NIPER
RAEBARELI

SYLLABUS

M.S. (Pharm.) Pharmaceutics

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Course No.		Course Name	Credits
Semester – I			
**	PE-510	Pharmaceutical Preformulation-I	1
***	PE-520	Biopharmaceutics and Pharmacokinetics	2
	PE-530	Pharmaceutical Preformulation-II	1
****	PE-540	Regulatory Consideration for Pharm Development	1
@	MC-511	Spectral Analysis	2
$	MC-530	Separation Techniques	1
**	MC-540	Industrial Process and Scale-up Techniques	1
*	GE-510	Biostatistics	2
¶	GE-520	Fundamentals of Intellectual Property (IP) & Technology Management	1
	GE-511	Seminar	1
	LG-510	General Laboratory Experience	3
		Total Credits	**16**
Semester – II			
	PE-620	Drug Delivery Systems	2
¤	PE-630	Pharmaceutical Product Development-I	1
	PE-640	Pharmaceutical Product Development-II	2
	PE-650	Drug Delivery II (Targeted drug delivery)	2
**	PE-660	Solid State Pharmaceutics	1
∞	PA-630	Stability Testing	1
µ	PC-610	Drug Metabolism	1
#	PC-611	Pharmacological Screening and Assays	1
	GE-611	Seminar	1
	LS-610	General Lab Experience in the Area of Specialization	2
		Total Credits	**14**
Semester – III			
Projects (22 weeks)			
	TH-598	Synopsis	5
	TH-599	Presentation	3
		Total Credits	**8**
Semester – IV			
	TH-698	Thesis	9
	TH-699	Defence of Thesis	3
		Total Credits	**12**
		Grand Credits (I to IV Semesters)	**50**

Note:

*	Common in all disciplines
**	Common in MC, PA, PE
***	Common in PE, PC, RT
****	Common in PE, RA, PC
@	Common in MC, PA, PE, BT
$	Common in MC, PA, PE, PC, BT
#	Common in PA, PE, RA, PC, RT
¤	Common in PA, PE
∞	Common in PA, PE, RA
µ	Common in MC, PE, PC, RT
¶	Common in PA, PE, RA, PC, RT, MD

M.S. (Pharm.) Pharmaceutics
SEMESTER - I

PE 510 - Pharmaceutical Preformulation - I (1 Credit)

1. **Preformulation studies:** Preformulation studies of drug substances, proteins and peptides. Fundamental and derived properties in preformulation profiling. Preformulation work-sheet.
2. **Role of pre-formulation in drug discovery:** material properties in lead selection, 'drugability' of new chemical entities, *in silico* and high throughput pre-formulation studies
3. **Role of preformulation in drug development:** Preformulation as a support for formulation development, identification of 'developmental challenges' during pharmaceutical development, dosage form specific studies.
4. **Salt selection:** Role of salt selection in drug discovery and development, theoretical concepts for selection of counter ions for salt formation, 'pKa rule' for salt formation, decision tree for salt selection, appropriate case studies.
5. **Solubilization:** Solubility and solubilization of non-electrolyte, drug solubilization in surfactant systems, use of co-solvents for development of liquid formulations, solid-state manipulations including use of metastable solid forms like amorphous state.

PE 520 – Biopharmaceutics and Pharmacokinetics (2 Credits)

1. **Introduction:** Definitions, ADME, concentration time profile, plotting the data, different fluid compartments and blood flow rate compartment models, biological half-life, elimination rate constant. Biopharmaceutics and pharmacokinetics in drug research.
2. **GIT Absorption of drugs:** Mechanism, physicochemical, biological and pharmaceutical factors affecting drug absorption through GIT. Techniques for the GIT absorption assessment.
3. **Drug disposition:** Total body clearance, renal clearance, mechanism of clearance, clearance ratio, factors affecting renal clearance, hepatic clearance, volume of distribution and its significance.
4. **Protein and tissue binding:** Factors affecting protein binding, kinetics of protein binding, determination of rate constant and different plots (direct, scatchard and reciprocal), Implication of protein binding on pharmacokinetic parameters
5. **Bioavailability and bioequivalence:** Definitions, federal requirements, methods of determination of bioavailability using blood and urinary excretion data. Protocol design for bioavailability assessment. Methods for bioequivalence determination.
6. **Pharmacokinetic characterization of drugs:** Pharmacokinetics of drugs following one/ two compartment open models with first order elimination kinetics as applied to rapid intravenous injection, Intravenous transfusion and oral administration. Determination of absorption rate constant using Wagner-Nelson, Loo Riegelman methods. Flip-flop models, method of residual. Urinary excretion data and its application in pharmacokinetic characterization of drugs. Pharmacokinetics of multiple dosing
7. **Dosage regimen:** Dosage regimen adjustment in patients with renal and hepatic diseases. Drug dosage in elderly, children and obese patients.
8. **Non Linear Pharmacokinetics:** Various causes of non-linearity, Michaelis-Menten kinetics, In-vivo estimation of Km and Vm. Case studies.
9. **Physiologic pharmacokinetics models:** Mean Residence Time; Statistical Moment Theory; Application and limitations of physiologic pharmacokinetic models.

