SRI SATHYA SAI INSTITUTE OF HIGHER LEARNING
(Deemed to be University)

Syllabus for
B.Sc. (Hons.) in Physics

(Applicable w.e.f. 2020-21)

SRI SATHYA SAI INSTITUTE OF HIGHER LEARNING
(Deemed to be University)

DEPARTMENT OF PHYSICS

Undergraduate Honours Programme Structure consists of Three Parts.

PART-I: LANGUAGES#

(a) General English   (four papers offered, one each in the first four semesters)
(b) Another Language (four papers offered, one each in the first four semesters – Any one out of: HINDI / SANSKRIT / TELUGU / ADDITIONAL ENGLISH)

PART-II: CORE SUBJECTS
(Offered in all the six semesters) – Titles of the papers are given below in the Scheme of Instruction & Evaluation and the syllabus contents are enclosed.

Part-II consists of three-subject-combination during the first four semesters, which, each student has to study. Three Subject combinations that are offered in the Honours Programme are Mathematics/Physics/Chemistry). In the third and fourth semesters; students will have to choose among the following elective streams.
Elective stream A: UMAT-301A: Real Analysis – I in the third semester followed by UMAT-401A: Real Analysis – II in the fourth semester.
<div align="center">OR</div>
Elective stream B: UMAT-301B: Mathematical Methods – I in the third semester followed by UMAT-401B: Mathematical Methods – II in the fourth semester.
The choice of the stream A or B will be made at the end of second semester; which will entitle the student to choose one of the three subjects (i.e., either MATHEMATICS or PHYSICS or CHEMISTRY), during the fifth and sixth semesters, as a subject of exclusive study as Honours
i.   Students opting for Stream A ONLY will be eligible for Mathematics as the exclusive study as Honours; during the fifth and sixth semesters.
ii.   Students opting for Stream B ONLY, will be eligible for Physics as the exclusive study of Honours; during the fifth and sixth semesters.
iii. Students opting for Chemistry as their exclusive study of Honours during the fifth and sixth semesters have the choice to either go through Elective stream A or Elective stream B. However, these students will also indicate the choice of Chemistry as their exclusive study of Honours at the end of the second semester itself.
(Regulation - 7: PART-II -CORE SUBJECTS of the B. Sc. (Hons.) MPC program may be referred for more details.)

PART-III: AWARENESS COURSE and ENVIRONMENTAL COURSE##

a) Awareness Courses – (UAWR) (six papers offered, one each in all the six semesters)
b) Environmental Courses – (UENT) (two papers offered, one each in the first two semesters)

NOTE: The title of the papers and the syllabus contents of Part-I and Part-III are provided separately.

SCHEME OF INSTRUCTION AND EVALUATION
B.Sc. (HONOURS) in PHYSICS
(Effective 2020/21 batch onwards)

PART-I: LANGUAGES

Paper Code	Title of the Paper	Credits	Hours	Mode of Evaluation	Theory / Practical	Maximum Marks
Semester I						
UGEN-101	General English-I #	5	5	IE1	T	100
	Another Language-I #	4	4	IE1	T	100
Semester II						
UGEN-201	General English-II #	5	5	IE1	T	100
	Another Language-II #	4	4	IE1	T	100
Semester III						
UGEN-301	General English-III #	5	5	IE1	T	100
	Another Language-III #	4	4	IE1	T	100
Semester IV						
UGEN-401	General English-IV #	5	5	IE1	T	100
	Another Language-IV #	4	4	IE1	T	100
	PART-I TOTAL	**36 credits**	**36 hours**			**800 marks**

PART-II: CORE SUBJECTS (Hons.in Physics)

Paper Code	Title of the Paper	Credits	Hours	Mode of Evaluation	Theory / Practical	Maximum Marks
Semester I						
UPHY-101	Electronics-I: Analog and Digital	3	3	IE1	T	100
UPHY-102	Electronics Laboratory –I	1	3	I	P	50
		4 credits	**6 hours**			**150 marks**
Semester II						
UPHY-201	Optics	3	3	IE1	T	100
UPHY-202	Optics Laboratory	1	3	I	P	50
		4 credits	**6 hours**			**150 marks**
Semester III						
UPHY-301	Classical Mechanics	4	4	IE1	T	100
UPHY-302	Mechanics Laboratory	1	3	I	P	50
		5 credits	**7 hours**			**150 marks**
Semester IV						
UPHY-401	Electromagnetism	4	4	IE1	T	100
UPHY-402	Electromagnetism Laboratory	1	3	I	P	50
		5 credits	**7 hours**			**150 marks**

Contd…

Paper Code	Title of the Paper	Credits	Hours	Mode of Evaluation	Theory / Practical	Maximum Marks
Semester V						
UPHY-501	Mathematical Physics	3	3	IE1	T	100
UPHY-502	Modern Physics	3	3	IE1	T	100
UPHY-503	Thermal Physics	3	3	IE1	T	100
UPHY-504	Electronics-II: Analog Systems and Applications	4	4	IE1	T	100
UPHY-505	Computational Techniques in Physics	3	3	IE1	T	100
UPHY-506	General Physics Laboratory-I	2	6	I	P	50
UPHY-507	Electronics Laboratory-II	2	6	I	P	50
UPHY-508	Python Programming Laboratory-I	2	4	I	P	50
		22 credits	**32 hours**			**650 marks**
Semester VI						
UPHY-601	Solid State Physics	4	4	IE1	T	100
UPHY-602	Nuclear Physics	3	3	IE1	T	100
UPHY-603	Quantum Mechanics	3	3	IE1	T	100
UPHY-604	Atomic and Molecular Spectroscopy	3	3	IE1	T	100
UPHY-605	Microprocessors	3	3	IE1	T	100
UPHY-606	General Physics Laboratory-II	2	6	I	P	50
UPHY-607	Microprocessors Laboratory	2	4	I	P	50
UPHY-608	Python Programming Laboratory-II	2	6	I	P	50
		22 credits	**32 hours**			**650 marks**
PART II TOTAL (Honours in Physics)		**62 credits**	**90 hours**			**1900 marks**

PART-II: CORE SUBJECT (Mathematics)

Paper Code	Title of the Paper	Credits	Hours	Mode of Evaluation	Theory / Practical	Maximum Marks
Semester I						
UMAT-101	Multivariable Calculus	4	4	IE1	T	100
UMAT-102	Foundations of Mathematics	2	2	IE1	T	50
		6 credits	**6 hours**			**150 marks**
Semester II						
UMAT-201A	Probability* (MPC and MCS groups) **OR**	3	3	IE1	T	100
UMAT-201B	Linear Programming** (MES group)	3	3	IE1	T	100
UMAT-202	Methods of Ordinary Differential Equations	3	3	IE1	T	100
		6 credits	**6 hours**			**200 marks**

Paper Code	Title of the Paper	Credits	Hours	Mode of Evaluation	Theory / Practical	Maximum Marks
Semester III						
UMAT-301A	Introduction to Real Analysis# **OR**	3	3	IE1	T	100
UMAT-301B	Mathematical Methods – I##	3	3	IE1	T	100
UMAT-302	Introduction to Linear Algebra	3	3	IE1	T	100
		6 credits	**6 hours**			**200 marks**
Semester IV						
UMAT-401A	Real Analysis# **OR**	3	3	IE1	T	100
UMAT-401B	Mathematical Methods – II##	3	3	IE1	T	100
UMAT-402	Algebraic Structures - I	3	3	IE1	T	100
		6 credits	**6 hours**			**200 marks**
	PART-II TOTAL (Mathematics)	**24 credits**	**24 hours**			**750 marks**

Notes: The Choice of Electives and Streams of Specialization offered shall be decided by the Head of the Department.

* UMAT- 201A is applicable for MPC and MCS group students only.

**UMAT-201B is applicable for MES group students only as a core paper.

UMAT-301A and UMAT-401A are elective papers applicable for students majoring in Mathematics or Chemistry.

UMAT-301B and UMAT-401B are elective papers applicable for students majoring in Physics or Chemistry.

PART-II: CORE SUBJECT (Chemistry)

Paper Code	Title of the Paper	Credits	Hours	Mode of Evaluation	Theory / Practical	Maximum Marks
Semester I						
UCHM-101	Principles of Structure and Bonding	3	3	IE1	T	100
UCHM-102	Laboratory Course in General Chemistry	1	3	I	P	50
		4 credits	**6 hours**			**150 marks**
Semester II						
UCHM-201	Chemical Thermodynamics	3	3	IE1	T	100
UCHM-202	Laboratory Course on Titrimetry and Thermodynamics	1	3	I	P	50
		4 credits	**6 hours**			**150 marks**
Semester III						
UCHM-301	Chemical Kinetics and Equilibria	4	4	IE1	T	100
UCHM-302	Laboratory course on Chemical Kinetics and Equilibria	1	3	I	P	50
		5 credits	**7 hours**			**150 marks**

Contd…

Paper Code	Title of the Paper	Credits	Hours	Mode of Evaluation	Theory / Practical	Maximum Marks
Semester IV						
UCHM-401	Chemistry of Organic Functional Groups	4	4	IE1	T	100
UCHM-402	Laboratory Course on Methods and Synthesis in Organic Chemistry	1	3	I	P	50
		5 credits	7 hours			150 marks
	PART-II TOTAL (Chemistry)	**18 credits**	**26 hours**			**600 marks**

PART-III: AWARENESS and ENVIRONMENTAL COURSES

Paper Code	Title of the Paper	Credits	Hours	Mode of Evaluation	Theory / Practical	Maximum Marks
Semester I						
UAWR-100	Awareness Course-1: Sai Education for Transformation (Based on Life and Teachings of Bhagawan Baba)	2	2	I	T	50
UENT-101	Environment-I ##	2	2	I	T	75
Semester II						
UAWR-200	Awareness Course-2: Unity of Religions	2	2	I	T	50
UENT-201	Environment-II ##	2	2	I	T	75
Semester III						
UAWR-300	Awareness Course-3: Study of Classics-I: Ramakatha Rasavahini	2	2	I	T	50

Paper Code	Title of the Paper	Credits	Hours	Mode of Evaluation	Theory / Practical	Maximum Marks
Semester IV						
UAWR-400	Awareness Course-4: Study of Classics-II: Bhagawatha Vahini	2	2	I	T	50
Semester V						
UAWR-500	Awareness Course-5: Eternal Values for the changing world	2	2	I	T	50
Semester VI						
UAWR-600	Awareness Course-6: Life and its Quest	2	2	I	T	50
	PART-III TOTAL	**16 credits**	**16 hours**			**450 marks**

Modes of Evaluation

Indicator	Legend
IE1	CIE and ESE ; ESE single evaluation
IE2	CIE and ESE ; ESE double evaluation
I	Continuous Internal Evaluation (**CIE**) only Note: 'I' does not connote 'Internal Examiner'
E	End Semester Examination (**ESE**) only Note: 'E' does not connote 'External Examiner'
E1	ESE single evaluation
E2	ESE double evaluation

Types of Papers

Indicator	Legend
T	Theory
P	Practical
V	Viva voce
PW	Project Work
D	Dissertation

Continuous Internal Evaluation (CIE) & End Semester Examination (ESE)

PS: Please refer to guidelines for 'Modes of Evaluation for various types of papers', and Viva voce nomenclature & scope and constitution of the Viva-voce Boards.

