd} Ed., Elsevier, 2011. 5. M.P. Allen and D.J.Tildesley, Computer Simulation in Liquids, Oxford University Press, 1987.

C-703 Organometallics and Bioinorganic Chemistry

Part 1: Organometallics of main group and transition elements

Overview: 18-electron rule, square planar complex. Carbonyl ligand – bonding, binary carbonyl complexes, oxygen-bonded carbonyls, other ligands similar to CO, IR spectrum, main group parallels with binary carbonyl. Pi-ligands – linear and cyclic pi systems, NMR spectra of organometallic complexes. Comparative survey of structure and bonding of metal alkyls and aryls, complexes with ∟ acids, CO and related ligands, complexes with olefins, acetylenes and related unsaturated molecules, catalytic properties of mononuclear compounds, stereochemical non-rigidity in organometallic compounds, boranes, carboranes and metallocarboranes, bimetallic and cluster complexes, structure and applications in catalysis, applications of organometallic compounds in organic synthesis, enantioselective synthesis via organometallic compounds, importance of organometallic compounds in certain biological systems. Other important ligands – complexes containing M – C, M= C, M ≡ C bonds, hydride and dihydrogen complexes, phosphines and related ligands.

Organometallic reactions occurring in metal – ligand substitution, oxidative, addition, reductive, elimination. Organometallic reactions involving modification of ligands – insertion and deinsertion, nucleophilic addition to ligands, nucleophilic abstraction, electrophilic reactions. Homogeneous catalysis and heterogeneous catalysis – use of transition metal complexes, hydroformylation reaction, Walker-Smidt synthesis of acetaldehyde, hydrogenation, Monsanto acetic acid process. Transition metal carbine complexes – structure, preparation and chemistry, metathesis and polymerization reactions. Applications of organometallics to organic synthesis and other applications. Metal cluster compounds - metal-metal bond, carbonyl and non-carbonyl clusters, structure and bonding low dimensional solids, clusters in catalysis.

Part 2: Bio-inorganic chemistry

Biochemistry of iron - its storage, transport and function, copper and zinc proteins, biological activation of oxygen, bioinorganic chemistry of alkali and alkaline earth metal cations, photosynthesis, nitrogen fixation, toxicity of metals. Chemical makeup and essential inorganic elements of organisms. Chemistry aspects of metal complexes. Spectral, biochemical and biological methods used in bioinorganic chemistry. Bioinorganic chemistry of Na^+, K^+, Mg^{2+} and Ca^{2+}. Role of metal ions in biology. Proteins and enzymes of V, Mn, Fe, Co, Ni, Cu, Zn and Mo. Structural and functional models. Transport and storage of metal ions. Carcinogenicity of chromium. Selenium in biology.

References

1. G. O. Spessard, G. L. Miessler, Organometallic Chemistry, Prentice Hall, 1997.
2. C. Elsehenbroich and A. Salzer, Organometallic Chemistry, 2^{nd} Ed., Wiley VCH, 1992.
3. F. A. Cotton, G. Wilkinson, C.A. Murillo and M. Bochmann, Advanced Inorganic Chemistry, 6^{th} Edn., Wiley, 1999.
4. N. N. Greenwood and A. Earnshaw, Chemistry of the Elements, I^{st} Ed., Pergamon, 1985.
5. S. J. Lippard & J. M. Berg, Principles of bioinorganic chemistry, University Science Books, Mill Valley, 1994.

C-704 Physical Organic Chemistry

Pericyclic reactions: Cycloadditions, Orbital correlation diagram, Frontier Molecular Orbital, Comments on forbidden and allowed reactions, Photochemical pericyclic reactions, D-A cycloadditions, regio- and stereo-selectivity, endo-effect, [2+2] cycloaddition, ketene cycloaddition, 1,3-dipolar cycloaddition, ene-reaction, retrocycloaddition,electrocyclicreactions,toregioselectivity,sigmatropic rearrangements, Claisen and Cope rearrangements, Cheletropic reactions.

Linear free energy relationship and Hammett and Taft plots

	Catalysis: Catalytic mechanism, homogenous, heterogenous catalysis, acid base catalysis. **Acidity Basicity:** Aqueous and non-aqueous solution, Hammett acidity function, super acid and super bases **Solvatochromism** **Methods of determining reaction mechanism** **References** 1. E. V. Anslyn and D. A. Dougherty, *Modern Organic Chemistry*, University Science, 2005. 2. I. Fleming, *Molecular Orbitals and Organic Chemical Reactions*, John Wiley, 2009. 3. J. Clayden, S. Warren, N. Greeves, P. Wothers, *Organic Chemistry*, 1st Ed., Oxford University Press, 2000 4. F. J. Carey and R. J. Sundburg, *Advanced Organic Chemistry, Part A and Part B*, 5th Ed., Springer, 2007 5. J. March, *Advanced Organic Chemistry*, 3rd edition, McGraw Hill, 1991.
C-801	**Materials Chemistry** **Introduction to Hard and Soft Matter** **Basic Aspects of the Solid State (Hard Matter)**: Types of solids, crystalline and amorphous structures. **Solid State Crystalline Structure***:* Primitive lattice vectors - reciprocal lattice - crystal systems and desymmetrization schemes. Bravais lattices; closed packed structures, octahedral and tetrahedral holes, crystallographic point groups and space groups - organic and in organic crystal structure motifs - polytypes and polymorphs. perovskites and related structures, normal and inverse spinels. **Defects and Non-stoichiometry***:* Intrinsic and extrinsic defects - point, line and plane defects; vacancies, Schottky defects, Frenkel defects - Charge compensation in defective solids - non-stoichiometry, thermodynamic aspects and structural aspects. **Thermal and electrical Properties***:* Specific heat of solids, thermal conductivity, Free electron theory, electrical conductivity, Hall effect - band theory, band gap, metals and semiconductors -intrinsic and extrinsic semiconductors, hopping semiconductors - semi-conductor/metal transition - p-n junctions – super conduction, Meissner effects, type I and II superconductors, isotope effect, basic concepts of BCS theory, manifestations of the energy gap, Josephson devices. **Ionic Conductors***:* Types of ionic conductors - Mechanism of ionic conduction; interstitial jumps (Frenkel), vacancy mechanism, diffusion - superionic conductors, phase transitions and mechanism of conduction in superionic conductors - examples and applications of ionic conductors. **High Tc Materials***:* Defect perovskites - high Tc superconductivity in cuprates – preparation and characterization of 1-2-3 and 2-1-4 materials - normal state properties, anisotropy, temperature dependence of electrical resistance, optical phonon modes – superconducting state, heat capacity, coherence length, elastic constants, positron lifetimes, microwave absorption - pairing and multigap structure in high Tc materials - applications of high Tc materials.

	Magnetic Properties*:* Classification of magnetic materials - Langevin diamagnetism - Quantum theory of paramagnetism - cooperative phenomena - magnetic domains and hysteresis - magnetism and dimensionality. **Optical Properties***:* Optical reflectance - excitons - Raman scattering in crystals - photoconduction - color centers - lasers - photovoltaic effect. **Synthesis of Materials***:* Phase diagrams - preparation of pure materials, mass transport, nucleation and crystal growth - preparative techniques, zone refining, chemical transport, etc. **Multiphase materials***:* Ferrous alloys, Fe-C phase transformations in ferrous alloys, stainless steels - non-ferrous alloys - properties of ferrous and non-ferrous alloys and their applications. **Nanocrystalline phase:** - preparation procedures – special properties - applications Thin Films, Langmuir-Blodgett Films: Preparation techniques, evaporation/sputtering, chemical processes, MOCVD, sol-gel etc. - LB film growth techniques - photolithography - properties and applications of thin films, LB films. **Soft Matter: Liquids Crystals***:* Mesomorphic behavior - thermotropic and lyotropic phases – description of ordering in liquid crystals, the director field and order parameters - nematic and semectic mesophases, smectic -nematic transition and clearing temperature - homeotropic, planar and twisted nematics - chiral nematics - smectic A and smectic C phases - cholesteric-nematic transition - optical properties of liquid crystals - effect of external field. **Materials for Solid State Devices:** Rectifiers, transistors, capacitors - IV-V compounds - low-dimensional quantum structures, optical properties. Organic materials: Organic Solids, Fullerenes, Conducting organics – organic superconductors - magnetism in organic materials, Fullerenes - doped fullerenes as superconductors **Nonlinear Optical Materials:** Nonlinear optical effects, second and third order – molecular hyperpolarisability and second order electric susceptibility - materials for second and third harmonic generation. **References** 1. H. V. Keer, Principles of the Solid State, Wiley Eastern, 1993. 2. N. W. Ashcroft, N. W. Mermin, Solid State Physics, Saunders College, Philadelphia, 1976. 3. W. D. Callister, Material Science and Engineering. An Introduction, Wiley, NY, 1985. 4. C. Kittel, Introduction to solid state physics, John Wiley & Sons, New York, 1968. 5. A. R. West, Solid State Chemistry and its Applications, John Wiley & Sons, NY, 2005. 6. N. N. Greenwood, Ionic crystals, Lattice defects and non-stoichiometry, Butterworths, London 1970
C-802	**Macro- and Supra-molecular Chemistry** **Part-I: Polymer Chemistry** **Polymerization reactions, mechanism and kinetics:** Cationic, anionic and radical polymerization. Template, emulsion and electrochemical polymerization, Condensation, ring opening, step growth and radiation polymerization reactions. Coordination complex polymerization, naturally occurring polymers, Biological polymers, inorganic polymers. Polymerization of cyclic organic compounds. Copolymerization and multicomponent polymerization, **Thermodynamics and kinetics**: Polymerization and depolymerization equilibria - Kinetics of condensation (Step-Growth), Free radical and ionic polymerizations.