10. **Miscellaneous Topics:** Chronopharmacokinetics, Drug toxicity and forensic pharmacokinetics, kinetics of maternal-fetal drug transfer, pharmacokinetics v/s pharmacological/ clinical response, metabolic kinetics.

Recommended Books:

1. Applied Biopharmaceutics& Pharmacokinetics, by Shargel, L., S. Wu-Pong
2. Biopharmaceutics and Pharmacokinetics: An Introduction by Notari, R. E.
3. Introduction to Biopharmaceutics, by Gibaldi, M.
4. Biopharmaceutics and Relevant Pharmacokinetics, by Wagner, J. G.
5. Textbook of Biopharmaceutics and Clinical Pharmacokinetics by Niazi, S.K.
6. Handbook of Bioequivalence Testing, by Niazi, S. K.
7. Modeling in Biopharmaceutics, Pharmacokinetics, and Pharmacodynamics: Homogeneous and Heterogeneous Approaches, by Macheras, P. and A. Iliadis
8. Comparative Pharmacokinetics: Principles, Techniques and Applications, by Riviere, J. E
9. Foundations of Pharmacokinetics, by Rescigno, A.
10. Clinical Pharmacokinetics and Pharmacodynamics: Concepts and Applications, by Rowland, M. and T. N. Tozer

PE 530 - Pharmaceutical Preformulation – II (1 Credit)

1. **Complexation:** Metal and organic molecular complexes, inclusion compounds with reference to cyclodextrins, chemical characteristics of inclusion complexes, methods of preparation of cyclodextrin complexes, applications in solubilization / taste masking / enhancement of permeability / enhancement of oral bioavailability
2. **Rheology**: Methods for evaluation of viscosity, concept of Viscoelastic, Newtonian/ non-Newtonian flow properties, thixotropy and their applications in development of dosage form, implications of viscosity on performance of liquid dosage forms like suspensions and emulsions, advanced techniques / equipment employed in the rheological characterization of pharmaceutical products.
3. **Micromeritics:** Particle size distribution, evaluation methods including advanced techniques like atomic force microscopy, significance of particle size in different dosage forms including aerosols, parenterals and solid dosage forms.
4. **Dissolution:** Theories of dissolution, release rates and constants, selection of dissolution media, bio-relevant media, Mechanisms of conventional release and controlled release, Dissolution data handling and correction factors, Dissolution equipments and IVIVC.

PE 540 - Regulatory considerations for Pharmaceutical Development - II (1 Credit)

1. International regulatory trends in pharmaceutical industry
2. Role of regulatory affairs department in pharmaceutical organization: regulatory audits, interactions with various other departments, single point contact with regulatory agencies.
3. Types of regulatory filings for pharmaceutical products: goals of regulatory registration procedures investigational new drug applications, introduction to various type of regulatory filings.
4. New drug applications: stages involved in NDA, different phrases of clinical trials, purpose of IND, types and categories of IND applications information to be given in IND applications
5. Chemistry, manufacturing and control (CMC) information in NDA: information related to drug substance like manufacturing process, specifications, description of tests methods. Information related to drug product: description of method of manufacturing, specifications and acceptable limits. Information related to placebo
6. Hybrid NDA : a difference from NDA, historical background, literature based hybrid NDAs and other sources of information for hybrid NDA, examples of types of products considered underhybrid NDA