SUMMARY

	Credits	Hours	Maximum Marks
PART-I: LANGUAGES			
PART-I TOTAL	**36** credits	**36** hours	**800** marks
PART-II: CORE SUBJECTS			
PART-II TOTAL (Honours in Physics)	**62** credits	**90** hours	**1900** marks
PART-II TOTAL (Mathematics)	**24** credits	**24** hours	**750** marks
PART-II TOTAL (Chemistry)	**18** credits	**26** hours	**600** marks
PART-III: AWARENESS and ENVIRONMENTAL COURSES			
PART-III TOTAL	**16** credits	**16** hours	**450** marks
GRAND TOTAL (B.Sc.(Hons.) in Physics)	**156** credits	**192** hours	**4500** marks

UPHY-101   ELECTRONICS-I: ANALOG AND DIGITAL   3 Credits

Course objectives:

The objectives of this course are to:
- introduce diodes and transistors, their working and applications
- introduce the world of digital electronics, use of basic logic gates, flip flops, registers and counters
- provide the necessary background for UPHY-504 (Electronics-II) and UPHY-605 (Microprocessors) courses in the final year of the Physics programme.

Learning outcomes:

At the end of the course, the student must be able to:
- state and apply Thevenin's and Norton's theorems
- understand the role of diodes in rectifier, wave shaping, voltage multiplier and voltage regulation circuits
- explain how the transistor works
- interconvert numbers between different number systems, identify logic gates, apply Boolean algebra theorems to arithmetic and logic circuits, flip-flops, registers, and counters

Course content:

1. **Introduction**:
   Voltage and current sources; superposition theorem;   *1 unit*
   Thevenin's and Norton's theorems; power transfer theorem   *2 units*

2. **Diode Theory:** Intrinsic and extrinsic semiconductors; pn junction diode; 3 approximations of a diode; biasing and its effects; V-I characteristics of a junction diode, specifications of a diode: Data sheet of a rectifier diode   *2 units*
   Rectifiers: Half wave rectifier, full wave rectifier, bridge rectifier. Calculation of ripple factor and efficiency   *3 units*
   Choke input filter and capacitor input filter, LC and RC filters, power supply   *2 units*
   Types of diodes and their applications: power, signal, Zener, Schottky, Varactors, LED, 7-segment displays and photodiodes   *1 unit*
   Clippers, negative and positive clampers; voltage multipliers   *2 units*
   Zener diode as a constant voltage source & as a voltage regulator   *2 units*

3. **Bipolar Junction Transistors (BJTs)**:
   Basic construction and working of a bipolar junction transistor; I_E, I_C, & I_B and their relationship in terms of current gains α and β; transistor specifications: Data sheet of small signal transistors   *1 unit*
   Collector curves, base curves and gain curves for a BJT. Load line analysis of transistors: DC load line and Q point   *2 units*

Biasing and different types of biasing; Base bias, emitter bias, collector feedback bias;
two supply emitter bias; voltage divider bias (designing included)   *3 units*
Transistor as a switch and as a current source   *2 units*
Coupling capacitor, bypass capacitor, Introduction to base biased amplifier   *1 unit*

4. **Digital Concepts:**
    Digital vs. analog signal; characteristics of digital signal; advantage of digital over analog;
    number systems: decimal, binary, hexadecimal and BCD; conversion from one to the other
                                                                                      1 unit

5. **Logic Gates**:
    Basic gates: NOT, OR, AND gates; combination logic, NOR, NAND, XNOR and XOR;
    symbol, truth tables and Boolean expressions and timing diagrams   *2 units*
    Universal property of NAND and NOR   *1 unit*
    Application of gates: binary controlled switch; word comparator; encoders; decoders;
    controlled inverters   *2 units*

6. **Boolean algebra and Karnaugh Maps:**
    Boolean relations; De Morgan's theorems; sum of products method; Karnaugh maps up to
    four inputs including don't care conditions   *3 units*

7. **Arithmetic logic units**:
    Binary addition and subtraction; Half adder, full adder and binary adders; Signed   binary
    numbers; 2's complement representation; 2's complement adder-subtractor;   *2 units*

8. **Latches and Flip Flops**:
    SR latch; D latch; clocked latches; basic types of flip flops based on triggering – JK flip flop,
    D flip flop and Master Slave flip flop.   *4 units*
    Registers and Counters: Buffer registers; shift registers; control shift registers; ripple
    counters; mod-10 counter; synchronous and ring counters.   *3 units*

KEYED TEXTS:

1. Malvino, A.P., Bates D., **Electronic principles**, VIII Edition, McGraw Hill Education,
    (2007)

2. Malvino, A.P., Brown J., **Digital computer electronics**, III Edition, McGraw Hill
    Education, (2017).

REFERENCES:

1. Floyd T. L., **Electronic Devices**, IX Edition, Pearson Education, (2015)

2. Floyd T. L., **Digital Fundamentals**, IX Edition, Pearson Education, (2017)

3. Khalsi H. S., **Electronic Instrumentation,** IV Edition, McGraw Hill Education, (2019)

UPHY-102   ELECTRONICS LABORATORY-I   1 Credit

Course objective:

The objectives of this laboratory course are to:
- provide hands-on experience to construct circuits using junction diodes, zener diodes, rectifiers and transistors and to use measuring instruments, such as, multimeter and CRO for analysis.
- introduce to the students the world of digital electronics starting with the basic logic gates and associated theorems

Learning outcomes:

Upon completion of this laboratory course, the student must be able to:
- design and construct circuits using electronic devices and components, take measurements to study relevant parameters and compare experimental results with theoretical analysis.
- verify the truth tables of logic gates experimentally and apply Boolean algebra theorems to simplify digital circuits.

Lab course content:

Familiarization: Components and equipment familiarization -
Power supply, multimeter, function generator, oscilloscope and digital trainer
Other relevant instruments' usage may be introduced as and when required.

1. Study of a potential divider circuit: Potential divider, current divider, Kirchhoff Voltage rule, Kirchhoff Current rule, and loading effect of a voltmeter

2. Verification of circuit theorems:
   a. Thevenin's theorem
   b. Norton's theorem.
   c. Maximum power transfer theorem.

3. Diode characteristics: Voltage vs. current plot

4. Zener diode: a) V-I characteristics b) as a voltage regulator (Load regulation)

5. Study of half wave, full wave and bridge rectifier without filters.

6. Study of half wave, full wave and bridge rectifier with capacitor input filter

UPHY-101   Contd….

7. Transistor: a) Testing using a multimeter   b) Characteristics (collector curves)

8. Truth tables of logic gates: a) Verification   b) Universality of NAND/NOR gates.

9. Half-adder and Full adder: Fabrication using logic gates

10. Study of Flip-Flops: NAND /NOR latch, Clocked RS NAND latch, D-flipflop using
     NAND /NOR gates on a digital trainer

Extra: Soldering skills

Note: Students should do a minimum of 8 experiments

∗ ∗ ∗

UPHY-201   OPTICS   3 Credits

Course objectives:

The objectives of this course are to:
- give students an in-depth look at geometrical and physical optics phenomena
- expose them to the various historical theories of light and its propagation - rectilinear propagation, reflection, refraction, culminating in Fresnel's equations derived from the electromagnetic wave approach
- provide a deeper knowledge of basic concepts and applications of phenomena like interference, diffraction and polarization and their related optical techniques

Learning outcomes:

Upon completion of this course, the student must be able to:
- describe basic optical phenomena and comment on basic concepts and principles of geometrical and physical optics.
- discuss the nature of light, its propagation and interaction with matter.
- understand ray-based optical system analysis and design, and operation of simple optical instruments.
- model a complex optical system using paraxial ray tracing.
- use the electromagnetic wave approach to explain the phenomena caused by the wave nature of light such as polarization, interference and diffraction, and their applications.
- explain fundamental limits in imaging and resolution of optical system due to diffraction and aberrations.

Course content:

I   Geometrical Optics:

1. **Introduction:**
   Electromagnetic spectrum, visible spectrum; Distinction between geometrical and physical optics   *1 unit*

2. **Laws of reflection and refraction**:
   Huygen's principle; Fermat's principle; principle of reversibility   *1 unit*
   Derivation of Fresnel's equations for TE and TM modes   *2 units*
   External and Internal reflections; Phase changes on reflection   *1 unit*

3. **Matrix methods in paraxial optics**:
   Translation, refraction and reflection matrices   *2 units*
   Thick and thin lens matrices; system matrix; cardinal points and examples   *3 units*

4. **Aberrations:**
   Concept of chromatic aberration; Removal using achromatic doublet and separated doublet   *2 units*

UPHY-201   Contd….

Overview of monochromatic/Seidel aberrations: Spherical aberration, Coma, Astigmatism, Distortion and Curvature of field   *1 unit*

5. **Optical Instruments:**

Principles of Optical Instruments: Spectrometer, Eyepieces: Huygens and Ramsden, Microscopes and Telescopes   *2 units*

II   Physical Optics

6. **Interference**:

Coherence: temporal and spatial; Relation between spectral bandwidth of light source and coherence time   *2 units*
Two beam interference; Young's double slit; interference in dielectric films; fringes of equal thickness   *3 units*
Newton's rings; film thickness measurement   *2 units*
Michelson interferometer and applications; Stokes relations   *3 units*

7. **Diffraction**:

Fresnel versus Fraunhofer diffraction; Fraunhofer diffraction from a single slit   *2 units*
Beam spreading; rectangular and circular apertures   *1 units*
Rayleigh's criterion of resolution; double slit   *2 units*
Multiple slits; Diffraction grating   *2 units*
Free spectral range, Resolution and Dispersion   *1 unit*

8. **Polarization**:

Distinction between polarized and unpolarized light; Jones vector representation of polarized light: plane polarized, circularly polarized and elliptically polarized light   *3 units*
Jones matrix representation of polarizers, phase retarders and rotator   *1 unit*
Production of polarized light:
Dichroism; Birefringence: Quarter wave plate and half wave plate   *2 units*
Double refraction: Nicol prism, Glan-air prism and Wollaston prism.   *2 units*
Reflection from dielectric surfaces- Brewster's law; Optical activity   *1 unit*

KEYED TEXTS:

1. Pedrotti, F. L. and Pedrotti, L. S., **Introduction to Optics**, III Edition, Pearson Publication, (2006).

REFERENCES:

1. Hecht, E. **Optics**, Pearson Education, (2003).

2. Meyer-Arendt, J. R., **Introduction to Classical and Modern Optics**, IV Edition, Prentice-Hall, (1994).

3. Ghatak, A., **Optics**, V Edition, Tata-McGraw-Hill, (2012).

UPHY-202   OPTICS LABORATORY   1 Credit

Course objectives:

The objectives of this laboratory course are to:
- give students an in-depth understanding of basic concepts of geometrical and physical optics through experiment
- give a hands-on experience to study different optical phenomena by performing experiments

Learning outcomes:

Upon completion of this laboratory course, the student must be able to:
- handle optical elements and perform experiments to study various optical phenomena and determine optical properties like wavelength, refractive index, etc.

Lab course content:

Familiarization of optical instruments: Construction of spectrometer, telescope, travelling microscope, eyepieces

A) Spectrometer based experiments
1) Refracting angle of the prism and Refractive Index of water using hollow prism
2) Dispersive power of a prism
3) Determination of refractive index using i-d curve.

B) Geometrical optics:
4) Focal length of lenses in combination using nodal slide assembly and verification using ABCD matrices
5) Cardinal points of an optical system
6) Determination of the focal length and refractive index of a concave lens using combination method.