Physical Characterization: Fabrication and Testing, Relationship between structure and properties - Thermal, flame and chemical resistance - Additives - Electroactive polymers - Biomedical applications. Molecular wieght (Mn, Mw) determination - Morphology -Glass transitions and crystallinity - Conformational analysis. Dynamics of dilute polymer solutions and effect of increasing concentration, NMR and neutron scattering studies.

Reactions and degradation of polymers: Biodegradable polymers. Thermal and oxidative degradation, catalysis by macromolecules, computer applications.

Part-II: Supramolecular Chemistry

Introduction to Supramolecular Chemistry.

Molecular and Chiral Recognition: Self-Organization, Self-Assembly and Preorganization, molecular and chiral recognition, self-Assembly and self-organization, role of preorganization in the synthesis of topological molecules, template reactions, one-pot' reactions.

Covalent self-assembly based on preorganization: Inclusion complexes, host-guest chemistry, early development of host-guest chemistry. Pedersen's works on crown ethers, nomenclature, the structure of inclusion complexes, dynamic character of inclusion complexes, the complexes involving induced fit and without it, endo-hedral fullerene, hemicarcerand and soft rebek's tennis ball-like hosts.

Mesoscopic Structures: An Intermediate Stage Between Molecules (Micro Scale) on the One Hand and Biological Cells (Macro Scale) on the Other: introduction, medium sized molecular aggregates.

Understanding and Mimicking Nature: Introduction, the role of self-organization and self-association in the living nature, modelling processes in living organisms.

Nanotechnology and Other Industrial Applications of Supramolecular Systems: Introduction to link between chemistry and solid-state physics- crystal engineering, obtaining crystals with desired properties, nanotechnology and other industrial applications, supramolecular catalysis.

Most Interesting Macrocyclic Ligands: Hosts for Inclusion Complexes, Crown ethers and coronands, cryptates and cryptands, calixarenes, hemispherands, and spherands, carcerands, hemicarcerands and novel `molecular flasks' enabling preparation and stabilization of short-lived species, cyclodextrins, and their Complexes, endohedral fullerene complexes, nanotubes and other fullerene-based supramolecular systems, dendrimers, cyclophanes and steroids forming inclusion complexes, anion binding receptors and receptors with multiple binding Sites.

Other Exciting Supramolecular Systems: Making Use of the preorganization phenomenon, topological molecules, multiple hydrogen-bonded Systems, organic zeolite, metal directed self-assembly of complex, supramolecular architecture, chains, racks, ladders, grids, macrocycles, cages, nanotubes and self-Intertwining strands (helicates).

The Prospects of Future Development of Supramolecular Chemistry.

References

1. H. R. Allcock, F. W. Lampe and J. Mark, Contemporary Polymer Chemistry, Prentice Hall, Inc., 1990.

2. M. P. Stevens, Polymer Chemistry: An Introduction, 2^{nd} Ed, Oxford University Press, 1990.
3. F. W. Billmeyer, Jr., Textbook of Polymer Science (3rd Edition) Wiley-Inter Science, 1984.
4. A. Ravve, Principles of Polymer Chemistry.
5. F. Vogtle, Supramolecular Chemistry, John Wiley, 1991.
7. G. R. Desiraju, Crystal Engineering. The Design of Organic Solids, Elsevier, 1989.
8. Helena Dodziuk, Introduction to Supramolecular Chemistry, Kluwer Academic Press, 2002.

C-803

Computational Chemistry

Introduction: Introducing the different length scales inherent for investigation of chemical problems, theoretical techniques inherent at different length scales and tools of computational chemistry, role of computational chemistry in the broad perspective of describing chemical systems and phenomena. A brief review of quantum chemistry, statistical mechanics, and chemical reactivity theories.
Microscopic length scales: Revisit and a brief review of quantum chemistry-based techniques for electronic structure calculations of molecular systems, semi-empirical approximations, ab initio methods, density functional theory, coupled cluster approaches, basis sets; Application of these computational methods for prediction of structural and electronic properties of molecules by using standard programs. A brief outline of molecular mechanics and its use for conformational analysis, FMOs in organic chemistry, crystal and ligand field calculations, computation of potential energy surfaces, etc.

Atomistic and continuum length scales: Outline of Monte Carlo and Molecular dynamics simulation, Implementation of these methods, using standard or own developed software, for equilibrium and dynamical properties of simple liquids. Calculation of radial distribution function, time correlation functions, transport coefficients and other thermodynamic properties.

Miscellaneous topics: Calculation of chemical reactivity parameters, numerical solution of diffusion equation

References

1. C. J. Cramer, Essentials of Computational Chemistry: Theories and Models, John Wiley & Sons, 2002.
2. David Young, Computational Chemistry: A practical Guide for applying Techniques to Real World Problems, Wiley Interscience, 2001.
3. A. R. Leach, Molecular Modelling: Principles and Applications, Pearson Education, 2001.
4. E. G. Lewars, Computational Chemistry, 2^{nd} Ed., Springer, 2011.
5. J. B. Foresman, A. Frisch, Exploring Chemistry with Electronic Structure Methods. Gaussian Inc., 1996.
6. M. P. Allen and D. J. Tildesley, Computer Simulations of Liquids, Oxford, 1987.

C-804

Lasers and its Applications (Elective Course)

Fundamental Principles of lasers*:* Key elements for a laser oscillator, Optical amplification – Einstein's theory of light absorption and emission, Stimulated emission and light amplification, population inversion, Three level and four level lasers and rate equations, total loss in the cavity and threshold population inversion. Resonator cavity and quality factor. Resonator configurations. Pumping processes and pumping efficiency. Laser modes, gain threshold, axial and longitudinal modes, TEM_{00} mode, Mode configurations and resonant frequencies. Selection of single longitudinal mode. Properties of laser beams.

Different kinds of lasers*:* (a) gas lasers: excitation mechanisms, He-Ne laser, Argon ion laser, Cu-vapor laser, nitrogen laser, excimer laser CO_2 laser, Chemical laser. (b) Liquid state laser: Dye laser. (c) Solid state laser: Doped insulator lasers- Nd:YAG,

	Nd:Glass, Ti: Sapphire and Ruby lasers, semiconductor laser. (d) Other lasers: Free electron laser. **Pulsed lasers***:* (a) Q-switching: Principle, rotating mirror, electro-optic Q-switch – half wave and quarter wave configurations, Passive or saturable absorber. (b) Mode-locking: Principle, Differences in the output of non-mode-locked and mode-locked lasers, Time – bandwidth product, condition for obtaining ultrashort pulses, peak power. Methods of mode-locking: Active mode-locking – Accousto-optic method, passive saturable absorber – CPM dye laser and Kerr lens mode-locking – Ti:Sapphire laser. Chirped pulse amplification, Frequency conversion techniques. **Applications of tuneable lasers in absorption and fluorescence spectroscopy:** Advantages of lasers in spectroscopy. High sensitivity methods of absorption spectroscopy – cavity ring down spectroscopy, Laser induced fluorescence, Fluorescence excitation spectroscopy, Photoacoustic spectroscopy, Optothermal spectroscopy, Ionization spectroscopy. Nonlinear optical spectroscopy: Basic concepts, Second order non-linear spectroscopies – surface harmonic generation. Third order non-linear optical spectroscopies – optical kerr effect. CARS spectroscopy, Z-scan method. **References** 1. J. Wilson and F. B. Hawkes, Optoelectronics, 2. A. Ghatak and Thyagarajan, Optical Electronics, 3. W. Demtroder, Laser Spectroscopy – Basic concepts and Instrumentation, 4. William T. Silfvast, Laser Fundamental,
C-805	**NMR in Chemistry (Elective Course)** **Advanced techniques in NMR spectroscopy** Nuclear magnetic resonance (NMR) phenomenon and the experimental aspects, Chemical shift, indirect spin-spin coupling, direct spin-spin coupling, Relaxation times, nuclear Overhauser effect, polarization transfer, Two-dimensional NMR, correlation spectroscopy (COSY), Nuclear Overhauser effect spectroscopy (NOESY). Hetero-nuclear correlation spectroscopy (HETCOR), Inverse experiments, hetero-nuclear multiple quantum spectroscopy (HMQC), NMR in higher dimensions, NMR of oriented molecules, Structure and dynamics of bio-molecules, NMR in the solid state, Magnetic resonance imaging. **Reference** 1. Andrew E. Derome, Editor, Modern NMR Techniques for Chemistry Research, Pergamon press, 1997.
CL-101	**Chemistry Laboratory** **Objectives of the Experiments**: To familiarise the students with chemistry laboratory and basic experiments involving simple chemical reactions and physical processes. Details of Safety requirement and practice in laboratory will be emphasised. **Topics to be covered**: Calibrations of pipette, burette, standard flasks etc., acid base titrations, recrystallization, thin layer chromatography, identification of organic functional groups, complexometric titrations based on EDTA complexation with metal ions, Synthesis of benzoic acid, diazotization etc. **References**