7. Abbreviated New Drug applications (ANDAs): historical developments leading to creation of ANDA process, Hatch Waxman Act, patent term restoration, criteria for patent term extension, various types of Hatch Waxman Exclusivities, concept of therapeutic equivalence, ANDA review process

8. Paragraph IV certification ANDAs: different ANDA Patent certification options, Medicare Modernization Act, implications of this act on 30 month stay period and 180 day exclusivity, triggering and forfeiture of 180 day exclusivity, shared exclusivity

9. ANDA with suitability petition: case studies of drug products considered appropriate for filing under suitability petition

MC 511 - Spectral Analysis (2 Credits)

1. Ultra Violet (UV) and visible spectroscopy:

(a) Energy levels and selection rules: Definitions, molecular orbital approach for energy absorption, various modes of transitions.

(b) Correlation of structural variation with UV absorption: Factors influencing the position and intensity of absorptions, Inductive and resonance effects, effect of ring size, influence of stereochemical factors.

(c) Predicting UV absorption: Woodward- Fieser, Fieser-Kuhn and Nelson rules;

(d) Other factors: Non-conjugative effect, solvent effect, S-Cis band.

2. Infrared (IR) spectroscopy:

(a) Characteristic regions of the spectrum: Various modes of vibrations, Energy levels

(b) Correlation of structure with IR spectra: Influence of substituents, ring size, hydrogen bonding, vibrational coupling and field effect on frequency

(c) Applications: Determination of stereochemistry. Spectral interpretation with examples.

3. Nuclear Magnetic Resonance (NMR) spectroscopy:

(a) Fundamentals: Physical basis, magnetic nuclei, resonance, relaxation processes, signal-sensitivity.

(b) Instrumentation: Continuous-Wave (CW) instrument, Pulsed Fourier Transform (FT) instrument, Functions, Relation with sensitivity, Sampling.

(c) 1H NMR, correlation of structure with spectra: Chemical environment and shielding, chemical shift and originof its concept, reference compound, local diamagnetic shielding and magnetic anisotropy, relation with chemical shift, chemical and magnetic non-equivalence, spin-spin splitting and its origin, Pascal's triangle, coupling constant, mechanism of coupling, integral, NMR solvents and their residual peaks, protons on heteroatoms, quadrupole broadening and decoupling, effect of conformations and stereochemistry on the spectrum, Karplus relationship, diastereomeric protons, Heteronuclear coupling to 19F and 31P, virtual coupling, long range coupling-epi, peri, bay effects. Shift reagents-mechanism of action, spin decoupling and double resonance. Explanation of spectra of some compounds and drugs.

(d) 13C NMR, correlation of structure with spectra: Chemical environment, shielding and carbon-13 chemical shift, calculation, proton-coupled 13C Spetra, Proton-decoupled 13C spectra, Nuclear Overhauser Enhancement (NOE), Problem with integration, Distortionless Enhancement by Polarization Transfer (DEFT), Heteronuclear coupling for carbon to deuterium, carbon to 19F, carbon to 31P.Explanation of spectra of some compounds and drugs.

4. **Mass spectrometry (MS):** Molecular ion and metastable peak, fragmentation patterns, nitrogen and ring rules, McLafferty rearrangement, electron and chemical ionization modes, applications

Recommended Books:

1. Spectroscopy by Donald L Pavia, Gary M Lampman, George S Kriz, James A Vyvyan
2. Organic spectroscopy by William Kemp
3. Spectroscopic Methods in Organic Chemistry by Dudley H. Williams & Ian Fleming
4. Spectrometric Identification of Organic Compounds by Robert M. Silverstein, Francis X. Webster & David J. Kiemie
5. Applications of Absorption Spectroscopy of Organic Compounds by Dyer
6. Fundamentals of Molecular Spectroscopy by Colin N. Banwell & Elaine M. McCash
7. Spectroscopy by Pavia, Donald L. Lampman, Gary M. Kriz, George S

NP 510 - Separation Techniques (1 Credit)