C) Interference experiments
7) Young's double slit experiment
8) Fresnel Biprism experiment: to determine the wavelength of Na-vapour/ biprism angle
9) Newton's rings experiment - to determine wavelength of given monochromatic source
10) To determine the thickness of insulation of a thin wire using air wedge set up

D) Diffraction experiments
11) Single slit diffraction – determination of wavelength
12) Resolving Power of the telescope

UPHY-202   Contd….

13) Determination of wavelength of given source using diffraction grating by minimum deviation method

14) Resolving power and dispersive power of a plane transmission grating

E) Polarization

15) Study of double refraction using spectrometer

16) Verification of Brewster's law

17) Verification of Malus' law

Note: Note: Students should do a minimum of 8 experiments covering all the above categories

* * *

UPHY-301   CLASSICAL MECHANICS   4 Credits

Course objectives:

The objectives of this course are to:

- provide an in-depth understanding of the principles of Newtonian mechanics and apply them to solve problems involving the dynamic motion of classical mechanical systems
- give a fundamental knowledge of fluids, their properties and behaviour under various conditions of internal and external flows.

Learning outcomes:

Upon completion of the course, student must be able to:

- apply Newton's laws of motion to different force fields for a single particle and for a system of particles
- set-up and solve differential equations to study the a) motion of a particle in a central force field, b) oscillatory motion and c) vibrations in a string and interpret the solutions obtained
- apply the concept of conservation of energy and linear momentum to solve problems involving collisions with respect to both laboratory frame of reference and center of mass frame
- apply the basic equation of fluid statics to determine forces on planar and curved surfaces
- design simple pipe systems to deliver fluids under specified conditions

Course content:

1. **Newton's Laws, Equations of motion and their Solutions for a Single Particle:**
   Newton's laws of motion and frame of reference, relative velocity;   *1 unit*
   Applications of Newton's laws to the motion of a single particle – Concepts of kinetic energy and potential energy, conservative force and Work-Energy theorem;   *2 units*
   Equations of Motion and their solutions for motion under - constant force (Atwood's machine), force depending only on time (sinusoidal force), resistive force depending on velocity, free-fall of an object under gravity with air-resistance – terminal velocity, projectile motion without air-resistance and with air-resistance – range and time-of-flight of projectile.
        4 units

2. **Mechanics of system of particles:**
   Centre of mass- definition and calculations, linear momentum of the system, angular momentum of the system, energy of the system (no derivation) `   *2 units*
   Motion of system with variable mass – rocket motion in free space, vertical ascent under gravity   *2 units*

3. **Dynamics of Rigid Body:**
   Description of rigid body; concept of degrees of freedom   *1 unit*

Center of mass of a rigid body and its determination for symmetric objects (hemi-spherical shell, solid hemi-sphere, solid cone, L and arc shaped objects)   *3 units*

Rotation about an axis; Parallel and perpendicular axis theorems, calculation of moment of inertia for regular bodies (thin rod, circular ring, circular disk, rectangular plate, solid sphere)
                                                                                    3 units

4.   Motion in a central force field:
Equivalent one body problem; motion in central force field: general features of the motion, equations of motion   3 *units*
orbits in a central field, centrifugal energy and the effective potential   3 *units*
motion in an inverse square law field; equation of orbit; Kepler's laws   3 *units*

5.   Oscillations:
Simple harmonic oscillator-simple pendulum, physical pendulum, bar pendulum and torsional pendulum, spring mass system;   6 *units*
damped harmonic oscillator; forced oscillations; coupled oscillations   6 *units*

6.   Fluids in Motion:
Kinematics of fluids: Eulerian system, Euler's equation, Continuity equation, Equation of motion for an ideal fluid flow, Bernoulli's equation   6 *units*
Viscosity and Viscous flow: Newtonian flow, Laminar flow in a cylindrical pipe, Poiseuille's law   3 *units*
Laminar (stream line) and Turbulent motions, Reynolds number   2 *units*

7.   Collisions of particles:
Elastic and inelastic scattering; elastic scattering in laboratory and center of mass systems
                                                                                    3 *units*
Kinematics of elastic scattering in laboratory system   3 *units*

KEYED TEXTS:

1.   Takwale, R.G., and Puranik, P.S., **Introduction to Classical Mechanics**, I Edition, McGraw Hill Education, (2017).

2.   Arya, P. A., **Introduction to Classical Mechanics**, II Edition, Pearson, (1997).

REFERENCES:

1.   Spiegel, M. R., **Theory & Problems of Theoretical Mechanics (Schaum's Outline Series) (SI Units)**, McGraw Hill Education, (2017).

2.   Marion, J. B. and Thornton, S. T.: **Classical Dynamics of Particles and Systems**, V Edition, Cengage, (2012).

UPHY-301   Contd….

3. Kittel C., Knight D. W., Ruderman A. M., Helmholz A. C., Moyer J. B., **Mechanics, Vol. 1**, Berkeley Physics Course, II Edition, McGraw Hill Education, (2017).

4. Goldstein H, Poole C, and Safko J, **Classical Mechanics**, III Edition, Pearson Education, (2002).

5. MIT lectures - https://ocw.mit.edu/courses/physics/

* * *

UPHY-302   MECHANICS LABORATORY   1 Credit

Course objective:

The objective of this laboratory course is to:
- provide hands-on experience to perform experiments to study some concepts in mechanics and properties of matter.

Learning outcomes:

Upon completion of the course, student must be able to:
- use required instruments with skill, and perform experiments to study the mechanical properties of solids and liquids, vibrations in strings, oscillations in a system, analyze experimental data and interpret graphs

Lab course content:

1. Young's modulus using uniform bending and/or non-uniform bending

2. Rigidity Modulus using torsional pendulum

3. Moment of Inertia of a fly-wheel

4. Acceleration due to gravity using bar pendulum

5. Study of standing waves using Melde's apparatus

6. **Scilab simulations**
   a. Superposition of waves- interference and beats
   b. Generation of a square wave
   c. Projectile motion

7. **Tracker based experiments**
   a. mass–spring system
   b. Simple pendulum
   c. Double pendulum

8. **Coefficient of viscosity**
   a. Stokes method
   b. Poiseuille's method

9. Set of experiments using Linear air track system

Note: Students should do a minimum of 8 experiments.

* * *

UMAT-301B   MATHEMATICAL METHODS-I   3 Credits

Course objectives:

The objective of this course is to:
- to acquaint the student with a range of mathematical methods that are important prerequisites for physics courses

Learning outcomes:

On completion of this course, the student must be able to:
- perform vector operations such as div, curl, grad and Laplacian and vector integration in the Cartesian Coordinate system, and understand their physical significance.
- use Laplace transforms to solve definite integrals and differential equations
- understand the significance and properties of Fourier series and Fourier transforms and find the Fourier transform of simple functions
- define and derive the properties of the Dirac Delta function and appreciate its application to particular physical situations
- solve partial differential equations of first order and second order that are common in physics.

Course content:

1. **Vector Analysis:**
   Vector algebra, Differential calculus: gradient, divergence, curl, Laplacian, product rules, second derivatives;   *5 units*
   Integral calculus in Cartesian coordinate system: Line, surface and volume integrals, Divergence theorem, Stokes' theorem   *3 units*

2. **Fourier Series and Fourier Transform:**
   Fourier series, arbitrary period, even and odd functions, half-range expansions, forced oscillations   *7 units*
   Fourier integral, Fourier cosine and sine transforms, Fourier transform   *6 units*

3. **Partial Differential Equations**
   Basic concepts of PDEs, Modeling: vibrating string, wave equation   *3 units*
   Solution by separating variables, use of Fourier series   *3 units*
   Modeling: heat flow from a body in space. Heat equation   *2 units*
   Heat equation: solution by Fourier series, steady two-dimensional heat problems, Dirichlet problem   *3 units*
   Modeling: membrane, two-dimensional wave equation   *1 unit*

4. **Laplace Transform:**
   Laplace transform, shifting property, transforms of derivatives and integrals; Convolution theorem;   *3 units*

Application to solving integrals and initial value problems   *3 units*

5. **Dirac Delta Function:**
   Strongly peaked functions and the Dirac delta function; Delta sequences-representations of the delta function (examples only)   *1 unit*
   Delta Calculus; Properties of the Delta function   *2 units*

KEYED TEXTS:

1. Kreyszig, E., **Advanced Engineering Mathematics**, IX Edition, Wiley Eastern, (2011).

2. Boas, M.L.: **Mathematical Methods in the Physical Sciences**, II Edition. John Wiley, (1992).

3. Arfken, G.B., and Weber, H.J.: **Mathematical Methods for Physicists**, VII Edition. Academic Press/Prism Books (2012).

REFERENCES:

1. Butkov, E, **Mathematical Physics**, 1st Edition, Addison Wesley (1968).

2. Ghatak A. K., Goyal I. C., Chua S. J., **Mathematical Physics: Differential Equations and Transform Theory**, Macmillan India, (1995).

3. Riley K. F, Hobson M. P., Bence S. J., **Mathematical Methods for Physics and Engineering**, Cambridge Low-price Edition, Cambridge Univ. Press (1999).

UPHY-401　　　　ELECTROMAGNETISM　　　　4 Credits

Course objective:

The objective of this course is to:
- provide a deeper understanding of electrostatics and magnetostatics leading to the fundamental laws of electrodynamics – Maxwell's equations in free space and their consequences

Learning outcomes:

Upon completion of this course, student must be able to:
- find expressions for the electric and magnetic fields produced by static and moving charges in a variety of configurations.
- comprehend the dynamics of a charged particle in electric, magnetic and electromagnetic fields and its applications
- formulate Maxwell's equations leading to electromagnetic wave equation and understand its propagation and energy transport

Course content:

1. **Electrostatics-I**:
   The electric field: Coulombs law; continuous charge distribution　　　　*3 units*
   Divergence and curl of electrostatic fields: field lines, flux and Gauss law　　　*1 unit*
   Divergence of E; Application of Gauss's law: spherical, cylindrical and plane symmetries; curl of E　　　　*2 units*
   Electric potential, Poisson's equation and Laplace's equation; the potential of a localized charge distribution　　　　*3 units*
   Potential at a distance along the axis perpendicular
   a) to the center of two point charges of opposite charge a distance d apart,
   b) passing through the center of uniform line charge
   c) to the uniform surface charge and passing through its center.　　　　*3 units*

2. **Electrostatics-II:**
   Work and energy in Electrostatics: work done to move a charge; energy of a point charge distribution; energy of a continuous charge distribution　　　　*3 units*
   Conductors: basic properties; induced charges; surface charge and force on a conductor; Capacitors　　　　*2 units*

3. **Dipoles:**
   Field and potential due to a dipole; torque on a dipole in an external electric field; mutual potential energy of dipoles　　　　*3 units*

UPHY-401　　　Contd….