1. Vogel's Textbook of Quantitative Chemical Analysis (5th Edition; Longman)
2. Vogel's Qualitative Inorganic Analysis (7th Edition)
3. Various relevant articles in Journal of Chemical Education, American Chemical Society

CL-201

Chemistry Laboratory

Objectives of the Experiments: To familiarise the students with various analytical procedures and use of a few equipments.

Topics to be covered: Use of colorimeter for quantitative estimation, determination of equilibrium constant of complexation reactions, use of conductometry, and pH meter for determination of concentration of acids and bases, their dissociation constants, and critical micelle concentration of surfactants and identification of functional groups/ inorganic ions.

References

1. Vogel's Textbook of Quantitative Chemical Analysis, 5th Edition
2. Vogel's Qualitative Inorganic Analysis, 7th Edition,
3. Various relevant articles in Journal of Chemical Education, American Chemical Society

CL-301

Chemistry Laboratory

Inorganic Chemistry

1. Determine the percentage of purity of the given sample of boric acid
2. To estimate the chloride ions from given sample of saline by Mohr's method
3. Synthesis of aluminium acetylacetonate, $Al(acac)_3$ and its further use in complex formation with 8-hydroxy quinoline
4. Preparation of Alum from aluminium and determination of aluminium and sulfate in the prepared Alum
5. Synthesis of Ni and Co-DMG complexes

Physical chemistry

1. Enzyme kinetics: Determination of Km and Vmax
2. Determination of protein concentration by Bradford method
3. Spectroscopic determination of concentration and purity of DNA and proteins (urea denaturation method)
4. An SDS-PAGE examination of protein quaternary structure
5. To determine the freezing point of two solutions and compare the effect of solute type and concentration for each solution.
6. Molecular weight determination by boiling-point elevation of a urea solution
7. Solar irradiations of bilirubin: An experiment in photochemical oxidation

CL-401

Chemistry Laboratory

Organic Chemistry

1. Acetylation of primary amine: preparation of acetanilide
2. Radical coupling reaction: Preparation of 1,1-bisnaphthol
3. Benzil-benzillic rearrangement
4. Use of diazonium salt: 4-nitro aniline to 1-iodo 4-nitrobenzene
5. Electrophilic aromatic substitution reaction: Nitration of Phenol
6. Co-enzyme catalysed Benzoin condensation: Thiamine hydrochloride catalysed synthesis of benzoin
7. Reduction of organic Compound: Borohydride reduction of ketone

	8. Green Phorochemical reaction: photoreduction of benzophenone 9. Pinacole Pinacolone rearrangement 10. Synthesis of Local Anaesthetic: Benzocaine **Physical Chemistry** 1. To determine the energy of activation of acid catalysed hydrolysis reaction of methyl acetate. 2. To determine the order of reaction between $K_2S_2O_8$ and KI 3. Determination of the rate and order of reaction using clock reaction 4. Catalyst effect on the rate of reaction using clock reaction 5. To determine the rate constant & the order of reaction with respect to crystal violet (with respect to variable concentration of crystal violet). 6. Learn chemical structure drawing tool: ChemDraw and Molden
CL-501	**Chemistry Laboratory** **Analytical Chemistry** 1. Estimation of Ascorbic acid by differential pulse polarography 2. Cyclic voltammetry of $K_3Fe(CN)_6$ + $K_4Fe(CN)_6$ 3. Estimation of copper by Normal pulse polarography and differential pulse polarography 4. Cyclic voltammetry of redox system 5. Electrochemical deposition of metals 6. Estimation of silver by differential pulse polarography 7. Making an alloy (solder) 8. Thermal decomposition of calcium carbonate 9. Microscale reactions of positive ions with sodium hydroxides 10. Making of a photographic print. **Organic Chemistry** 1. Preparation of 2,5-dimethyl-1-phenylpyrrole 2. Preparation of 1,2,3,4-tetmhydrocarbozole 3. Preparation of benzimidazole 4. Preparation of benzofurazan-l-oxide 5. Preparation of ethyl 2-oxo-2H-1-benzopyran-3-carboxylate 6. Preparation of 4-methyl-2(1H)-quinoline 7. Preparation of pyrimidone
CL-601	**Chemistry Laboratory** **Bio-Physical Chemistry** 1. Determination of fluorescence quenching rate constant (kq) using Stern-Volmer plot: Elucidation of mechanism of collisional and static quenching 2. Characterization of intermediate states of protein using fluorescence spectroscopy 3. Determination of association constant (Ka) and binding capacity (n) of drug-protein interaction using difference spectroscopy. 4. Determination of Tm of protein unfolding 5. Determination of protein aggregation kinetics parameters, kapp, Vmax, Vi, amplitude and lag time 6. To estimate the melting temperature of DNA by spectroscopic methods. 7. Protein labelling with fluorescent dye FITC 8. Crystallization of commercial HEW-Lysozyme and draw the phase diagram to

	identify the nucleation zone for the protein 9. Determination of Helix –coil transitions in polypeptides: Conformational changes in poly-γ-benzyl-l-glutamate (PBG) in mixed solvent of dichloro acetic acid (DCA) and ethylene dichloride using polarimeter 10. Conformational characterization of proteins and nucleic acids using circular dichroism spectropolarimeter. 11. Secondary structure prediction of proteins from CD data using different structure prediction software 12. Quantitative determination of DNA-ligand binding using fluorescence 13. Assessment of the purification of a protein by ion exchange and GFC 14. Evaluation of the Hill coefficient from Scatchard and Klotz plots 15. Determination of equilibrium constant (K) and vant Hoff's enthalpy (ΔHVH) N-acetylglycosamine (NAG) and lysozyme interaction using fluorescence spectrophotometer 16. Determination of melting temperature (Tm), calorimetric enthalpy (ΔHcal), vant Hoff's enthalpy (ΔHVH) and heat capacity (ΔCp) of lysozyme unfolding using Differential scanning calorimeter 17. Determination of binding constant (Ka), enthalpy (ΔH), entropy (ΔS) and reaction stoichiometry of drug-serum albumin association 18. Thermodynamics characterization of intermediate states of protein using isothermal titration calorimetry
CL-701	**Chemistry Laboratory** **Physical Chemistry** 1. Use of three-dimensional excitation and emission matrix fluorescence spectroscopy for predicting the dissolved organic compound in drinking and waste water 2. Determination of pKa of protein using denaturation method 3. Determination of the Octanol/Water Partition Coefficients for Organic Pollutants of Varying Hydrophobic/Hydrophilic Character 4. Nuclear Chemistry: Experiment-1 5. Nuclear Chemistry: Experiment-2 **Organic Chemistry** 1. Experiment on solvent extraction 2. Isolation of caffeine from tea/coffee 3. Isolation of lycopene from tomato 4. Synthesis of heterobiaryl compound and synthesis of drug (dentrolene) 5. An operationally simple aqueous Suzuki-Miyaura cross-coupling reaction 6. Preparation and use of Wilkinson's catalyst
CL-801	**Chemistry Laboratory** 1. Determination of critical micellar concentration (cmc) of surfactant using pyrene fluorescence 2. Determination of enthalpy (ΔmicH), entropy (ΔmicS) and Gibbs free energy change (ΔmicG) of micellization using isothermal titration calorimetry. 3. Determination of partitioning parameters of different drugs in HTAB micelles using isothermal titration calorimetry 4. Powder XRD 5. Powder XRF 6. Study of excimer formation using pyrene 7. Thermodynamics of DNA Duplex Formation 8. Study of microenvironment Trp and Tyr in native protein by Synchronous

	fluorescence 9. Study the change in dynamic of protein upon ligand binding by REES 10. Quantification of chemical mixtures using 1D NMR. 11. Analysis of small organic molecules using 1D and 2D-NMR spectra 12. Pymol; VMD; CCP4img