1. **Separation Techniques:** Need for learning separation techniques, separation techniques in natural product research and drug discovery, extraction techniques.
2. **Chromatography:** General principles, classification of chromatographic techniques, normal and reverse phase, bonded phase chromatography, stationary phases, activity of stationary phases, elutropic series, and separation mechanisms.
3. **Column Chromatography and Short Column Chromatography:** Column packing, sample loading, column development, detection
4. **Flash Chromatography and Vacuum Liquid Chromatography:** Objectives, optimization studies, selecting column and stationary phases, selecting suitable mobile phases, automated flash chromatography, and reverse phase flash chromatography.
5. **High Performance Liquid Chromatography:** Principles, instrumentation, peak shapes, capacity factor, selectivity, plate number, plate height, resolution, band broadening, pumps, injector, detectors, columns, column problems, gradient HPLC, HPLC solvents, trouble shooting, sample preparation, method development.
6. **Planar Chromatography - TLC/HPTLC/OPLC:** Basic principles, sample application, development of plates, visualization of plates, 2D TLC, densitometry, Over pressure layer chromatography.
7. **Counter Current Chromatography:** Basic principles, droplet counter current chromatography, centrifugal partition chromatography, choice of solvents for SP and MP.
8. **Gas Chromatography:** Principles, instrumentation, split-splitless injector, head space sampling, columns for GC, detectors, quantification
9. **Biochromatography:** Size exclusion chromatography, ion exchange chromatography, ion pair chromatography, affinity chromatography general principles, stationary phases and mobile phases
10. **Hyphenated Techniques:** Introduction to GC-MS and LC-MS techniques and their applications in natural products.

Recommended Books:

1. Methods in Biotechnology, Natural Product Isolation by Sarker, Latif, Gray
2. Methods in Biotechnology, Natural Product Isolation by Richard Canell
3. Various Reviews and Research Papers

MC 540 - Industrial Process and Scale up Techniques (1 Credit)

1. **Status of pharmaceutical industry:** Status of bulk drugs, natural products and formulations in India vis-a-vis industrialized nations.
2. **Scale-up Techniques:** Pilot Plant Scale-up techniques: General Considerations including the significance of personnel requirements, Space requirements, raw materials, pilot plant scale-up considerations for solids, liquid orals, semi-solids, and relevant documentation. SUPAC Guidelines, Introduction to platform technology. Scale-up techniques for process optimization, maximization of productivity, in-process control techniques.
3. **Chemical technology of selected drugs:** Case studies with emphasis on rationale for selection of routes, raw materials, process control methods, pollution control procedures etc.

4. **Chemical technology of selected drugs:** Data collection during pilot plant trails, preparations of flow diagrams, material balance sheets and technical data sheets.
5. Process technologies for some selected natural products of commercial interest, e.g. 4-hydroxyisoleucine, penicillin.
6. Scale-up techniques for industrial pharmacy, typical standard operating procedures for different dosage forms; In-process control procedures.
7. **Pharmaceutical manufacturing equipment:** Equipment used to manufacture bulk drugs and formulations.

Recommended Books:

1. Process Chemistry in Pharmaceutical Industry by Kumar Gadamasetti, Vol I & II
2. Advanced Organic Chemistry by Jerry March
3. Pharmaceutical Process Chemistry for Synthesis: Rethinking the Routes to Scale-Up by Peter J. Harrington, Wiley
4. Practical Process Research and Development by Neal G. Anderson, Academic Press
5. Strategies for Organic Drug Synthesis and Design by Daniel Lednicer

GE 510 - Biostatistics (2 Credits)

1. **Statistics:** Introduction, its role and uses. Collection; Organization; Graphics and pictorial representation of data; Measures of central tendencies and dispersion. Coefficient of variation
2. **Probability:** Basic concepts; Common probability distributions and probability distributions related to normal distribution
3. **Sampling:** Simple random and other sampling procedures. Distribution of sample mean and proportion.
4. **Estimation and Hypothesis Testing:** Point and interval estimation including fiducial limits. Concepts of hypothesis testing and types of errors. Student- t and Chi square tests. Sample size and power
5. **Experimental design and analysis of variance:** Completely randomized, randomized blocks. Latin square and factorial designs. Post- hoc procedures
6. **Correlation and regression:** Graphical presentation of two continuous variables; Pearson's product moment correlation coefficient, its statistical significance. Multiple and partial correlations. Linear regression; Regression line, coefficient of determination, interval estimation and hypothesis testing for population slope. Introduction to multiple linear regression model. Probit and logit transformations
7. **Non-parametric tests:** Sign; Mann-Whitney U; Wilcoxon matched pair; Kruskal wallis and Friedman two way anova tests. Spearman rank correlation
8. **Statistical techniques in pharmaceutics:** Experimental design in clinical trials; Parallel and crossover designs. Statistical test for bioequivalence. Dose response studies; Statistical quality control