4. **Electric Fields in Matter:**

Polarization: dielectrics; induced dipoles; alignment of polar molecules	*1 unit*
Field of a polarized object: bound charges; field inside a dielectric	*1 unit*
The Electric displacement: Gauss's Law in presence of dielectric	*1 unit*
Linear dielectrics: susceptibility, permittivity, dielectric constant;	*3 units*

5. **Magnetostatics-I:**

The Lorentz force law: magnetic fields; magnetic forces; currents	*1 unit*
BiotSavart's law and applications to find **B** due to infinitely long straight wire and circular loop	*2 units*
Steady currents; magnetic field of a steady current; Divergence and curl of B straight line currents	*1 unit*

6. **Magnetostatics-II:**

Ampere's law- B due to infinitely long wire, infinite uniform surface, B due to solenoid and toroid.	*4 units*
Magnetic vector potential	*2 units*
Motion of charged particle in electromagnetic field: motion in a constant electric field, a uniform magnetic field B, motion in crossed fields;	*3 units*
The Hall effect	*1 unit*

7. **Magnetic Fields in Matter**:

Magnetization: diamagnetism, paramagnetism, ferromagnetism.	*2 units*
Torque and forces on the magnetic dipoles; effect of a magnetic field on atomic orbits	*2 units*
Magnetization and Hysteresis of ferromagnetic materials	*2 units*

8. **Electrodynamics:**

Electromotive force: motional emf; Electromagnetic induction: Faraday's laws; induced electric field	*2 units*
Self-inductance & mutual inductance; energy in magnetic field	*2 units*
Maxwell's equations: electrodynamics before Maxwell; Maxwell- Ampere's law; Maxwell's equations; Poynting's theorem	*3 units*

9. **Electromagnetic Waves:**

Electromagnetic Waves in vacuum: wave equation for E and B monochromatic plane waves; energy and momentum in EM waves	*3 units*

UPHY-401   Contd….

KEYED TEXTS:

1. Griffiths, D. J: **Introduction to Electrodynamics**, IV Edition, Pearson Education Limited, (2018)

2. Mahajan, A S, Rangwala, A. A, **Electricity and Magnetism**, I Edition, McGraw Hill Education, (2004)

3. Brophy, J. J, **Basic Electronics for Scientists**, V Edition, McGraw Hill Education, (1990)

REFERENCES:

1. Jordan, E. C., and Balmain, K. G.: **Electromagnetic Waves and Radiating Systems**, II Edition, Pearson India (2015)

2. Halliday, D. and Resnick, R. Krane K S: **Physics (Part 2)**, V Edition, Wiley Eastern, (2007)

3. Halliday, D. and Resnick, R.: **Fundamentals of Physics**, X Edition, John Wiley & Sons, (2013)

4. Grob B: **Basic Electronics**, XI Edition, Tata McGraw Hill, (2010)

* * *

UPHY-402   ELECTROMAGNETISM LABORATORY   1 Credit

Course objective:

The objective of this laboratory course is to:
- develop competence in using laboratory instruments to carry out experiments to study different electromagnetic phenomena, that will enhance and reinforce the student's class room learning.

Learning outcome:

Upon completion of this course, the student must be able to:
- set up and perform basic experiments to investigate the behaviour of electric and magnetic fields for different configurations,
- determine capacitance and inductance and study the effect of these components on the behaviour of different circuits.

List of Experiments:

1. Study of RC circuits:
   a) Transient response: Study of rise and decay of current
   b) Steady state response: Integrator, Differentiator, High pass and low pass filters

2. Study of LR circuits:
   a) Investigation of Inductance
   b) Study of rise and decay of current

3. To study the response curve of a Series LCR circuit and determine its
   a) Resonant Frequency,
   b) Impedance at Resonance
   c) Quality Factor Q
   d) Band Width.

4. Measurement of dielectric constant of a liquid.

5. Study of Hall Effect and determination of Hall Coefficient of a semiconductor

6. Determination of e/m of an electron by Thomson's method.

7. Study of the variation of the magnetic field along the axis of a current carrying coil.

   (Stewart and Gees galvanometer/ Helmholtz double coil)

8. Study of the variation of the magnetic field along the axis of a solenoid and determination of the permeability constant μ_0.

UPHY-402   Contd….

9. Determination of inductance, L, using Faraday's law

10. Study of B-H curves of a ferromagnetic material.

11. Determination of the Curie temperature of ferromagnetic materials

Note: Students should do a minimum of 8 experiments

* * *

UMAT-401B   MATHEMATICAL METHODS-II   3 Credits

Course objectives:

The objective of this course is to:
- to acquaint the student with a range of mathematical methods that are important prerequisites for physics courses

Learning outcomes:

On completion of this course, the student must be able to:
- switch between various orthogonal coordinate systems while solving problems of physics.
- understand the fundamental concepts of series, their convergence tests and the importance of Power Series and Taylor's expansion
- perform basic error analysis techniques
- employ appropriate methods to fit data to polynomials of desired order
- solve ordinary differential equations of first order and second order that are common in physics.

Course content:

1. **Curvilinear Coordinates**:
   Orthogonal curvilinear coordinate systems; Transformation of coordinates;   *2 units*
   Unit vectors in curvilinear system; arc length, area and volume elements;   *2 units*
   Gradient, divergence, curl and Laplacian in orthogonal coordinate systems   *4 units*
   Separation of Diffusion, Schrodinger, Laplace and Helmholtz equations in Spherical polar
   and Cylindrical polar coordinates   *3 units*

2. **Series**
   Fundamental concepts, convergence tests, alternating series   *4 units*
   Algebra of series, series of functions, Taylor's expansion, power series   *5 units*

3. **Error Analysis***:*
   Significant figures; Accuracy and precision; Error definition; Round off errors and
   truncation errors; Taylor series   *5 units*

4. **Ordinary Differential equations – Applications to the sciences:**
   Examples of First Order Differential Equations and their solutions   *2 units*
   General form of second order differential equations; Ordinary and singular points;   *2 units*
   Series solution around an ordinary point – Power Series method; Series solution around a
   regular singular point - Frobenius Method;   *4 units*
   Getting a second solution   *2 units*

5. **Least Square Regression:**
   Linear Regression – Best fit line, Co-efficient of determination and Correlation co-efficient;
   Linearization of Non-linear Relationships   *5 units*
   Extension to Polynomial Regression – Quadratic Regression   *2 units*

UMAT-401B   Contd…

KEYED TEXTS:

1. Spiegel, M. R., **Theory and Problems of Vector Analysis**, McGraw Hill, (1974).

2. Boas, M.L.: **Mathematical Methods in the Physical Sciences**, II Edition. John Wiley, (1992).

3. Arfken, G.B., and Weber, H.J.: **Mathematical Methods for Physicists**, VII Edition. Academic Press/Prism Books (2012).

4. Chapra S. C. and Canale R. P., **Numerical Methods for Engineers**; VII Edition, Tata McGraw Hill, (2016)

REFERENCES:

1. Riley K. F, Hobson M. P., Bence S. J., **Mathematical Methods for Physics and Engineering**, Cambridge Low-price Edition, Cambridge Univ. Press (1999).

UPHY-501　　　MATHEMATICAL PHYSICS　　　3 Credits

Course objectives:

The objective of this course is to:
- highlight the application of mathematical methods in physics by:
  i. giving a good mathematical background required for quantum mechanics through the study of special functions
  ii. acquainting the student with a range of mathematical methods that are important prerequisites for physics courses

Learning outcomes:

On completion of this course, student must be able to:
- solve mathematical problems in physics by a variety of mathematical techniques
- describe special functions and their properties
- generate orthogonal polynomials in any domain
- solve problems involving complex numbers
- apply theorems of complex analysis to solve some complicated real integrals
- find eigenvalues and eigenvectors of matrices and apply the concept to physical systems

Course content:

1. **Special Functions**
   Differential equation, Series solution, Generating function, Recurrence relations, Rodrigues' formula and Orthonormality relation of:
(a) Legendre polynomials	*3 units*
(b) Associated Legendre functions	*3 units*
(c) Laguerre polynomials (d) Associated Laguerre polynomials and	*3 units*
(e) Hermite polynomials	*2 units*

   Generation of Legendre polynomials through Gram-Schmidt orthonormalization process
   　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　3 units

2. **Complex Analysis**
Complex Numbers*:* Curves and regions in complex plane; limit, derivative, analytic function	*2 units*
Cauchy-Riemann equations; Laplace equation	*2 units*
Functions of complex variables	*2 units*
Complex Integrals*:* Line integral and properties; Cauchy's integral theorem	*2 units*
Indefinite integration; Cauchy's integral formula	*2 units*
Derivatives of analytic function	*1 unit*
Series*:* Power series; Taylor series; methods for power series	*2 units*
Laurent series; zeroes and singularities	*3 units*
Residues: Residue theorem and application to the evaluation of integrals	*4 units*

3. **Matrices, Eigenvalue problems and Diagonalization:**
    Types of matrices and their properties: Symmetric, Skew-symmetric, orthogonal, Hermitian, skew-Hermitian and unitary   *2 units*
    Eigen-value problems: determination of eigenvalues and eigenvectors of matrices   *1 unit*
    Theorems associated with eigenvalues and eigenvectors   *2 units*
    Quadratic, Hermitian and skew Hermitian forms   *1 unit*
    Diagonalization and applications   *2 units*

KEYED TEXTS:

1. Chattopadyay, P.K.: **Mathematical Physics**, III Edition, Wiley Eastern, (2008).

2. Kreyszig, E., **Advanced Engineering Mathematics**, IX Edition, Wiley Eastern, (2011).

3. Boas, M.L.: **Mathematical Methods in the Physical Sciences**, II Edition. John Wiley, (1992).

4. Arfken, G.B., and Weber, H.J.: **Mathematical Methods for Physicists**, VII Edition. Academic Press/Prism Books (2012).

REFERENCES:

1. Ghatak A. K., Goyal I. C., Chua S. J., **Mathematical Physics: Differential Equations and Transform Theory**, Macmillan India, (1995).

2. Riley K. F, Hobson M. P., Bence S. J., **Mathematical Methods for Physics and Engineering**, Cambridge Low-price Edition, Cambridge Univ. Press (1999).

3. Gupta, B.D., **Mathematical Physics**, III Edition, Vikas Publishing House (2004).

4. Butkov, E, **Mathematical Physics**, Addison Wesley (1968)

* * *

UPHY-502   MODERN PHYSICS   3 Credits

Course objectives:

The objectives of this course are to:
- impress the limitations of Newtonian mechanics for motion at very high velocities, and thus introduce the special theory of relativity
- explore the concepts and experiments that led to the development of quantum theory
- introduce the underlying foundations and basic principles of quantum mechanics
- acquaint the fundamentals of lasers, their unique properties and explore the techniques used in different laser designs

Learning outcomes:

On completion of the course, the student should be able to:
- appreciate the study of special theory of relativity and understand its consequences- length contraction, time dilation, simultaneity of events, mass variation, equivalence of mass and energy, connection between space and time
- appreciate the need to study quantum mechanics by accepting the limitations of classical physics through experimental evidences and understand quantum theory of radiation and matter
- understand the dual nature of matter
- discuss the principles involved in lasing action, describe the requirements of a laser system and the properties of laser radiation

Course content:

1. **Special theory of relativity**:
   Newtonian relativity; Michelson Morley experiment   *2 units*
   Postulates of special theory of relativity; Lorentz transformations and consequences: time dilation, length contraction and simultaneity of events.   *4 units*
   Doppler effect – expanding universe   *1 unit*
   addition of velocities; variation of mass with velocity; mass-energy relation, massless particles;   *4 units*
   Space-time continuum   *1 unit*

2. **Limitations of classical physics – Evolution of quantum theory**
   Blackbody radiation; Classical Maxwell‑Boltzmann statistics, Rayleigh Jeans formula; Ultraviolet catastrophe;   *3 units*
   Planck's quantum hypothesis, Planck's Radiation formula, Bose-Einstein statistics, Wein's displacement law; Stefan- Boltzmann law;   *3 units*
   Classical theory of specific heats of solids; Fermi-Dirac Statistics, free electrons in a metal, dying stars   *2 units*

3. **Particle properties of waves:**
   Photoelectric effect; Particle nature of light; Einstein's theory of photoelectric effect; X rays, Compton effect - Compton shift and Compton wavelength; pair production, photons and gravity   *4 units*