CPr-701	To be assigned by the Supervisor
CPr-801	To be assigned by the Supervisor
CPr-901	To be assigned by the Supervisor
CPr-1001	To be assigned by the Supervisor

M-301	**Foundations**
	1. Logic: Quantifiers and negations, illustrated by examples of mathematical and non-mathematical statements. 2. Set Theory: Unions and intersections of arbitrary families, illustrated by examples. Complements. De Morgan's laws for arbitrary collection of sets. Symmetric difference. Power set of a set. Cartesian product of two sets. 3. Relations and maps: (a) Relations between two sets, including the case when the two sets are the same. (b) Definition of a map. Composite of two maps. Injective, surjective and bijective maps and their composites. A map is bijective if and only if it is invertible. (c) Image and inverse image under a map. Relation between images (resp. inverse images) and set theoretic operations. Inverse images under a composite map. Clarify a common misconception: If $f : X \to Y$ is a map and $B \subseteq Y$ then the definition of $f^{-1}(B)$ does not require the existence of f^{-1}. (d) Equivalence relations. Lots of examples including fibres of map and congruence of integersmodulo *n*.. Equivalence classes. Giving an equivalence relation on a set *X* is equivalent to giving a partition of *X.* Quotient set. Construction of Z as a quotient of N × N. 4. Cardinality: (a) Finite and infinite sets. (b) Bijection relates to same cardinality. (c) Countable sets. Countably infinite and uncountable sets. Examples. (d) Every infinite set has a proper, countably infinite subset. (e) Uncountability of R and P(N). Algebraic numbers are countable. This yields existence of transcendental numbers. (f) Schroeder-Bernstein theorem. 5. Partially Ordered Sets: (a) Concept of partial order and total order. Examples. (b) Upper bound. lub, lower bound, glb. (c) Maximum and maximal. Minimum and minimal. (d) Chains, Zorn's Lemma. (e) Lexicographic order. 6. (a) Well-ordering Principle. (b) Weak and Strong Principles of Mathematical Induction. (c) Axiom of Choice, product of an arbitrary family of sets. (d) Statement (without proof) of the equivalence of Axiom of Choice, Zorn's Lemma

and Well Ordering Principle.

7. Additional Topics (Optional)
(a) Dedekind's Construction of Real Numbers.
(b) Binary, ternary, hexadecimal etc expansions of integers (and real numbers).
(c) Cantor Sets.

References

[1] Naive Set Theory, P. Halmos.
[2] Set Theory and Logic, R. Stoll.
[3] Topology, J. Munkres.
[4] Real Analysis, Bartle and Sherbert.

M-302

Analysis-I (Single Variable Analysis)

1. Real number system: Construction via Cauchy sequences. (Note: Dedekind cuts is an optional topic in M301.)
2. Concept of a field, ordered field, examples of ordered fields, supremum, infimum. Order completeness of R, Q is not order complete. Absolute values, Archimedean property of R. The fact that C is a field that cannot be made into an ordered field. Denseness of Q in R. Every positive real number has a unique positive *n*-th root.

3. Sequences: A monotone increasing sequence which is bounded above converges to its supremum.
   1
   Sandwich $lim\ \left(1+\frac{1}{n}\right)^n = e,\ lim\ \sqrt[n]{n}$ theorem.= 1 and *liman* = 1.

4. Subsequence and Cauchy sequences: Every sequence of real numbers has a monotone subsequence. Cauchy completeness of R; Q is not Cauchy complete.
5. Infinite Series: Absolute and conditional convergence. Comparison test, ratio test, root test, Abel's alternating series test. Dirichlet's test for convergence of $\Sigma a_n b_n$. Statement of Riemann's rearrangement theorem. Power series, radius of convergence, uniform convergence via examples.

6. Continuous functions: Sequential and neighbourhood definitions; sums and products of continuous functions are continuous. Intermediate value property; continuous functions on closed and bounded intervals are bounded and attain their bounds; monotone continuous functions, inverse functions. Uniform Continuity, examples and counter-examples.

7. Differentiable functions: Definition as a function infinitesimally approximal by a linear map, equivalence with Newton's ratio definition. One-sided derivatives. The *O, o* and ~ notations with illustrative examples. Chain rule with complete proof (using the above definition). Relation between the sign of f^0 and local monotonicity. Proofs of Rolle's theorem, Lagrange's and Cauchy's mean value theorems. L'Hospital's rule.
   Higher order derivatives. Convex functions. Local maxima/minima, saddle points; examples of curve sketching in the plane.
   Taylor's theorem, estimation of the remainder in Taylor's theorem.
   Power series expansions of elementary functions. Validity of term by term differentiation and integration. Binomial theorem for arbitrary real coefficients. Standard example:

$$f(x) = \begin{cases} e^{-\frac{1}{x^2}}, & x \neq 0 \\ 0, & x = 0 \end{cases}$$

8. Riemann Integration: Upper and lower Riemann sums, basic properties. Riemann integrability, $f : [a,b] \longrightarrow R$ continuous implies f is Riemann integrable, examples of Riemann integrable functions which are not continuous on $[a,b]$. If $f : [a,b] \longrightarrow R$ is Riemann integrable then so is $|f|$ and $\left|\int_a^b f(x)dx\right| \le \int_a^b |f(x)|dx$. Cauchy-Schwarz inequality: $\left|\int fg\right| \le \sqrt{\int f^2}\sqrt{}$ $(\int f^p)^{\frac{1}{p}}(\int g^q)^{\frac{1}{q}}$, where $\frac{1}{p}+\frac{1}{q} = 1$. Mean value theorem for integrals.
9. (Optional, if time permits): Improper integrals. Cauchy's condition for the existence of improper integrals, test for convergence. Gudermannian and other examples.

References

[1] Introduction to Real Analysis: Robert G. Bartle and Donald R. Sherbert, 4th ed., Wiley Publications, 2011
[2] A First Course in Analysis: George Pedrick, Undergraduate Texts in Mathematics, SpringerScience and Business Media, 2012. ISBN: 1441985549, 9781441985545
[3] Principles of Mathematical Analysis, Walter Rudin, (Indian Edition), 3rd ed,. McGraw-Hill, 1976. ISBN: 9780070542358.
[4] Tom M. Apostol, Mathematical Analysis, 2nd ed., Pearson Education, 1974. ISBN: 9780201002881.
[5] Michael Spivak, Calculus, 4th ed., Publish or Perish, 2008. ISBN: 9780914098911.

M-303 Algebra-I (Groups and Rings)

1. Division algorithm in Z, fundamental theorem of arithmetic.
2. Recollection of equivalence relations and equivalence classes, illustrate by congruence classes of integers modulo n.
3. Definition of a group, examples including matrices, permutation groups, groups of symmetry, roots of unity.
4. First properties of a group, laws of exponents, finite and infinite groups.
5. Subgroups and co-sets, order of an element, Lagrange theorem, normal subgroups, quotient groups.
6. Detailed look at the group S_n of permutations, cycles and transpositions, even and odd permutations, the alternating group.
7. Homomorphisms, kernel, image, isomorphism, the fundamental theorem of group homomorphisms.
8. Cyclic groups, subgroups and quotients of cyclic groups, finite and infinite cyclic groups.
9. Cayleys theorem on representing a group as a permutation group.
10. Conjugacy classes, centre, class equation, centre of a p-group.
11. (Optional, if time permits) Sylow theorems.
12. Definition of a ring, examples including congruence classes modulo n.
13. Ideals, quotient rings, homomorphisms, units, fields, non-zero divisors, integral domains, field offractions of an integral domain.
14. Division algorithm in $K[X]$, where K is a field; $K[X]$ and Z are PID's.
15. (Optional, if time permits) Unique factorization domains, Gauss Lemma.

References

[1] M. Artin, Algebra, Prentice Hall of India, 1994.
[2] D.S. Dummit and R.M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
[3] Joseph Gallion, Contemporary Abstract Algebra, Narosa.
[4] N. Jacobson, Basic Algebra (volumes I and II), Hindustan Publishing Corporation, 1983.

M-304 Elementary Number Theory

1. Fundamental theorem of arithmetic, divisibility in integers.
2. Prime numbers and infinitude of primes. Infinitude of primes of special types. Special primes like Fermat primes, Mersenne primes, Lucas primes etc.
3. Euclidean algorithm, greatest common divisor, least common multiple.
4. Equivalence relations and the notion of congruences. Wilson’s theorem and Fermat’s little theorem. Chinese remainder theorem.
5. Gaussian integers.
6. Continued fractions and their applications.
7. Primitive roots, Euler’s Phi function.
8. Sum of divisors and number of divisors, M¨obius inversion.
9. Quadratic residues and non-residues with examples.
10. Euler’s Criterion, Gauss’ Lemma.
11. Quadratic reciprocity and applications.
12. Applications of quadratic reciprocity to calculation of symbols.
13. Legendre symbol: Definition and basic properties.
14. Fermat’s two square theorem, Lagrange’s four-square theorem.
15. Pythagorean triples.
16. Diophantine equations and Bachet’s equation. The duplication formula.