Recommended Books:

1. Fundamentals of Biostatistics by Bernard Rosner
2. Pharmaceutical Statistics: Practical and Clinical Applications by Bolton and Bon
3. Statistical Misconceptions by Huck

GE 520 - Fundamentals of Intellectual Property (IP) and Technology Management (1 Credit)

1. **Intellectual property:** Concepts and fundamentals; Concepts regarding intellectual property (IP), intellectual property protection (IPP) and intellectual property rights (IPR); Economic importance, mechanisms for protection of intellectual property-patents, copyrights, trademark; Factors effecting choice of IP protection; Penalities for violation; Role of IP in pharmaceutical

industry; Global ramifications and financial implications.

2. **Trade related aspects of intellectual property rights:** Intellectual property and international trade; Concept behind WTO (World Trade Organization), WIPO (World Intellectual Property Organization) GATT (General Agreement on Tariff and Trade), TRIPs (Trade Related Intellectual Property Rights), TRIMS (Trade Related Investment Measures) and GATS (GeneralAgreement on Trade in Services); Protection of plant and animal genetic resources; Biological materials; Gene patenting; Biotechnology / drug related IPR issues; Status in India and other developing countries; Case studies and examples; TRIPS issues on herbal drugs.

3. **Nuts and bolts of patenting, copyright and trademark protection criteria for patentability, types of patents; Indian Patent Act, 1970; WTO and modifications under TRIPS:** Filing of a patent application; Precautions before patenting-disclosures / non-disclosures, publication-article / thesis; Prior art search-published patents, internet search patent sites, specialized services-search requests, costs; Patent application-forms and guidelines, fee structure, time frames, jurisdiction aspects; Types of patent applications-provisional, non-provisional, PCT and convention patent applications; International patenting-requirement procedures and costs; Financial assistance for patenting- introduction to schemes by NRDC and TIFAC; Publication of patents-gazette of India, status in Europe and US; Patent annuity; Patent attornies technical aspects, criteria for selection, addresses, fee, rights and responsibilities of a patentee; Practical aspects regarding maintaining of a PATENT FILE; Patent infringment- meaning, scope, litigation, case studies and examples; Patenting by research students, lecturers and scientists-University / organizational rules in India and abroad; Thesis research paper publication, credit sharing by workers, financial incentives; Useful information sources for patents related information-internet sites, brouchers, periodicals, CD roms; Significance of copyright protection for researchers; Indian Copyright Law and digital technologies-Beme convention, WIPO copyright treaty (WCT), WIPO performance and Phonogram Treaty (WPPT); Protection for computer data bases, multi-media works; Trademarks legislation and registration system in India-an introduction, meaning of trademark criteria for eligibility; filling application for trademark registration; Trade secrets-scope modalitiesand protection; Case studies-drug related patents infringements.

4. **Technology development / transfer / commercialization related aspects:** Technology development-meaning; Drug related technology development; Toxicological studies, bioequivalence (BU), clinical trials-phase-I, phase-II and phase-III; Approved bodies and agencies; Scale-up, semi-commercialization and commercialization-practical aspects and problems; Significance of transfer of technology (TOT), bottlenecks; Managing technology transfer-guidelines for research students, scientists and related personal; TOT agencies in India-APCTD, NRDC, TIFAC, BCIL, TBSE/SIDBI; TOT related documentation-confidentiality agreements, licensing, MOUs, legal issues; Compulsory licensing excess to medicine issues; DOHA declaration, POST WTO product patent regime from 2005; Challenges for Indian pharmaceutical industry in the context of globalization of IP; Drug registration and licensing issues-national and global; Drug master file submissions, SOPS; Related registration and marketing issues; Case studies-antiretroviral drugs and others

5. **Funding sources for commercialization of technology:** Preparation of a project report, financial appraisal, business models; GOI schemes and incentives; NRDC, TePP, HGT, TDB schemes. PATSER; Venture capitalists, banks. Incubator concept-Case studies with respect to IIT, CCMB, IMTECH, and NIPER. Documentation and related aspects.