4. **Wave properties of particles:**
   De-Broglie waves, probability waves, phase velocity and group velocity, particle diffraction -Davisson and Germer experiment   *3 units*

5. **Atomic structure:**
   Nuclear atom, planetary model; atomic spectra; hydrogen spectrum - Bohr model of hydrogen atom; energy levels and spectra, Correspondence principle, effect of nuclear mass on spectral lines; atomic excitation, Franck Hertz experiment;   *7 units*

6. **Lasers**:
   Spontaneous and stimulated emission; Einstein approach - A and B coefficients; interpretation   *2 units*
   Metastable states; population inversion; pumping   *1 unit*
   Principle of a laser; laser operation; characteristics of laser light   *2 units*
   Laser types: Ruby laser, He-Ne, Nd-YAG, CO_2 lasers, Dye lasers, Semiconductor lasers; energy level diagrams   *3 units*

* * *

KEYED TEXTS:

1. Beiser A, Mahajan S, Rai Choudhary S, **Concepts of Modern Physics,** VI Edition, McGraw Hill Education, (2018)

REFERENCES:

1. Halliday, D. and Resnick, R. Krane K S: **Physics (Part 2)**, V Edition, Wiley Eastern, (2007)

2. Halliday, D. and Resnick, R. Walker, **Fundamentals of Physics,** VI Edition, Wiley India Pvt. Ltd; (2006)

3. Wilson, J. and Hawkes, J. F. B., **Optoelectronics- An Introduction**, III Edition, Prentice Hall, (1998)

4. Pedrotti, F. L. and Pedrotti, L. S., **Introduction to Optics**, III Edition, Pearson Publication, (2006)

5. Eisberg, R. and Resnick, R., **Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles**, II Edition, John Wiley, (2006)

6. Zettili, N. **Quantum Mechanics Concepts and Applications**, II edition, Wiley, (2009)

UPHY-503   **THERMAL PHYSICS**   **3 Credits**

Course objectives:

The objectives of this course are to:
- give the fundamentals of thermodynamic systems, the laws of thermodynamics and their application to thermodynamic problems
- provide essential tools to analyze Carnot engine, heat engines and refrigerators with the help of their thermodynamic cycles
- highlight the use of mathematical methods to derive thermodynamic relationships
- introduce the microscopic approach through kinetic theory of gases

Learning outcomes:

Upon completion of the course, students must be able to:
- have a fundamental understanding of thermodynamic quantities and the laws of thermodynamics
- to calculate work and heat transfers, efficiency of ideal heat engines and refrigerators, and entropy changes
- represent thermodynamic processes on appropriate thermodynamic diagrams
- appreciate the application of thermodynamic laws to liquefaction of gases for low temperature production
- use kinetic theory of gases to derive expressions for pressure of an ideal gas, heat capacities of solids and gases and transport properties

Course content:

1. **Introduction**:
   Macroscopic and microscopic point of view; thermal equilibrium and Zeroth law, concept of temperature; Thermodynamic equilibrium   *2 units*
   Concept of work; different types of processes; Quasi-static process   *2 units*
   Example of work in changing the volume of a hydrostatic system; PV diagram and calculation of PdV integral for quasi static processes   *1 unit*

2. **First Law of Thermodynamics:**
   Work and heat; the concept of heat; modes of heat transfer   *1 unit*
   Adiabatic work, internal energy function; mathematical formulation of first law; differential form of first law   *2 units*
   Definition of heat capacity; specific heat of water; equations for hydrostatic system; thermal energy reservoirs   *1 unit*

3. **Second Law:**
   Conversion of heat to work; Heat engine; different types of engines- diesel and steam engines   *2 units*
   Kelvin-Planck statement of second law; refrigerators; Clausius statement of second law; equivalence of the two statements   *2 units*

Reversibility and irreversibility and its types; Conditions for reversibility   *1 unit*

4. **The Carnot cycle**:
    The Carnot cycle and the Carnot principles; Carnot heat engine and refrigerators   *2 units*
    Heat pumps, Carnot theorem; thermodynamic temperature scale; absolute zero and Carnot efficiency   *4 units*

5. **Entropy:**
    Reversible part of second law; entropy; entropy of an ideal gas, T-S diagrams; entropy and reversibility; entropy and irreversibility; irreversible part of second law; principle of increase of entropy; entropy and disorder.   *4 units*
    Introduction to macro and micro states; thermodynamic probability; statistical interpretation of entropy.   *3 units*

6. **Thermodynamic Functions:**
    Characteristic functions; enthalpy; Gibbs and Helmholtz function; Maxwell's Thermodynamic relations; T-dS equations; Clausius-Clapeyron equation; Internal energy equations; ratio of heat capacities; difference in heat capacities   *4 units*

7. **Application:**
    Joule-Kelvin effect expansion; The Joule- Kelvin Coefficient; Joule-Kelvin Coefficient for a Van der Waals gas; Liquefaction of gases; Adiabatic demagnetization   *3 units*

8. **Kinetic theory of gases**:
    Basic assumptions; Maxwellian distribution of velocities, molecular flux; equation of state of an ideal gas; principle of Equipartition of energy; intermolecular forces   *3 units*
    Classical theory of specific heat; specific heat of a solid; Van der Waals" equation of state
    2 units
    Collision cross section; mean free path – resistivity in metallic conductors, coefficient of viscosity, coefficient of thermal conductivity   *3 units*

KEYED TEXTS:

1. Zemansky, M. W., Dittman R., **Heat and Thermodynamics**, VIII Edition, McGraw-Hill (2017).

2. Sears, F. W., and Sallinger, G. L., **Thermodynamics, Kinetic theory and Statistical Thermodynamics,** Indian Edition Reprint, Narosa Publications, (2013).

REFERENCES:

1. Guha E., **Basic Thermodynamics**, Narosa Publications, (2012).

2. Cengel A. Y, and Boles A. M, **Thermodynamics: an engineering approach**, III Edition, Tata McGraw Hill, (2011).

3. Aruldhas G and Rajagopal P, **Modern Physics,** Prentice Hall India, (2005).

UPHY-504   ELECTRONICS-II: ANALOG SYSTEMS AND   4 Credits
APPLICATIONS

Course objectives:

The objectives of this course are to:
- provide in-depth knowledge of voltage and power amplifiers, operational amplifiers IC timers and oscillators
- establish the general methods for analyzing, modeling and predicting the performance of op-amps and related linear integrated circuits.
- develop the students' faculty in designing realistic circuits to perform specified operations using op-amps

Learning outcomes:

On completion of the course, the student should be able to:
- describe the characteristic features of voltage amplifiers and discuss power amplifiers in class A, class B and class C operation and determine the efficiency of these amplifiers
- analyze and design various op-amp circuits using the ideal model assumptions
- understand the practical limitations of realistic op-amps and the associated dc and ac effects on operating performance
- analyze frequency dependent circuits like integrators and differentiators
- employ the op-amp in comparator circuits, both open-loop and feedback circuits
- understand the working of a 555 timer and use it in astable and monostable modes of operation
- design and analyze waveform generation circuits using op-amps by employing the Barkhausen criterion

Course content:

1. **Amplifiers:**
   Transistor circuits as an amplifier:
   Role of coupling and bypass capacitors in amplifiers, ac models of transistors used for analyzing amplifier circuits, dc and ac equivalent circuits of amplifiers.   *2 units*
   Study of Common emitter, Swamped, Common collector and Darlington amplifiers. Characteristics and analysis of the above amplifiers in terms of their voltage gain, input and output impedance.   *4 units*
   Cascaded stages of different amplifiers   *2 units*
   Class A power amplifier; Ac load line, formulae for class A; power gain, efficiency of each stage.   *3 units*
   Class B and class AB push-pull amplifier;   *3 units*
   Class C operation; tuned amplifier; Working and analysis   *3 units*

2. **FETs:**
   JFET basics, JFET characteristics, biasing; drain curves; transconductance curves, MOSFET; characteristics and parameters; MOSFET biasing; drain curves; transconductance curves.   *2 units*

3. **Operational Amplifiers:**
   Introduction; op-amp fundamentals; Block diagram of a typical op-amp and equivalent circuit.   *1 unit*
   Ideal and practical op-amp characteristics; the 741C general purpose op-amp data sheet and its interpretation; op-amp powering.   *1 unit*

4. **Linear Op-amp circuits:**
   Introduction; 4 types of negative feedback in op-amp circuits; VCVS, VCIS, ICVS, ICIS Ideal assumptions and their implications.   *1 unit*
    VCVS: basic op-amp configurations– inverting, non-inverting and voltage follower.
   Design and role of compensation resistance.   *2 units*
   VCIS: Floating load inverting and non-inverting, Grounded load VCIS   *1 unit*
   Current controlled sources; ICVS and ICIS   *1 unit*
   Linear combination circuits: inverting and non-inverting summing circuit, Closed -loop differential amplifier   *2 units*
   Common- mode Rejection Ratio; Instrumentation amplifier   *2 units*
   Integrators and differentiator circuits using op-amps   *1 unit*

5. **Op Amp- dc effects and limitations:**
   Low-frequency model of op-amp; finite open–loop gain, finite input impedance and non-zero output impedance of op-amp, Non-inverting amplifier and Inverting Amplifier; Gain, Input impedance and Output impedance due to realistic model of op-amp, Noise Gain
                                                                                                            3 units
   Dc Offset voltage and currents, experimental procedure to measure offset voltage and bias currents, Drift specifications, nulling of 741 op-amp   *2 units*

6. **Op Amp- ac effects and limitations:**
   Frequency response; Open-loop gain as a function of frequency, Gain-bandwidth relationship, Closed-loop bandwidth   *3 units*
   Slew Rate; effect of slew rate on pulse type and sinusoidal signals
   Combination of linear bandwidth and Slew rate   *3 units*
   Noise in op-amps.   *1 unit*

7. **Non Linear Op-Amp Circuits:**
   Comparators with zero reference; inverting and non-inverting comparators; input / output characteristics; Comparators with non-zero references (voltage level detectors); specifications and applications; Comparators with hysteresis (Schmidt trigger circuits).
                                                                                                            3 units

8. **Oscillators**: **(Operational amplifiers based)**
   Introduction; Oscillator principles; positive feedback in amplifier; Barkhausen criterion; RC oscillators: Wien Bridge and phase shift oscillators; LC oscillators- Hartley and Colpitt's oscillators; piezoelectric effect and crystal oscillators   *4 units*

UPHY-504 Contd….

Non-sinusoidal oscillators: IC 555 Timer as Astable and Monostable multi-vibrators.

3 units

9. **Data Converters:**
   D/A converter R/2R ladder network and A/D converters: Successive-Approx   *3 units*

KEYED TEXTS:

1. Malvino, A. P., **Electronics Principles,** VIII Edition**,** Tata-McGraw Hill, (2007).

2. Stanley, W. D, **Operational amplifiers with linear integrated circuits**, IV Edition, Pearson Education, (2002).

3. Coughlin, R. F. and Driscoll, F. F., **Operational Amplifiers and Linear Integrated Circuits**, IV Edition, Pearson Education, (2001).

REFERENCES:

1. Fiore, M J., **Op-Amps and Linear Integrated Circuits**, I Edition, Cengage Learning, (2001).

2. Floyd, L T.: **Electronic Devices**, IX Edition, Pearson Education, (2015).

3. Gayakwad R, **Op-Amps and linear Integrated circuits**, IV Edition, Pearson Education, (2002).

∗ ∗ ∗

UPHY-505   COMPUTATIONAL TECHNIQUES IN PHYSICS
3 Credits

Course objectives:

The objectives of this course are to:
- make the student appreciate the limitations of analytical methods in solving problems
- introduce various computational methods and use them to solve problems, such as, linear algebraic equations, integrals, differential equations, etc.