References

[1] D. Burton, Elementary Number Theory.
[2] Kenneth H. Rosen, Elementary number theory and its applications.
[3] Niven, Ivan M.; Zuckerman, Herbert S.; Montgomery, Hugh L, An Introduction to the Theory of Numbers.

M-401

Analysis-II (Multi-variable Analysis)

1. Linear maps from R^n to R^m, partial derivatives. Tangent plane and normal line to a surface at a point. Directional derivative. Jacobian, polar and spherical polar coordinates. Chain rule. Mean value property and Taylor’s theorem for several variables.
2. Parametrized surfaces, coordinate transformations, Inverse function theorem, Implicit function theorem, Rank theorem.
3. Critical points, maxima and minima, saddle points, examples of quadric surfaces in 3-space. Lagrange multiplier method.
4. Multiple integrals, Riemann and Darboux integrals, Iterated integrals. Area and volume. Improper-integrals.
5. Integration on curves and surfaces: Green’s theorem, Differential forms, Gauss’ Divergence theorem, Stokes’ theorem.
6. (Optional, if time permits): Beta and gamma functions; $\Gamma(\frac{1}{2}) = \sqrt{\pi}$

References

[1] Michael Spivak, Calculus on Manifolds, A Modern Approach to Classical Theorems of Advanced Calculus, Westview Press, 1965. ISBN: 0805390219.
[2] James Munkres, Analysis on Manifolda, Westiew Press, 2nd ed.,1997. ISBN: 0201315963.
[3] Wendell H. Fleming, Functions of Several Variables, Undergraduate Texts in Mathematics, 2nd Ed., Springer-Verlag, 1977.
[4] Jerrold E. Marsden, Anthony J. Tromba and Alan Weinstein, Basic Multivariable Calculus, W. H. Freeman and Co. Ltd., 2001. ISBN: 9780716724438
[5] Principles of Mathematical Analysis, Walter Rudin, (Indian Edition), 3rd ed,. McGraw-Hill, 1976. ISBN: 9780070542358.

M-402

Algebra-II (Linear Algebra)

60

Note 1: This is essentially a first course on vector spaces. However, as modules over a general ring are needed later in several courses and as it is desirable to give students time to become comfortable with this concept, modules are already introduced in the first item of this syllabus. Emphasize that vector spaces are special cases of modules, in which case several properties are available as discussed in the remaining items.

1. Modules over a commutative ring, submodules and quotient modules, homomorphisms, fundamental theorem of module homomorphisms, exact sequences, finitely generated modules, free modules.
2. Vector spaces as modules over a field, subspaces, quotient spaces.
3. Span and linear independence, basis, dimension.
4. Linear maps and their correspondence with matrices with respect to given bases, change of bases.
5. Eigenvalues, eigenvectors, eigenspaces, characteristic polynomial, Cayley-Hamilton.
6. Bilinear forms, inner product spaces, Gram-Schmidt process, diagonalization, spectral theorem.
7. (Optional) Classical groups.

Note 2: Jordan and rational canonical forms to be done in ***M-602*** *in Semester-VI* as an application of the structure of finitely generated modules over a PID.

References

[1] M. Artin, Algebra, Prentice Hall of India, 1994.
[2] D.S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
[3] K. Hoffman and R. Kunze, Linear Algebra, Prentice Hall, 1992.
[4] N. Jacobson, Basic Algebra II, Hindustan Publishing Corporation, 1983.
[5] S. Lang, Algebra, 3rd ed. Springer (India) 2004.

M-403

Topology-I

1. Metric spaces: Definition and basic examples including the following:
(i) The discrete metric on any set.
(ii) R and R^n with Euclidean metrics, Cauchy-Schwarz inequality, definition of a norm on a finite dimensional R-vector space and the metric defined by a norm.
(iii) The set C[0,1] with the metric given by sup$|f(t) - g(t)|$ (resp. $\int_0^1 |f(t) - g(t)|dt$).
(iv) Metric subspaces, examples.
2. Topology generated by a metric: Open and closed balls, open and closed sets, complement of an open (closed) set, arbitrary unions (intersections) of open (closed) sets, finite intersections (unions) of open (closed) sets, open (closed) ball is an open (closed) set, a set is open if and only if it is a union of open balls, Hausdorff property of a metric space.
3. Equivalence of metrics, examples, the metrics on R^2 given by $|x_1 - y_1|+|x_2 - y_2|$ (resp. $\max\{|x_1 - y_1|,|x_2 - y_2|\}$) is equivalent to the Euclidean metric, the shapes of open balls under these metrics.
4. Limit points, isolated points, interior points, closure, interior and boundary of a set, dense and nowhere dense sets.
5. Continuous maps: ε-δ definition and characterization in terms of inverse images of open (resp. closed) sets, composite of continuous maps, pointwise sums and products of continuous maps into R, homeomorphism, isometry, an isometry is a homeomorphism but not conversely, uniformly continuous maps, examples.
6. Complete metric spaces: Cauchy sequences and convergent sequences, a subspace of a completemetric space is complete if and only if it is closed, Cantor intersection theorem, Baire category theorem and its applications, completion of a

	metric space. 7. General topological spaces, stronger and weaker topologies, continuous maps, homeomorphisms, bases and subbases, finite products of topological spaces. 8. Basic separation axioms and first and second countability axioms. 9. Compactness for general topological spaces: Finite sub-coverings of open coverings and finite intersection property, continuous image of a compact set is compact, compactness and Hausdorff property. 10. Compactness for metric spaces: Bolzano-Weierstrass property, the Lebesgue number for an open covering, sequentially compact and totally bounded metric spaces, Heine-Borel theorem, compact subsets of R, a continuous map from a compact metric space is uniformly continuous. 11. Connectedness: definition, continuous image of a connected set is connected, characterization in terms of continuous maps into the discrete space N, connected subsets of R, intermediate value theorem as a corollary, countable (arbitrary) union of connected sets, connected components. **References** [1] E. T. Copson, *Metric spaces.* [2] M. Eisenberg, *Topology.* [3] R.H. Kasriel, *Undergraduate topology.* [4] W. Rudin, *Principles of mathematical analysis.* [5] G. F. Simmons, *Topology and modern analysis*. [6] W. A. Sutherland, *Introduction to metric and topological spaces.*
M-404	**Discrete Mathematics** 1. Basics: Pigeonhole Principle, Elementary Counting Techniques, Permutations and Combinations, Binomial and Multinomial Theorems, Partitions, Stirling Numbers. 2. Formal Series: Formal series, Generating functions, Formal convergence, Infinite sum and products. 3. Generating Functions: Recurrences, Catalan numbers, Convolutions, Evaluating sums, Exponential formula, Partition functions, Infinite series. 4. Sieve Methods: Inclusion-Exclusion, Mobius inversion, Involution principle. 5. Enumeration of Patterns: Symmetries and patterns, Burnside's Lemma, Symmetries on R and N. 6. Partitions and Young Tableaux: An Introduction to the Combinatorics of Young Tableaux. 7. Additional Topics: Lattice Paths and Gaussian Coefficients. Infinite Matrices and Inversion of Sequences. Probability Generating Functions. Symmetric Polynomials and Functions. Schur Functions. RSK Algorithm. Hypergeometric Sums and Hypergeometric Series. **References** [1] Martin Aigner - *A Course in Enumeration.* [2] W. Fulton - *Young Tableaux.* [3] Ronald Graham, Donald Knuth, Oren Patashnik - *Concrete Mathematics.* [4] Richard Stanley - *Enumerative Combinatorics.* [5] Ioan Tomescu, Robert Melter - *Problems in Combinatorics and Graph Theory.*
M-405	**Complex Analysis** 1. Complex numbers and Riemann sphere. M¨obius transformations. 2. Analytic functions. Cauchy-Riemann conditions, harmonic functions, Elementary functions, Powerseries, Conformal mappings.