6. **Ethics and values in IP:** IP and ethics-positive and negative aspects of IPP; Societal responsibility; Avoiding unethical practices; Echo-responsibility-economic, social and environmental benefits of modern biotechnology; Voluntary adoption of pollution control strategies

Recommended Books:

1. Law Relating to Intellectual Property by B.L.Wadhera
2. IPR Handbook for Pharma Students and Researchers by P. Bansal
3. The Patents Act, 1970 (Bare Act with Short Notes) (New Delhi: Universal Law Publishing CompanyPvt. Ltd. 2012)
4. Patent Agent Examination by Sheetal Chopra and Akash Taneja
5. Making Innovation Happen- A simple and Effective Guide to Turning Ideas into Reality by MichaelMorgan
6. Making Breakthrough Innovation Happen by Porus Munshi
7. Innovation X- Why a Company's Toughest Problems are its Greatest Advantage by Adam

Richardson
8. Legal Drafting for the Layman by Nabhi Kumar Jain
9. How to Write and Publish a Scientific Paper by Rober A Day
10. Concise Law Dictionary-with Legal Maxims, Latin Terms and Words and Phrases by JusticeY.V. Chandrachud
11. Biomedical Research- From Ideation to Publication by G.Jagadeesh and others

GE 511 - Seminar (1 Credit)

1. Introduction, information retrieval systems
2. Writing term papers and reports
3. Organization of scientific material, thesis, dissertation and references
4. Reading research papers
5. Skill in oral presentation

Each student has to present a seminar before end of the semester

LG 510 - General Laboratory Experience - 15 hours / week (3 Credits)

1. Analytical techniques: (75 hours)

(a) Spectral analysis workshop (45 hours).

(b) Separation Techniques (30 hours)

2. To provide training on various softwares used in specialization – 100 hours

3. **Pharmacology (25 hours):** Animal handling, route of administration of drugs, dose response relationship, acute toxicity testing of drug, analgesic activity of a compound, estimation of protein and haematological parameters.

4. Biotechnology for pharmaceutical sciences (20 hours):

Day-1: Preparation for plasmid miniprep

Day-2: Plasmid miniprep and restriction digestion

Day-3: Gel electrophoresis and molecular weight calculation

Day-4: Discussion of result and viva

Specialization (50 hours):

(a) To prepare granules by dry granulation using Roller compactor.

(b) To optimize wet granulation process and perform scale up using Rapid MixerGranulator (RMG)

(c) Study the dissolution behaviour/drug release pattern of various conventional, sustained release, enteric coated and nanoparticulate dosage form and establishment of dissolution kinetics. Study of various factors affecting dissolution/ drug release.

(d) Study of drug protein binding and effect of competitive agent on binding kinetics.

(e) Plotting and interpretation of pharmacokinetics data and calculation of various pharmacokinetic parameter

M.S. (Pharm.) Pharmaceutics
SEMESTER - II

PE 620 - Drug Delivery Part – I Controlled Drug Delivery (2 Credits)