Learning outcomes:

On completion of the course, the student must be able to:
- appreciate the computational approach to problem solving and data analysis
- numerically solve non-linear equations, system of linear equations, integrals and differential equations
- describe the algorithms used to compute the Fast Fourier Transform
- employ appropriate methods to fit and interpolate data
- appreciate the use of random numbers in physics

Course content:

1. **Non- linear Equations**:
   Bracketing methods; Bisection; False Position Methods   *2 units*
   Open Methods; Newton Raphson, Secant method and Simple One Point Iteration Methods
       3 units

2. **Linear Algebraic Equations**:
   Gauss Elimination; LU Decomposition: Doolittle and Crout decomposition; Matrix inverse
       6 units
   Special Matrices – Tridiagonal Matrices and Thomas Algorithm   2 units

3. **Numerical Integration**:
   Trapezoidal rule and Simpson's Rules; Romberg Integration   *4 units*

4. **Interpolation**:
   Interpolation by Newton's divided difference interpolating Polynomials   *2 units*
   Lagrange interpolating polynomials and Spline interpolation   *4 units*

5. **Ordinary and Partial Differential Equations**:
   Divided Differences: Forward, Backward and Centered and their associated errors   *1 unit*
   One Step methods: Euler's method and Runge-Kutta methods   *4 units*

Types of partial difference equations (PDEs) – Elliptic, parabolic and hyperbolic, Crank-Nicholson method and solution to heat diffusion equation, Application to Schrodinger equation   *4 units*

6. **Random number Generation:**
   Psuedo-random numbers; Random number generation by Mid Square (Von Neumann) Method and Linear Congruential Generators   *2 units*
   Tests for randomness: Chi-squared test for uniformity, Serial Auto-Correlation Test   *2 units*

7. **Fast Fourier Transforms:**
   Discrete Fourier Transform with example problems; Fast Fourier Transform by Sande-Tukey Algorithm.   *6 units*

KEYED TEXTS:

1. Chapra S. C. and Canale R. P., **Numerical Methods for Engineers**; VII Edition, Tata McGraw Hill, (2016)

2. Wong S. S. M., **Computational Methods in Physics and Engineering**, World Scientific Publishing Co., (1997).

3. Press W. H., Teukolsky S. A., Vetterling W. T., Flannery B. P., **Numerical Recipes in C: The Art of Scientific Computing;** III Edition, Cambridge University Press (2007).

REFERENCES:

1. Verma R. C., Ahluwalia P. K. and Sharma K.C., **Computational Physics, An Introduction**; I Edition, New Age International Publishers (2007)

2. Gerald C. F. and Wheatley P. O., **Applied Numerical Analysis,** VII Edition, Pearson Education (2007)

3. Griffiths, D. V. and Smith, I. M., **Numerical Methods for Engineers**, Blackwell Scientific, (2006)

4. Ralston, A. and Rabinowtz, P., **A First Course in Numerical Analysis**, II Edition, McGraw Hill, Kogakusha, (2001)

5. Atkinson, K. E., **An Introduction to Numerical Analysis**, II Edition, John Wiley, (1989)

6. Jain, M. K., Iyengar, S. R. K., Jain, R. K., **Numerical Methods for Scientific and Engineering Computation**, VI Edition, Wiley Eastern, (2012)

7. Hildebrand, F. B., **Introduction to Numerical Analysis**, (Revised) II Edition, Tata McGraw Hill, (1987)

* * *

UPHY-506   GENERAL PHYSICS LABORATORY-I   2 credits

Course objectives:

The objectives of this laboratory course are to:
- illustrate and reinforce the concepts of interference, diffraction and polarization with advanced experiments in optics.
- impart the thrill of experimental physics by determining fundamental constants using the laboratory equipment.

Learning outcomes:

On completion of this lab course students must be able to:
- carry out basic experimental investigations in physics
- use instruments for various measurements and troubleshoot the same
- analyze experimental data with appropriate treatment of errors and uncertainties
- apply analytical techniques and graphical analysis to the experimental data to elicit suitable conclusions.

Lab Course content:

Optics

1. Determination of wavelength of He- Ne Laser using
   a) Michelson Interferometer
   b) Lloyd's mirror method
2. Verification of Fresnel's equations of EM theory
3. Study of Ultrasonic diffraction – determination of velocity of ultrasound in liquids
4. Particle size determination using diffraction
5. Babinet's compensator

Fundamental constants / Modern Physics

6. Determination of electronic charge 'e' - Millikan's oil drop experiment
7. Determination of Rydberg's constant
8. Determination of Stefan's constant
9. Study of Photoelectric effect using photocell
10. Determination of Planck's constant using LED
11. Determination of Boltzmann constant
12. Determination of the speed of light
    a) Speed of light using ε_o and μ_o values
    b) Speed of light using oscilloscope
13. Study of Frank Hertz Experiment
14. Study of Electron diffraction

UPHY-506   Contd….

Software based experiments
15. Familiarization of data acquisition systems using LABVIEW

Electromagnetism
16. Verification of Curie Weiss law for a ferroelectric material

Thermal Physics

17. Verification of Clausius-Clapeyron equation
18. Determination of Specific heat of solids and Specific heat of water

Note: Student should do a minimum of 14 experiments

* * *

UPHY-507   ELECTRONICS LABORATORY-II   2 Credits

Course objectives:

The objectives of this laboratory course are to:
- study the performance of voltage amplifiers, operational amplifiers IC timers and oscillators
- establish the general methods for analyzing, modeling and predicting the performance of Class A amplifiers, op-amps and related linear integrated circuits.
- develop the students' faculty in designing realistic circuits to perform specified operations using op-amps

Learning outcomes:

On completion of this lab course students must be able to:
- design, fabricate and test a regulated power supply
- design, fabricate and analyse the operation of class A amplifier
- fabricate on the breadboard various flip flops, registers and counter circuits using relevant IC's and analyse the working of the circuits
- design, fabricate and test various op-amp based circuits
- design, fabricate and test 555 timer based circuits
- design, fabricate and test op-amp based oscillator circuits
- troubleshoot the circuits built and analyse their performances

Lab course content:

1. Design of Electronic Power Supplies: Unregulated supply
2. Design of Regulated power supply (fixed and variable, Use of 78XX series and 317 regulator)
3. Design and study of CE and Swamped amplifier.
4. Design and study of CC/Emitter follower amplifier.
5. Registers 7495 (Shift right, Shift left, serial and parallel loading)
6. Counters: 7490, 7492 & 7493 ($\div$10, $\div$12 & $\div$16)
7. Decoder driver 7448 & seven segment display.
8. Study of FET characteristics

Op-Amp (741) based experiments:

9. VCVS (Inverting and Non-inverting): Design, fabricate and study gain and small signal band-width
10. VCIS (Grounded Load), ICVS& ICIS: Fabricate and study
11. a) Voltage offset Null Circuit for 741
    b) Closed Loop Differential. Amplifier

12   a) Measurement of DC input offset Voltage and
     b) Measurement of DC bias and offset current for 741

13. Study Slew rate response of 741 op-amp to square wave and sinusoidal waveforms using a
     voltage follower circuit

14. Study of Comparators: a) Non-Inverting & Inverting (Open Loop)
                               b) Comparators with bias
                               c) Inverting and Non Inverting Schmitt trigger

15. Integrator and Differentiator

16. 555 Timer: Design and study of astable operation

17. 555 Timer: Design and study of monostable operation

18. Wein bridge oscillator

19. Hartley and Colpitt's oscillator

Experiments numbers 1 - 4 may be soldered on a lug board. All other experiments are bread-board based.

Note: Students should complete experiments 1-8 and at least 8 op-amp based experiments

* * *

UPHY-508   PYTHON PROGRAMMING LAB - I   2 Credits

Course objectives:

The objectives of this software lab course are to:
- inculcate a "programming way of thinking" in students
- introduce Python as a programming language
- write programs in Python for implementing computational techniques learnt in UPHY-505
- use Python as a visualization tool in physics

Learning outcomes:

On completion of this lab course students must be able to:
- have a firm grip over the basic concepts of programming, such as, print command input statements, arithmetic operations and fundamental datatypes
- write and execute basic python programs using functions, loops and conditional constructs
- implement the complex datatype - list
- plot expressions involving concepts in Physics, using appropriate python libraries, and interpret them for better understanding
- write and execute programs to solve non-linear equations, system of linear equations, integrals and differential equations

Lab course content:

- Introduction to python programming, basic arithmetic and Hello world programs
- Variables, Operators and Datatypes; Operations on datatypes; Input and Output
- Functions: Modules, Built-in functions, User defined functions, keyword arguments
- Conditional statements (if, elif, else) and Loops
- Lists, Strings, Tuples and Dicts
- Introduction to numpy
- Introduction to matplotlib for basic plotting.

(Examples from UPHY 505 – Computational Techniques in Physics)

- Non-Linear Equations: Bisection, False-Position, Newton Raphson and Secant Methods
- Numerical Integration: Trapezoidal and Simpson's Rules
- Linear Regression
- Euler's Method and Runge-Kutta Methods

REFERENCE TEXTS:

1. David J. Pine, **Introduction to Python for Science and Engineering,** CRC Press, Taylor and Francis Group, (2018)

2. Chapra S. C. and Canale R. P., **Numerical Methods for Engineers**; VII Edition, Tata McGraw Hill, (2016)

UPHY-601   SOLID STATE PHYSICS   4 Credits

Course objectives:

The objectives of this course are to:
- introduce solid state systems
- give an in-depth knowledge of various crystalline structures and experimental techniques like X-ray diffraction
- provide an understanding of thermal, electrical, optical and magnetic properties of solid state matter

Learning outcomes:

Upon completion of this course, student must be able to:
- appreciate the physics of materials and understand the importance of solid state physics in current technology
- describe different types of crystal structures in terms of the crystal lattice and basis
- formulate the theory of X-ray diffraction in reciprocal lattice formalism and explain the concepts like form factor, structure factor, scattering amplitude, etc.
- understand the different physical mechanisms involved in crystal binding
- comprehend the concept of phonons and thereby the thermal properties of solids.
- explain electrical, optical and magnetic properties of solids based on theoretical models

Course content:

1. **Crystal Structure**:
   Lattice concept; lattice types; index system for system planes,
   Simple crystal structures; Lattice symmetries; absence of five-fold symmetry   *7 units*

2. **Crystal Diffraction and the Reciprocal Lattice**:
   Experimental techniques using X-rays, neutrons, and electrons   *1 unit*
   Bragg law; experimental diffraction methods: Laue method, rotating crystal method, powder method   *3 units*
   Laue Equations; Bragg's Law and Ewald's Construction   *3 units*
   Reciprocal lattice; Brillouin zone, construction, Brillouin zone of SC, BCC and FCC lattice; Fourier analysis of basis.   *5 units*

3. **Crystal Types and Crystal Binding**:
   The five crystal types; inert gas crystals – properties   *2 unit*
   Van der Waals – London Interaction; Lennard Jones potential   *2 units*
   Cohesive energy; bulk modulus and compressibility; ionic crystals-
   Madelung energy and Madelung constant   *2 units*

UPHY-601 Contd....