	3. Contour integrals, Cauchy theorem for simply and multiply connected domains. Cauchy integralformula, Winding number. 4. Moreras theorem. Liouvilles theorem, Fundamental theorem of Algebra. 5. Zeros of an analytic function and Taylors theorem. Isolated singularities and residues, Laurentseries, Evaluation of real integrals. 6. Zeros and Poles, Argument principle, Rouchs theorem. **References** [1] L. Ahlfors, Complex Analysis. [2] R.V. Churchill and J. W. Brown, Complex Variables and Applications, International Student Edition, Mc-Graw Hill, 4th ed., 1984. [3] B. R. Palka, An Introduction to Complex Function Theory, UTM Springer-Verlag, 1991. [4] Donald Sarason, Notes on Complex Function Theory, HBA.
M-501	**Analysis-III (Measure and Integration)** 1. Sigma algebra of sets, measure spaces. Lebesgues outer measure on the Real line. Measurable set in the sense of Caratheodory. Translation invariance of Lebesgue measure. Existence of a non-Lebesgue measurable set. Cantor set-uncountable set with measure zero. 2. Measurable functions, types of convergence of measurable functions. The Lebesgue integral for simple functions, nonnegative measurable functions and Lebesgue integrable function, in general. 3. Convergence theorems- monotone and dominated convergence theorems. 4. Comparison of Riemann and Lebesgue integrals. Riemanns theorem on functions which are continuous almost everywhere. 5. The product measure and Fubinis theorem. 6. The L^p spaces and the norm topology. Inequalities of H¨older and Minkowski. Completeness of L^p and L^∞ spaces. **References** [1] H.L. Royden, Real Analysis, Pearson Education. [2] G. DeBarra, Introduction to Measure Theory, Van Nostrand Reinhold. [3] I. K. Rana, An Introduction to Measure and Integration, Narosa. [4] H.S. Bear, A Primer on Lebesgue Integration, Academic press.
M-502	**Algebra-III (Field Theory)** 1. Prime and maximal ideals in a commutative ring and their elementary properties. 2. Field extensions, prime fields, characteristic of a field, algebraic field extensions, finite field extensions, splitting fields, algebraic closure, separable extensions, normal extensions, 3. Finite Galois extensions, Fundamental Theorem of Galois Theory. 4. Solvability by radicals. 5. Extensions of finite fields. **References** [1] M. Artin, Algebra, Prentice Hall of India, 1994. [2] D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002. [3] N. Jacobson, Basic Algebra I & II, Hindustan Publishing Corporation, 1983. [4] R. Lidl and H. Niederreiter, Introduction to Finite Fields and Their Applications, Cambridge University Press, 1986. [5] TIFR pamphlet on Galois Theory.

M-503	**Topology-II** 1. Products and quotients. Tychonoff's theorem. Product of connected spaces is connected. Weak topology on X induced by a family of maps $f_\alpha : X \longrightarrow X_\alpha$ where each X_α is a topological space. The coherent topology on Y induced by a family of maps $g_\alpha : Y_\alpha \longrightarrow Y$ where Y_α are given topological spaces. Examples of quotients to illustrate the universal property such as embeddings of $\mathbb{R}P^2$ and the Klein's bottle in $\mathbb{R}^4$. 2. Completely regular spaces and its embeddings in a product of intervals. One-point compactification. 3. Normal spaces and the theorems of Urysohn and Tietze. 4. Local compactness, local connectedness and local path-connectedness and their basic properties. If $q : X \longrightarrow Y$ is a quotient map and Z is locally compact Hausdorff space then $q \times \mathrm{id} : X \times Z \longrightarrow Y \times Z$ is also a quotient map. 5. Locally finite families of sets and Partitions of unity. Baire Category theorem for locally compact Hausdorff spaces. 6. Paths, homotopy of paths. The fundamental group and its basic properties. The fundamental group of a topological group is abelian. Homotopy of maps, retraction, deformation retraction, contractibility. Homotopy type and homotopy equivalence. Covering projections, path-lifting. The fundamental group of a product space. The fundamental group of the circle, torus, n-sphere, lens spaces. 7. Covering spaces, equivalence of covering spaces, deck transformation group and its action, regular covering spaces, homotopy lifting property, universal covering space, fundamental group of orbit space. **References** [1] G. F. Simmons, *Topology and modern analysis* [2] W. A. Sutherland, *Introduction to metric and topological spaces.* [3] S. Willard, *General Topology*, Dover, New York.
M-504	**Graph Theory** 1. Basics: Vertices and edges, Vertex degree and counting, Matrices and Isomorphisms, Decomposition and Special Graphs, Extremal Problems, Graphic Sequences, Travelling Salesman Problem, Koenisburg Seven-Bridges problem. 2. Paths, Cycles and Trails: Walks, Paths, Circuits, Bipartite Graphs, Eulerian Graphs, Directed Graphs, Hamiltonian Paths and circuits. 3. Trees: Basic Properties, Spanning Trees, Enumeration, Optimization and Trees. 4. Matchings and Factors: Halls Condition, Matchings in Bipartite Graphs, Applications and Algorithms, Matchings in General, Stable Matchings. 5. Connectivity and Paths: Connectivity, Edge Connectivity, Structure of 2-connected and 3connected graphs, k-connected and k-edge connected graphs, Mengers Theorem, Maders Theorem, Edge-disjoint Spanning Trees, Paths between given pair of vertices, Network Flow Problems. 6. Colouring: Vertex colourings, Structure of k-chromatic graphs, Chordal graphs, Perfect graphs, List of colourings, Counting proper colourings. 7. Planar Graphs: Plane graphs, Embeddings, Drawings, Kuratowski's Theorem, Algebraic Planarity Criteria, Plane duality. 8. Edges and Cycles: Line Graphs and Edge Colourings, Hamiltonian Cycles, Planarity, Colouring and Cycles. 9. Additional Topics: Ramsey Theory, Random Graphs, Extremal Problems. **References** [1] Douglas West - *Introduction to Graph Theory.* [2] Reinhard Diestel - *Graph Theory.*

[3] J.A. Bondy and U.S.R. Murty - *Graph Theory with Applications.*
[4] D.A. Marcus - *Graph Theory - A Problem Oriented Approach.*
[5] Ioan Tomescu, Robert A. Melter - *Problems in Graph Theory and Combinatorics.*

M-601 Analysis-IV (Fourier Analysis)

1. Fourier series. Discussion of convergence of Fourier series.
2. Uniqueness of Fourier Series, Convolutions, Cesaro and Abel Summability, Fejer's theorem, Dirichlets theorem, Poisson Kernel and summability kernels. Example of a continuous function with divergent Fourier series.
3. Summability of Fourier series for functions in L^1, L^2 and L^p spaces. Fourier-transforms of integrable functions. Basic properties of Fourier transforms, Poisson summation formula, Hausdorff-Young inequality, Riesz-Thorin Interpolation theorem.
4. Schwartz class of rapidly decreasing functions, Fourier transforms of rapidly decreasing functions, Riemann Lebesgue lemma, Fourier Inversion Theorem, Fourier transforms of Gaussians, Plancheral theorem, Paley-Weiner theorem.
5. Distributions and Fourier Transforms: Calculus of Distributions, Tempered Distributions: Fourier transforms of tempered distributions, Convolutions, Applications to PDEs.

References

[1] Y. Katznelson, Introduction to Harmonic Analysis, Dover.
[2] R. E. Edwards, Fourier Series, Academic Press.
[3] E. M. Stein and R. Shakarchi, Fourier Analysis: An Introduction, Princeton University Press, Princeton 2003.
[4] W. Rudin, Fourier Analysis on groups, Interscience.

M-602 Algebra-IV (Module Theory)

1. Recollection of modules, submodules, quotient modules, homomorphisms.
2. External and internal direct sums of modules.
3. Tensor product of modules over a commutative ring. Functorial properties of ⊗ and Hom.
4. Definitions and elementary properties of projective and injective modules over a commutative ring.
5. Structure of finitely generated modules over a PID. Applications to matrices and linear maps overa field: Jordan and rational canonical forms.
6. Simple modules over a not necessarily commutative ring, modules of finite length, Jordan-H¨older Theorem, Schur's lemma.
7. (Optional, if time permits) Semisimple modules over a not necessarily commutative ring, Wedderburn Structure Theorem for semi-simple rings.

References

[1] M. Artin, Algebra, Prentice Hall of India, 1994.
[2] D.S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
[3] N. Jacobson, Basic Algebra I & II, Hindustan Publishing Corporation, 1983.
[4] S. Lang, Algebra, 3rd ed. Springer (India) 2004.

M-603 Differential Equations and Special Functions

Module 1 – Ordinary Differential Equations

1. Basic existence and uniqueness of systems of ordinary differential equations satisfying the Lipschitz' condition. Examples illustrating non-uniqueness when Lipschitz or other relevant conditions are dropped. Gronwall's lemma and its

applications to continuity of the solutions with respect to initial conditions. Smooth dependence on initial conditions and the variational equation. Maximal interval of existence and global solutions. Proof that if (a, b) is the maximal interval of existence and $a < \infty$ then the graph of the solution must exit every compact subset of the domain on the differential equation.

2. Linear systems and fundamental systems of solutions. Wronskians and its basic properties. The Abel Liouville formula. The dimensionality of the space of solutions. Fundamental matrix. The method of variation of parameters.