1. **Influence of drug properties and routes of drug administration on design of sustained and controlled release systems:** Rationale for controlled drug delivery, physico-chemical properties and biological factors influencing the design and performance of sustained/controlled release products.
2. **Polymeric materials in controlled drug delivery:** Polymer classification, physical and chemical characterization techniques of biomaterials, biocompatibility testing of biomaterials and their pharmaceutical/biomedical applications in tissue engineering
3. **Biopharmaceutic and pharmacokinetic aspects of peroral Controlled Drug Delivery Systems:** Strategies and design, factors affecting controlled release drug delivery system, Computation of desired release rate and dose for CRDDS, Pharmacokinetic design for DDS; in-vitro/in-vivo considerations, Intermittent zero order and first order release.
4. **Peroral controlled release delivery:** Design and fabrication of oral systems, dissolution controlled release, diffusion and dissolution controlled release, Ion-exchange resins, pH-independent formulations, osmotically controlled release, altered density formulations, Case studies.
5. **Parenteral drug delivery:** Major routes of parenteral administration; selection, design and development, biopharmaceutics of sustained/controlled release parenteral drugs products, polymer microspheres and their biocompatibility and dispersed DDS.
6. **Transdermal / skin drug delivery system:** Principles of skin permeation, factors affecting percutaneous absorption of drug, sorption promoters, absorption enhancement by energy input-Iontophoresis, sonophoresis and electroporation, pharmacokinetics of skin permeation, design, development and evaluation of transdermal patches, overview of microneedles in transdermal drug delivery.
7. **Implantable Therapeutics Systems** - Historical background; Advantages, disadvantage and applications; Types of implantable therapeutic systems including self-regulated and implantable pump systems; non-biodegradable and biodegradable polymers used for implantable systems, Tissue and blood compatibility testing.
8. **Proteins / peptides drug delivery systems:** Enzyme, epithelial/endothelial barriers, pharmacokinetics, different routes of delivery, practical considerations.
9. **Controlled release formulations for alternate routes of administration:** Consideration for controlled release in pulmonary/nasal drug delivery, bioadhesive systems and controlled ocular delivery (Ocusert systems).
10. **Regulatory approval pathways involved in controlled release formulations:** New Drug Application and abbreviated new drug applications
11. **Role of controlled release in veterinary formulations**: Background and present scenario, formulation considerations, major hurdles and challenges, future prospects

PE 630 - Pharmaceutical Product Development - I (1 Credit)

1. **Development of dosage forms:** Four stage development including preformulation, prototypedevelopment, scale up studies and commercialization.
2. **Design of materials and product specifications:** Creation and optimization of material andproduct specifications. In-process, product release and regulatory specifications
3. **Quality by design (QbD):** Fundamentals of pharmaceutical quality by design, identification of critical quality attributes, critical material attributes, critical process parameters and quality

risk management

4. **Methods of optimization –** OVAT and Design of experiments (DOE).Experimental designs, screening designs, factorial designs, composite designs, mixture designs, response surface methodology. Applications of systematic optimization techniques
5. **Process analytical technology (PAT)** and other control strategies for QbD
6. **Pharmaceutical Packaging:** Pack types for different dosage forms, packaging materials like glass and plastic, selection of proper material, labelling, preformulation screening of package components; barrier, child resistance and temper evident packaging systems; regulatory perspectives
7. **Testing of packaging materials** – equipment used, extractable and leachable
8. **Documentation protocols:** Forms and maintenance of records in product development department including clinical batches
9. **Case studies or regulatory guidelines** related to above topics shall be discussed after each topic

PE 640 - Pharmaceutical Product Development - II (2 Credits)

1. **Formulation additives**: Study of different types of additives e.g. antioxidants and preservatives, coloring and flavouring agents, emulsifying and suspending agents, basic materials for ointment bases, diluents and pharmaceutical solvents, regulatory perspectives: GRAS, IIG; new developments in excipient science, functional and co-processed excipients, international patented excipients. Implications of quantitative selection of each excipient in product development
2. **Drug-excipient interaction**: Drug-excipient interaction and incompatibilities like physical, chemical, pharmaceutical and therapeutic, analytical techniques to characterize drug-excipient incompatibility
3. **Improved tablet production:** Advances in materials, material handling, granulation equipments and granulation technologies; process automation. Processing problems in tablet and troubleshooting
4. **Tablet coating:** Advances equipment for coating, sugar coating, film coating, advanced coating technologies, aqueous based film coating, solvent free coating, coating defects
5. **Specialized tablets:** Formulation and evaluation of effervescent, orodispersible and chewable tablets
6. **Liquid and poly-disperse systems:** Suspensions: theoretical considerations, flocculated and deflocculated suspensions, adjuvants utilized, evaluation of suspension stability. Emulsions: descriptive theory of emulsification, formulation aspects, stability evaluation, advances in emulsion technology-multiple, micro and nano emulsions
7. **Sterile products and admixtures:** Formulation development, vehicles and other additives, containers and closures, evaluation of stability and sterility, requirements of facilities for production, recent advances and developments
8. **Drug Nano-crystals**: Generation – ‘top down approach, ‘bottoms up approach’ and ‘mixed approaches’, stabilization of nano-crystals and their applications
9. **Inhalation Products:** Nebulizers, Inhalers – Metered Dose Inhalers (MDI) and Dry Powder Inhalers (DPIs): Formulation aspects, types of excipients / propellants, devices used and stability aspects
10. **Herbal Formulation Development**: Importance of herbal formulations, Challenges, Formulation considerations, testing of herbal formulations, Regulatory guidelines, Stability consideration and future prospects