4. Lattice vibrations and Thermal Properties:

Vibrations of mono atomic lattices; lattice with two atoms per primitive cell; quantization of lattice vibrations *4 units*

Phonon momentum *1 unit*

Lattice heat capacity; Planck distribution; Einstein's model *2 units*

Enumeration of normal modes; density of modes in one and three dimensions *3 units*

Debye model of lattice specific heat capacity; Debye T^3 law *2 units*

5. Free Electron Fermi gas:

Energy levels and density of orbitals in 1-D *2 units*

Free electron gas in 3-D; effect of temperature on Fermi – Dirac distribution *2 unit*

Heat capacity of electron gas; electrical conductivity and Ohm's law *2 units*

Hall effect and magneto-resistance; Mattheissan's rule; thermal conductivity of a metal

1 unit

6. Optical properties: refractive index, extinction coefficient, absorption coefficient and relation between them *3 units*

7. Magnetic properties:

Diamagnetism, paramagnetism due to free ions and conduction electrons, Curie's law, ferromagnetism, domains, hysteresis loop, outline of antiferro- and ferrimagnetism; ferrites

7 units

8. Superconductivity:

Introduction; experimental facts, zero resistivity, critical temperature, critical magnetic field

1 unit

Effect of magnetic field; Meissner effect *1 unit*

KEYED TEXTS:

1. Kittel, C.: **Introduction to Solid State Physics**, VIII Edition, Wiley Eastern, (2005)

REFERENCES:

1. Ashcroft, N. W and Mermin, N. D., **Solid State Physics,** Cengage Learning India Pvt. Ltd., Revised India Edition, (2016)

2. Hummel Rolf E., **Electronic Properties of Materials**, IV Edition, Springer, (2011)

3. Fox M., **Optical Properties of Solids**, II Edition, Oxford University Press, (2010)

4. Ali Omar M., **Elementary Solid State Physics: Principles and Applications,** I Edition, Pearson Education, (2003)

5. Pillai S. O., **Solid State Physics**, New Age Science, VI Edition, New Age Science, (2009)

6. Blakemore J. S.: **Solid State Physics**, II Edition, Cambridge University Press, (1985)

7. Azaroff, L. V.: **Introduction to Solids**, McGraw Hill Education, Indian Edition, (2017)

UPHY-602   **NUCLEAR PHYSICS**   **3 Credits**

Course objectives:

The objectives of this course are to:
- provide an understanding of radioactive phenomena
- explore the nuclear properties and understand them through nuclear models
- impart knowledge of the nuclear processes that yield nuclear energy
- introduce the experimental tools used for studying nuclear physics

Learning outcomes:

On completion of the course, students must be able to:
- appreciate the importance of nuclear physics and its applications
- understand radioactive decay modes and nuclear reactions
- discuss nuclear properties
- explain the principle, construction and working of detectors and accelerators
- describe fission and fusion reactions and nuclear power production
- have a basic idea of elementary particles and their conservation laws

Course content:

1. **Radioactivity**:
   The radioactive decay law; half-life and mean life;   *1 unit*
   Statistical nature of radioactivity; statistical errors in nuclear physics   *1 unit*
   Radioactive growth and decay; transient and secular equilibrium   *1 unit*
   Natural radioactivity and radioactive series   *1 unit*
   Artificial radioactivity; Determination of age of the Earth, Carbon dating; Units for measuring
   radiation   *1 unit*

2. **Nuclear Reactions**:
   Introduction; nomenclature; Types of nuclear reactions   *1 unit*
   Balance of mass and energy in nuclear reactions; the Q-equation; solution of the Q equation;
   Threshold energy;   *2 units*

3. **Nuclear Properties:**
   Constituents of a nucleus; Discovery of neutron;   *1 unit*
   Nuclear radius; distribution of nuclear charge; Measurement of nuclear radius;   *1 unit*
   Nuclear mass and abundance of nuclides; Mass spectrometer   *1 unit*
   Nuclear binding energy; Nuclear angular momentum and parity; statistics, Nuclear Magnetic
   moment; Nuclear electric quadrupole moment   *2 units*
   Nuclear excited states; failure of proton-electron hypothesis   *1 unit*

4. **Nuclear decays:**
    Alpha decay: Basic alpha decay process; Disintegration energy of spontaneous alpha decay
    1 unit
    Geiger Nuttal law; Alpha spectrum *1 unit*
    Decay scheme of alpha decaying nucleus; Alpha decay paradox; Barrier penetration as applied to alpha decay theory *2 units*
    Beta Decay: Continuous beta ray spectrum; Pauli's neutrino hypothesis *1 unit*
    Detection of neutrino; Cowan and Reines experiment *1 unit*
    Types of beta decay; Energy release in beta decay; Decay scheme of a beta decaying nucleus,
    1 unit
    Gamma decay: Energetics of gamma decay; Gamma spectrum; Angular momentum and parity selection rules; multipolarity of gamma transitions; *1 unit*
    Internal conversion; Internal conversion coefficient; Level scheme of gamma emitting nucleus *1 unit*

5. **Liquid Drop Model**:
    Binding energies of nuclei; plot of B/A against A *1 unit*
    Weizsacker's semi-empirical mass formula: volume energy, surface energy, asymmetry energy, pairing energy *2 units*

6. **Nuclear Force**:
    Few properties of nucleon-nucleon force; the deuteron; Binding energy, spin and parity, magnetic dipole moment, electric quadrupole moment *1 unit*
    Ground state of deuteron; spin dependence; charge independence; short range and tensor nature *1 unit*
    Square-well solution for the deuteron *1 unit*
    Exchange force: meson theory of nuclear force; Estimation of mass of a meson using uncertainty principle *1 unit*

7. **Nuclear Energy**:
    Characteristics of Nuclear fission; mass distribution of fragments; number of emitted neutrons; delayed neutrons; radioactive decay processes; fission cross section; energy in fission *2 units*
    Controlled fission reactions; neutron moderators; fission reactors, types of reactors, type of fuel; moderator; assembly; coolant *1 unit*
    Neutron cycle in a thermal nuclear reactor and the four factor formula, fission explosives
    1 unit
    Basic fusion processes; energy release; solar fusion; proton-proton cycle; carbon or CNO cycle; controlled fusion reactors; *1 unit*

8. **Charged Particle Accelerators and Detectors**:
    Van de Graff generator; Tandem Van de Graff accelerator *1 unit*
    The cyclotron and synchrotron; linear accelerator *2 units*
    Gas filled counters-principle; pulse height vs. applied voltage graph; Geiger counter and proportional counter *1 unit*

9. **Elementary Particles**:
    Particles and fields; classification   *1 unit*
    Conservation laws of particles: energy and momentum, angular momentum, parity, baryon number, lepton number, strangeness   *1 unit*
    The quark model of baryons, hyperons and mesons;   *1 unit*

KEYED TEXTS:

1. Patel, S. B., **Nuclear Physics, An Introduction**, II Edition, New Age International Pvt. Publishers, (2011)

2. Krane, K. S., **Introductory Nuclear Physics**, III Edition, John Wiley, (1987)

3. Krane, K.S., **Modern Physics**, IV Edition, John Wiley, (1983)

REFERENCES:

1. Evans, R. D., **Atomic Nucleus**, Tata McGraw Hill, (1982)

2. Enge, H., **Introduction to Nuclear Physics**, Addison Wesley, (1969)

* * *

UPHY-603   QUANTUM MECHANICS   3 Credits

Course Objectives:

The objectives of this course are to:
- impart the underlying foundations and basic principles of quantum mechanics
- apply non- relativistic Schrödinger wave mechanics to a variety of potentials in one and three dimensions

Learning outcomes:

On completion of the course, the student should be able to:
- understand the wave-particle duality, develop the concept of the wave function and give its interpretation; discuss Heisenberg's uncertainty principle and its applications
- discuss the concept of probability conservation and probability current density; formulate the set of postulates to study quantum mechanics and apply the principles of quantum mechanics to calculate observables of a quantum system
- solve time-dependent and time-independent Schrödinger wave equation for simple potentials in one and three dimensions

Course content:

1. **Wave mechanical concepts:**
   Matter waves; Superposition principle and construction of wave packet; Motion of wave packet. *2 units*
   Heisenberg's uncertainty principle; Position-momentum uncertainty; Uncertainty relation for other variables *2 units*
   Applications of uncertainty relations *1 unit*
   Exact statement and proof of uncertainty principle *1 unit*

2. **Time-independent Schrödinger equation:**
   One dimensional equation for a free particle; Particle in 1-D box *3 units*
   Probabilistic interpretation of the wave function and its normalization; Time independent Schrödinger equation *1 unit*
   Stationary state solutions of the Schrödinger equation, Operators for momentum and energy. *1 unit*
   Expectation values of dynamical quantities; Momentum operator *1 unit*
   Wave function in momentum space; Probability current density *2 units*

3. **Operators in quantum mechanics:**
   Linear operator; Algebra of linear operators *1 unit*
   Eigen functions and Eigen values of operators; Boundary and continuity conditions; Orthonormal set of Eigen functions *1 unit*
   Hermitian operator; Properties of Hermitian operators *2 units*
   Postulates of Quantum mechanics; Expansion postulate and its physical interpretation *2 units*

Simultaneous measurability and commutators	*1 unit*
Uncertainty relation for commutators; Dirac's notation	*1 unit*
The fundamental commutation relation; Equation of motion for operators, Ehrenfest theorem; Correspondence principle	*1 unit*

4. One dimensional potentials:

Square well potential with rigid walls	*1 unit*
Potential step	*1 unit*
Potential barrier: Tunneling	*2 units*
Linear Harmonic oscillator: Energy eigen values, energy eigen functions	*2 units*

5. Angular Momentum:

The angular momentum operators in spherical polar co-ordinates	*1 unit*
Angular momentum commutation relations	*1 unit*
Eigen values and eigen functions of L^2 and L_z	*2 units*
Stern- Gerlach experiment	*1 unit*

6. Three dimensional Eigen value problems:

Particle in a three dimensional box; Degeneracy	*1 unit*
Particle moving in a spherically symmetric potential, Separation of variables; Solution of the φ equation, Solution of the θ-equation; Spherical harmonics.	*2 units*
Radial Equations, Rigid rotator, Hydrogen atom; Radial equation; Energy Eigen values	*3 units*
Wavefunctions of hydrogen like atoms; Radial Probability density; Hydrogenic orbitals	*2 units*

KEYED TEXTS:

1. Goswami, A, **Quantum Mechanics**, II Edition, Waveland Press, (2003)

2. Ghatak, A, **Introduction to Quantum Mechanics**, Macmillan India Ltd, (2000)

3. Powell, J. and Crasemann, B., **Quantum Mechanics**, Narosa, Publ. House, (1988)

REFERENCES:

1. Schiff, L. I., **Quantum Mechanics**, IV Edition, McGraw Hill, (2017)

2. Gasiorowicz, S., **Quantum Physics**, III Edition, John Wiley, (2005)

3. Nouredine Zettili., **Quantum Mechanics: Concepts and Applications**, II Edition, Wiley, (2009)

4. Eisberg R., and Resnick R., **Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles**, II Edition, Wiley, (2006)

5. Bransden B. H., Joachain C. J., **Quantum Mechanics**, II Edition, Pearson Education, (2008)

UPHY-604   ATOMIC AND MOLECULAR SPECTROSCOPY   3 Credits

Course objectives:

The objectives of this course are to:
- develop an understanding of the structure of matter through the study of atoms and molecules
- give the basics of atomic and molecular spectroscopy and to gain a clear understanding of the principles and processes involved in spectroscopy

Learning outcomes:

At the end of the course, the student should be able to:
- describe the atomic spectra of one and two valence electron systems/atoms
- explain the change in behaviour of atoms in external magnetic fields
- explain the details of rotational, vibrational and Raman spectra of molecules, evaluate the bond length and force constant of diatomic molecules

Course content:

1. **Elements of Molecular Spectroscopy**:
   Characterization of electromagnetic radiation; quantization of energy; representation of spectra; elements of practical spectroscopy   *2 units*
   Signal to noise ratio, resolving power; width and intensity of spectral transitions; Fourier transform spectroscopy   *3 units*

2. **Microwave Spectroscopy**:
   Rotation of molecules; rotational spectra; diatomic molecules   *1 unit*
   The rigid diatomic molecule; intensities of spectral lines; the effect of isotopic substitution
                                                                                       2 units
   The non-rigid rotator; the spectrum of non-rigid rotator   *1 unit*
   Polyatomic molecules: Linear molecules; symmetric top molecule; the microwave oven
                                                                                       2 units
   Techniques and Instrumentation   *1 unit*

3. **Infrared Spectroscopy**:
   Vibrating diatomic molecule; energy of a diatomic molecule; the simple harmonic oscillator
                                                                                       1 unit
   The anharmonic oscillator   *2 units*
   The diatomic vibrating rotator; vibration rotation spectrum of carbon monoxide;   *2 units*
   Breakdown of the Born-Oppenheimer approximation: the interaction of rotations and vibrations   *2 units*
   Vibrations of polyatomic molecules- Fundamental Vibrations and their symmetry;   *2 units*
   Techniques and Instrumentation   *1 unit*

UPHY-604 contd…

4. **Elements of Raman Spectroscopy**:

Quantum theory of Raman effect; classical theory of Raman effect	*2 units*
Pure rotational Raman spectra: Linear molecules, symmetric top molecules	*2 units*
Spherical top molecules; asymmetric top molecules	*1 unit*
Vibrational Raman spectra: Raman activity of vibrations, rule of mutual exclusion, overtone and combination vibrations	*2 units*
Vibrational Raman spectra- rotational fine structure	*2 units*
Techniques and Instrumentation	*1 unit*

5. **Atomic Spectra**:

Orbital magnetic dipole moments; the spin-orbit interaction; total angular momentum;	*3 units*
Alkali atoms; residual coulomb and spin-orbit interactions; spin coupling; LS coupling;	*3 units*
Spin and orbital angular momenta and related quantum numbers; jj coupling	*2 units*
Lande's interval rule; energy levels of carbon atom; Zeeman effect	*2 units*

KEYED TEXTS:

1. Eisberg, R. and Resnick, R., **Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles**, II Edition, John Wiley, (2006)

2. Banwell, C.N., McCash E, **Fundamentals of Molecular Spectroscopy**, V Edition, McGraw Hill, (2013)

REFERENCES:

1. Pedrotti, F. L. and Pedrotti, L. S., **Introduction to Optics**, III Edition, Pearson Publication, (2006)

* * *

UPHY-605   MICROPROCESSORS   3 Credits

Pre-requisites:

This course assumes a sound understanding of digital electronics and binary and hexadecimal number systems covered in UPHY-101

Course objectives:

The objectives of this course are to:
- impart a comprehensive knowledge about the working of a microprocessor, both hardware and software, with particular reference to Intel's 8085 microprocessor
- familiarize the student with the Arduino microcontroller board

Learning outcomes:

At the end of the course, the student must be able to:
- describe the architecture of the 8085 microprocessor and list its operations
- discuss various types of memory, explain memory organization and memory mapping
- design counters and time delays using the concepts of looping and counting
- explain the concept of the stack, stack pointer and subroutine
- explain the concept of interrupts in microprocessors, describe the types of interrupts and the interrupt structure of 8085
- describe the interface between the microprocessor and the physical world using data converters and the general - purpose programmable device- 8255 chip
- use the Arduino board

Course content:

1. **General features of a digital computer and microprocessors:**
   Hardware, Software, CPU, Memory, Input/output devices. Type of memory: RAM ROM, SDRAM, PROM, EPROM etc. Flash memory, magnetic memory, Cache memory; *2 units*

2. **Interfacing devices& Memory mapping**:
   Tristate devices, buffers, Decoders, Latches. Hexadecimal counting; Conversion to Binary and decimal. Address space. Memory mapping; Peripheral I/O and memory mapped I/O.
   4 units

3. **Architecture of 8085**:
   Multiplexing; Address-data bus, Control and status signals. Timing diagram of op-code fetch machine cycle. Registers: general purpose and special purpose. ALU, Control unit. Instruction cycle, Machine cycle, T-state; *4 units*

4. **Assembly Language Programming for 8085**:
   Instruction set. Classification. Instruction format; Opcode format. Examples of 1-byte, 2-byte and 3-byte instructions. Addressing modes: Register, Register indirect, direct, immediate, Implied. Programs using data transfer, arithmetic and logic instructions. Branching instructions: Unconditional and conditional.   *5 units*

5. **Programming techniques**:
   Looping, Counting and Indexing, Use of register pairs-Additional data transfer and 16 – bit arithmetic instructions, arithmetic and logic operations related to memory   *5 units*

6. **Counters and time delays**:
   Time delay loops: using a register, register pair and nested loops, counter design with time delay   *2 units*

7. **Stack and Subroutines:**
   Stack: Definition, Initialization; PUSH and POP instructions; Program status word. Subroutine: CALL and RET: Stepwise execution in terms of machine cycles.
                       3 units

8. **Interrupts:**
   Types of interrupt: Maskable and Non-maskable; INTR and INTA signals; RST instructions. Vectored interrupts: RST7.5, RST6.5, RST5.5 and TRAP.   *4 units*

9. **Arduino:**
   Introduction: brief history, open-source electronics prototyping;
   Basic ideas: familiarize with the arduino board, setting up of the arduino board, installation of ide for arduino programming (sketch)   *3 units*

10. **Programmable interfacing devices**:
    Requirements of a programmable peripheral device, Control register, Status register; Role of handshake signals. Block diagram of 8255; Control word; Mode 0 and BSR mode.
                       7 units

11. **Introduction to other Microprocessors:**
    Overview of Advanced processors:8088/8086, 286, 386, 486, Pentium I, II, dual core, Core 2 duo, quad core   *3 units*

KEYED TEXTS:

1.   Gaonkar R. S., **Microprocessor architecture, Programming and applications with the 8085**, VI Edition, Penram International Publishing, (2013).

2.   Monk S., **Programming Arduino: Getting started with sketches**, II Edition, McGraw-Hill Education, (2016).

UPHY-605 Contd….

REFERENCES:

1. Ram B., **Fundamentals of microprocessors and microcontrollers**, Dhanpat Rai Publications, (2012).

2. Triebal W. A., Singh A., **The 8088 and 8086 microprocessors: Programming, Interfacing, Software**, **Hardware, and Applications**, IV Edition, Pearson, (2003).

3. Ayala K. J., **The 8086 microprocessor: programming and interfacing the PC**, Cengage Learning, (2007).

4. Liu Y, C., Gibson G. A., **Microcontroller systems: the 8086/88 Family Architecture, Programming and Design,** II Edition, Pearson Education India, (2015).

5. Uffenbeck J., **The 80x86 Family: Design, Programming, and Interfacing,** III Edition, Pearson, (2001).

UPHY-606   GENERAL PHYSICS LABORATORY-II   2 credits

Course objectives:

The objectives of this laboratory course are to:
- strengthen the general concepts by carrying out experiments that probe various aspects of modern physics namely solid state physics, thermal physics, spectroscopy and nuclear physics
- introduce students to independently design and set up a few experiments
- familiarize students with Latex/Libreoffice/MS Office for scientific report writing

Learning outcomes:

On completion of this lab course students must be able to:
- carry out experimental investigations which will broaden their perspectives of physics
- to independently prepare a scientific report from conception to completion.
- make a presentation of their scientific findings

Lab Course content:

Solid State Physics

Magnetic properties:
1. Measurement of susceptibility of paramagnetic material using
   a) Quincke's method
   b) Guoy's method

Electrical properties:
2. Lorentz number of copper
3. Determination of Fermi energy of Copper
4. Determination of energy band gap of a given semiconductor
5. Solar cell characteristics

Thermal properties:
6. Determination of coefficient of thermal conductivity of a bad conductor
7. Study of temperature transducers; RTD, Thermocouple, Thermistor, LM35

Spectroscopy

8. Determination of wavelengths of emission spectral lines of metal arc sources (Cu, Br, Fe)
9. Study of Zeeman Effect
10. Determination of the wavelength of absorption spectral lines of $KMnO_4$

11. Verification of Beer Lambert's law
12. Determination of Laser beam parameters

Nuclear Physics:

13. GM counter based experiments
    a) Characterization of the GM counter
    b) Determination of the End point energy of a beta source
    c) Counting statistics

Note:
- Student should do a minimum of 10 experiments (exclusive of few open-ended experiments)
- Student shall use Latex/Libreoffice/MS Office to submit the report of open-ended experiments only.

* * *

UPHY-607   MICROPROCESSOR LABORATORY   2 Credits

Course objectives:

The objective of this laboratory course is to:
* introduce 8085 assembly language programming

Learning outcome:

On completion of this lab course students must be able to:
* write and execute assembly language programs using the instruction set for 8085 system categorized under data transfer, arithmetic, logical, branching and machine control instructions using stand-alone 8085 kits

Lab course content:

Preparation: Introduction to the 8085 kit and to basic programming with the kit

Sample programs with Microprocessor 8085:

1. Transfer of a block of numbers.
2. Addition of n 8-bit numbers.
3. a) Multiplication by repeated addition.
   b) Multiplication by shift and add method.
4. Sorting to arrange in ascending order.
5. Delay routine for a specified time.
6. 16-bit arithmetic (Register pair operations)
7. Using subroutines: main program to display hex-numbers continuously with delay subroutine.
8. Introduction to interfacing with IC 8255.

* * *

UPHY-608   PYTHON PROGRAMMING LAB-II   2 Credits

Course objectives:

The objective of this software lab course is to:
- introduce students to advanced features of Python, such as complex datatypes (Strings, Dicts and Tuples), classes and file handling.

Learning outcomes:

On completion of this lab course, students must be able to:
- write and execute simple programs using strings, dicts and tuples, and on classes and file handling in Python
- simulate examples from Physics, using advanced features of numpy, scipy and matplotlib and visualize them for better understanding

Lab Course content:

Advanced Programming in Python and Physics Simulations using Python
- Object Oriented Programming: Classes, Inheritance
- Exception handling
- Basic File Handling
- Introduction to pandas: extraction of data from CSV, XLSX and TXT files.
- Basics of GUI Programming using tkinter

Examples of Physics Simulations
- Monte-Carlo Methods and Random number generation: Estimation of pi, Chi squared test for uniformity and Serial Auto-correlation test.
- Linear Algebraic Equations: Gauss Elimination method with Partial Pivoting, Gauss Jordan method, LU decomposition method
- Solving Elliptic PDEs using the Crank Nicholson Method

Open-Ended Mini Project for about 6-7 weeks

REFERENCE TEXTS:

1. Chapra S. C. and Canale R. P., **Numerical Methods for Engineers**; VII Edition, Tata McGraw Hill, (2016)
2. Eric Matthes, **Python Crash Course: A Hands-on, Project-based Introduction to Programming,** No Starch Press, (2015)
3. David J. Pine, **Introduction to Python for Science and Engineering,** CRC Press, Taylor and Francis Group, (2018)

* * *