3. Linear systems with constant coefficients and the structure of the solutions. Matrix exponentials and methods for computing them. Solving the in-homogeneous system. The Laplace transform and its applications.

4. Second order scalar linear differential equations.

Module 2 – Special Functions

1. Beta Functions, Gamma Functions, Riemann Zeta Function.
2. Series Solution for Ordinary Differential Equations, Behaviour of Solutions near Regular Points, Solutions of Bessel's Equation.
3. Theory of Orthogonal Polynomials.

References

1. G. F. Simmons, *Differential equations with applications and historical notes*, McGraw Hill.
2. George Andrews, Richard Askey, Ranjan Roy, *Special Functions (EMSAA- 71),* Cambridge University Press.
3. Ernst Hairer, Gerhard Wanner, S.P. Norsett, *Solving Ordinary Differential Equations I – Nonstiff Problems,* Springer-Verlag.
4. V. I. Arnold, *Ordinary Differential Equations*, Springer.
5. R. Courant and D. Hilbert, *Methods of Mathematical Physics, Volume – I,* Wiley Classics Library.
6. W. Hurewicz, *Lectures on ordinary differential equations*, Dover, New York.

M-604 Probability Theory

1. Probability as a measure, Probability space, conditional probability, independence of events, Bayes formula. Random variables, distribution functions, expected value and variance. Standard Probability distributions: Binomial, Poisson and Normal distribution.
2. Borel-Cantelli lemmas, zero-one laws. Sequences of random variables, convergence theorems, various modes of convergence. Weak law and the strong law of large numbers.
3. Central limit theorem: DeMoivre-Laplace theorem, weak convergence, characteristic functions, inversion formula, moment generating function.
4. Random walks, Markov Chains, Recurrence and Transience.
5. Conditional Expectation, Martingales.

References

[1] Marek Capinski and Tomasz Zastawniak, Probability through Problems, Springer, Indian Reprint 2008.
[2] P. Billingsley, Probability and Measure, 3rd ed., John Wiley & Sons, New York, 1995.
[3] J. Rosenthal, A First Look at Rigorous Probability, World Scientific, Singapore, 2000.
[4] A.N. Shiryayev, Probability, 2nd ed., Springer, New York, 1995.
[5] K.L. Chung, A Course in Probability Theory, Academic Press, New York, 1974.

M-701 Functional Analysis

1. Normed linear spaces. Riesz lemma. Heine-Borel theorem. Continuity of linear maps.
2. Hahn-Banach extension and separation theorems.
3. Banach spaces. Subspaces, product spaces and quotient spaces. Standard examples of Banach spaces like ℓ^p, L^p, $C([0,1])$ etc.
4. Uniform boundedness principle. Closed graph theorem. Open mapping theorem. Bounded inverse theorem.
5. Spectrum of a bounded operator. Eigen spectrum. Gelfand-Mazur theorem and spectral radius formula.
6. Dual spaces. Transpose of a bounded linear map. Standard examples.
7. Hilbert spaces. Bessel inequality, Riesz-Schauder theorem, Fourier expansion, Parseval's formula.
8. In the framework of a Hilbert space: Projection theorem. Riesz representation theorem. Uniquenessof Hahn-Banach extension.
9. Sobolev spaces.

References

[1] J.B. Conway, A course in Functional Analysis, Springer-Verlag, Berlin, 1985.
[2] G. Goffman and G. Pedrick, First course in functional analysis, Prentice-Hall, 1974.
[3] E. Kreyszig, Introductory Functional Analysis with applications, John Wiley & Sons, NY, 1978.
[4] B.V. Limaye, Functional Analysis, 3rd ed., New Age International, New Delhi, 2014.
[5] A. Taylor and D. Lay, Introduction to functional analysis, Wiley, New York, 1980.

M-702 Commutative Algebra

1. Prime and maximal ideals in a commutative ring, nil and Jacobson radicals, Nakayamas lemma, local rings.
2. Rings and modules of fractions, correspondence between prime ideals, localization.
3. Modules of finite length, Noetherian and Artinian modules.
4. Primary decomposition in a Noetherian module, associated primes, support of a module.
5. Graded rings and modules, Artin-Rees, Krull-intersection,
6. Hilbert-Samuel function of a local ring, dimension theory, principal ideal theorem.
7. Integral extensions, Noether's normalization lemma, Hilberts Nullstellensatz (algebraic and geometric versions).

References

[1] M.F Atiyah and I.G MacDonald, Introduction to Commutative Algebra, Addison-Wesley, 1969.
[2] D. Eisenbud, Commutative Algebra with a view toward algebraic geometry, Springer-Verlag, Berlin, 2003.
[3] H. Matsumura, Commutative ring theory, Cambridge Studies in Advanced Mathematics No. 8, Cambridge University Press, Cambridge, 1980.
[4] S. Raghavan, B. Singh and R. Sridharan, Homological methods in commutative algebra, TIFR Math. Pamphlet No.5, Oxford, 1975.
[5] B. Singh, Basic Commutative Algebra, World Scientific, 2011.

M-703 Algebraic Topology

1. Review of quotient spaces, connectedness, path-connectedness, compact-open topology. Examples of projective spaces, Klein's bottle, Möbius band, $SO(n,\mathbb{R})$. Topological groups and their basic properties. Proof that if H is a connected

subgroup such that *G/H* is also connected (as a topological space) then *G* is connected.

2. Free groups, free products with amalgamations. Concept of push outs in the context of topological spaces and groups. Seifert Van Kampen theorem and its applications. Fundamental group of a torus, n-sphere, lens space. Structure of fundamental group of a compact surface.
3. Introduction to Singular Homology Theory. Relation between fundamental group and first homology (also co-homology) group. Axioms of Homology Theory.
4. Degree of a map, Brouwer's fixed point theorem, Fundamental Theorem of Algebra, Borsuk-Ulamtheorem.
5. Simplices and simplicial complexes, simplicial maps. CW-complexes. Geometric complexes and orientation. Simplicial Approximation Theorem. Chain complexes and homology groups. Examples and structure of simplicial homology groups. Induced homomorphisms of homology groups and applications. Euler - P¨oincare Theorem. Relative homology groups. Identification of simplicial and singular homology.

References

[1] F.H. Croom, *Basic Concepts of Algebraic Topology*, **UTM**, Springer-Verlag, 1978.
[2] A. Hatcher, Algebraic Topology, Cambridge, 2001.
[3] C. Kosniowski, *A First Course in Algebraic Topology*, Cambridge University Press, 1980.
[4] L. Lima, *Fundamental Groups and Covering Spaces*, A. K. Peters, 2003.
[5] W.S. Massey, *A Basic Course in Algebraic Topology.*, **GTM-127**, Springer-Verlag, 1991.
[6] J.R. Munkres, *Topology (Second Edition)*, Prentice Hall, 2000.

M-704 Differential Geometry and Applications

1. Curvature of curves in E^n: Parametrized Curves, Existence of Arc length parametrization, Curvature of plane curves, Frennet-Serret theory of (arc-length parametrized) curves in E^3, Curvature of (arc-length parametrized) curves in E^n, Curvature theory for parametrized curves in E^n. Significance of the sign of curvature, Rigidity of curves in E^n.
2. Euler's Theory of curves on Surfaces: Surface patches and local coordinates, Examples of surfaces in E^3, curves on a surface, tangents to the surface at a point, Vector fields along curves, Parallel vector fields, vector fields on surfaces, normal vector fields, the First Fundamental form, Normal curvature of curves on a surface, Geodesics, geodesic Curvature, Christoffel symbols, Gauss' formula, Principal Curvatures, Euler's theorem.
3. Gauss' theory of Curvature of Surfaces: The Second Fundamental Form, Weingarten map andthe Shape operator, Gaussian Curvature, Gauss' *Theorema Egregium*, Guass-Codazzi equations, Computation of First/Second fundamental form, curvature etc. for surfaces of revolution and other examples.
4. More Surface theory: Mean Curvature and Minimal Surfaces (introduction), surfaces of constant curvature, Geodesic coordinates, Notion of orientation, examples of non-orientable surfaces, Euler characteristic, statement of Gauss-Bonnet Theorem.
5. Modern Perspective on Surfaces: Tangent planes, Riemannian metrics on surfaces.

References

[1] Elementary Differential Geometry: Andrew Pressley, Springer Undergraduate Mathematics Series.
[2] Elementary Differential Geometry: J. Thorpe, Elsevier.
[3] Differential Geometry of Curves and Surfaces: M. do Carmo.
[4] Elements of Differential Geometry: R. Millman & G. Parker.

M-801	**Partial Differential Equations** 1. Generalities on the origins of partial differential equations. Generalities on the Cauchy problem for a scalar linear equation of arbitrary order. The concept of characteristics. The Cauchy-Kowalevskya theorem and the Holmgren's uniqueness theorem. The fundamental equations of mathematical physics as paradigms for the study of Elliptic, Hyperbolic and Parabolic equations. 2. Quasilinear first order scalar partial differential equations and the method of characteristics. Detailed discussion of the inviscid Burger's equation illustrating the formation of discontinuities in finite time. The fully nonlinear scalar equation and Eikonal equation. The Hamilton-Jacobi equation. 3. Detailed analysis of the Laplace and Poisson's equations. Green's function for the Laplacian and its basic properties. Integral representation of solutions and its consequences such as the analyticity of solutions. The mean value property for harmonic functions and maximum principles. Harnack inequality. 4. The wave equation and the Cauchy problem for the wave equation. The Euler-Poisson-Darboux equation and integral representation for the wave equation in dimensions two and three. Properties of solutions such as finite speed of propagation. Domain of dependence and domain of influence. 5. The Cauchy problem for the heat equation and the integral representation for the solutions of the Cauchy problem for Cauchy data satisfying suitable growth restrictions. Infinite speed of propagation of signals. Example of non-uniqueness. 6. Fourier methods for solving initial boundary value problems.
M-802	**Algebraic Number Theory** 1. Field extensions and examples of field extensions of rational numbers, real numbers and complex numbers. Monic polynomials, Integral extensions, Minimal polynomial, Characteristic polynomial. 2. Integral closure and examples of rings which are integrally closed. Examples of rings which are not integrally closed. The ring of integers. The ring of Gaussian integers. Quadratic extensions and description of the ring of integers in quadratic number fields. 3. Units in quadratic number fields and relations to continued fractions, connections with quadratic forms. 4. Noetherian rings, Rings of dimension one. Dedekind domains. Norms and traces. Derive formulae relating norms and traces for towers of field extensions. 5. Discriminant and calculations of the discriminant in the special context of quadratic number fields. Different and it's applications. 6. Cyclotomic extensions and calculation of the discriminant in this case. Factorization of ideals into prime ideals and its relation to the discriminant. 7. Ramification theory, residual degree and its relation to the degree of the extension. Ramified primes in quadratic number fields. 8. (Optional, if time permits) Ideal class group. Geometric ideas involving volumes. Minkowski's theorem and its application to proving finiteness of the ideal class group. 9. (Optional, if time permits) Real and complex embeddings. Structure of finitely generated abelian groups. Dirichlet's Unit Theorem and the rank of the group of units. Discrete valuation rings, Local fields. **References** [1] G.J. Janusz, Algebraic Number Fields, Second Edition, AMS, 1996.

[2] J. Neukirch, Algebraic Number Theory, Springer, 2013.
[3] D.A. Marcus, Number Fields, Springer, 2013.
[4] P. Samuel, Algebraic Theory of Numbers, Dover, 2008.
[5] TIFR pamphlet on Algebraic Number Theory, 1966.

M-803 Differential Topology

1. Differentiable functions on R^n : Review of differentiable functions $f : R^n \to R^m$, Implicit and Inverse function theorems, Immersions and Submersions, critical points, critical and regular values.
2. Manifolds: Level sets, sub-manifolds of R^n, immersed and embedded sub-manifolds, tangent spaces, differentiable functions between sub-manifolds of R^n, abstract differential manifolds and tangent spaces.
3. Differentiable functions on Manifolds: Differentiable functions $f : M \to N$, critical points, Sard's theorem, non-degenerate critical points, Morse Lemma, Manifolds with boundary, Brouwer fixed point theorem, *mod 2* degree of a mapping.
4. Transversality: Orientation of Manifolds, oriented intersection number, Brouwer degree, transverse intersections.
5. Integration on Manifolds: Vector field and Differential forms, integration of forms, Stokes' theorem, exact and closed forms, Poincar Lemma, Introduction to de Rham theory.

References

[1] Topology from a Differentiable Viewpoint: J. Milnor.
[2] Differential Topology: V. Guellemin & A. Pollack.
[3] Differential Topology: M. Hirsch.

M-804 Computational Mathematics

Objective: Learning basics of python programming language and using it to learn the open source computer algebra system SAGE. Furthermore, using SAGE to explore symbolic and numerical computations in toics such as calculus, Linear Algebra, Group-Theory and Number-Theory, etc.

Module I: Python Programming

1. Introduction to python, basic operations, data types, use of 'math' and 'cmath' modules to do basic computations.
2. Decision making (if-else) and loops
3. Creating user defined functions and modules
4. Lists, tuples, dictionaries and strings
5. Plotting graphs in various forms using 'matplotlib'
6. Reading and writing data in files
7. Brief introduction to python classes
8. Numerical computations in python using **numpy**, **scipy** and **sympy** packages.
9. Developing python programmes to solve problems in numerical analysis.

Module II: Numerical and Symbolic computations with SAGE

1. Introduction to SAGE, using SAGE as an advanced calculator
2. Plotting graphs of 2d and 3d objects in various forms
3. Use of SAGE to explore calculus of single and multi-variables
4. Use of SAGE to explore row transformations, linear transformations, Gram-Schmidt process, application of matrix diagonalization, matrix factorizations with applications to least square problems and image processing etc.
5. Use of SAGE to explore concepts in Group-Theory, Number-Theory and Combinatorics.

	References [1] Learning Python, Mark Lutz, Orielly Publication [2] A Premier on Scientific Programming with Python, Hand Peter langtangen, Springer [3] Numerical Methods in Engineering with Python, Jaan Kiusalaas, Cambridge [4] Calculus with Sage, Sang-Gu Lee, Ajit Kumar and other, Kyongmoon Publication [5] A First Course in Linear Algebra, Robert Beezer, a free online textbook available on http://linear.ups.edu/ [6] Linear Algebra with Sage, Sang-Gu Lee, Ajit Kumar and other, a free online available at http://matrix.skku.ac.kr/2015-Album/Big-Book-LinearAlgebra-Eng-2015.pdf [7] Numerical Analysis Using Sage, Anastassiou, George A., Mezei, Razvan, Springer [8] Richard Stanley, Enumerative Combinatorics, Vol 2, Cambridge, 2001.

MPr-701	To be assigned by the Supervisor
MPr-801	To be assigned by the Supervisor
MPr-901	To be assigned by the Supervisor
MPr-1001	To be assigned by the Supervisor

Elective courses offered by different disciplines

Chemistry	Mathematics	Physics
1. Experimental Biophysical Chemistry 2. Biochemistry and biophysical chemistry laboratory 2. Elective NMR Laboratory Course - Experimental NMR 3. Advanced NMR spectroscopy and its applications 4. Advanced bio-organic chemistry 5. Advanced theoretical chemistry 6. X-ray crystallography 7. Protein chemistry and conformational diseases 8. Medicinal chemistry and drug designing 9. Radioisotopes – production and applications 10. Chemical Applications of Group Theory 11. Environmental chemistry 13. Advanced topics in inorganic chemistry	1. Advanced Commutative Algebra & Applications 2. Advanced Differential Topology 3. Advanced Numerical Techniques. 4. Analytic Number Theory 5. Coding Theory & Cryptography. 6. Combinatorics / Combinatorics & Enumeration. 7. Financial Mathematics 8. Fractals & Applications 9. Advanced Graph Theory 10. Introduction to Ergodic Theory 11. Lie Groups & Geometry 12. Quantum Computing 13. Topics in Algebraic Geometry 14. Advanced Algebraic Topology & Applications 15. Advanced Complex Analysis 16. Advanced Differential Geometry & Applications 17. Algebraic curves 18. Class field theory 19. Combinatorial Design Theory 20. Econometrics 21. Elliptic curves 22. Finite Fields & Applications 23. Fluid Mechanics 24. Geometric algebra 25. Homological Algebra & Applications 26. Industrial Mathematics 27. Introduction to Algebraic Groups. 28. Mathematical Applications to Engineering 29. Mathematics & Nano 30. Technology. Modular forms. 31. Operator Theory. 32. Perturbation Theory 33. Wavelet Analysis & Applications. 34. Representation Theory of Finite Groups. 36. Stochastic Analysis.	1. Quantum Chemistry 2. Molecular Biology 2. Discrete Mathematics 3. Particle Physics 4. Quantum Mechanics III 5. Quantum Field Theory 6. Quantum computing and Information Theory 7. Plasma Physics 8. Quantum Optics 9. General Relativity and Cosmology 10. Non-equilibrium Statistical Mechanics 11. Dis-ordered Systems 12. Advanced Atomic Physics 13. Computational Electrodynamics 14. Nanoscience and Nanotechnology 15. Advanced Nuclear Physics 16. Accelerator Physics 17. Radiation Physics 18. Reactor Physics 19. Dynamical Systems and Nonequilibrium Statistical Mechanics 20. Postmodern Quantum Mechanics 21. Soft Condensed Matter 22. Statistical Field Theory 23. Many Body Theory 24. Biophysics 26. Few Body Systems