PE 650 - Drug Delivery Part II - Targeted Drug Delivery and Novel Carrier Systems (2 Credits)

1. **Fundamentals of targeted drug delivery:** Need of targeted drug delivery, ligand receptor interaction, levels of targeting, active and passive targeting, EPR effects, receptor mediated endocytosis, multifunctional approach in targeted drug delivery
2. **Chemical drug delivery systems:** Prodrug concept for drug design, drug targeting and antibody directed enzyme prodrug therapy (ADEPT), soft drug design, Lipid-drug/ polymer-drug conjugate
3. **Targeted brain delivery:** Overview of brain, specific targets for brain delivery, concept, Nasal tobrain delivery, types and key elements: Ideal carrier system and approach with case studies depicting utility in various brain diseases
4. **Targeted Tumor Delivery:** Structural features of tumor vasculature, levels of tumor targeting, tumor ligands for targeted drug delivery, biopharmaceutical characteristics of delivery systems for tumor specific delivery
5. **Colloidal drug delivery systems:** Preparation and characterization, biopharmaceutical considerations, evaluation and applications in drug delivery of the following delivery vectors
   (a) Liposomes and niosomes
   (b) Solid lipid nanoparticles and nanostructured lipid carriers
   (c) Polymeric nanoparticles – PLGA, chitosan, albumin, gelatin, alginate etc
   (d) Carbon nanotubes
6. **Overview of Specialized drug delivery systems:** Transfersomes, ethosomes, Layersomes, Bilosomes, Emulsomes, Virosomes, Cubosomes, Aquasomes, Pharmacosomes. Dendrimers, Polymeric micelles and Resealed Erythrocytes
7. **Stimuli responsive drug delivery systems:** Magnetically, thermal and pH-assisted drug delivery systems
8. **Miscellaneous targeting approaches:** Fundamentals of gene delivery,Overview of colon, liver, macrophage, mitochondrial and M cells targeting

PE 660 - Solid State Pharmaceutics (1 Credit)

1. **Levels of solid state properties:** Molecular / particle / bulk level properties, interdependenceof various levels on each other, role of different levels during pharmaceutical development and process development
2. **Molecular level:** Crystalline form, definition, concept of long range order, supramolecular arrangements, building blocks of crystals, unit cell, basic types of unit cells, demonstration of unit cells using crystal visualization softwares.
3. **Polymorphism**: Definition, significance of polymorphism in drug product performance, packing / conformational polymorphism, thermodynamics of polymorphs, enatiotropy / monotropy, concept of transition temperature, Burger and Ramberger rule
4. **Crystallization process**: Molecular aggregation events in crystallization, energetic of crystallization, enthalpy entropy balance, types of nucleation, Ostwald's step rule, experimental protocols for polymorph screening
5. **Implications of polymorphism in pharmaceutical development**: Regulatory concerns related to polymorphism, introduction to latest regulatory position on polymorphism
6. **Amorphous state**: Definition, long range order versus short range order, disorder in the amorphous state, concept of glass transition temperature (Tg), thermodynamic necessity for Tg, entropy crisis.
7. **Role of amorphous state in drug delivery**: Solubility advantage, spring parachute effect

during solubility studies, physical instability of the amorphous form, techniques for stabilization of amorphous form, amorphous solid dispersions.

8. **Co-crystals:** Introduction, synthons used for formation of co-crystals and applications in drugdelivery.
9. **Particulate level properties:** Crystal habit, generation of different crystal habits, implicationsof crystal habit on product performance and processing.
10. **Bulk level**: Bulk density, compressibility, flow properties, cohesivity, electrostatics, aggregation, agglomeration, role in formulation development and processing

Recommended Books:

1. Polymorphism in Pharmaceutical Solids Edited by Harry Brittain
2. Solid State Characterization of Pharmaceuticals Edited by Angeline and Mark Zarkrzewski
3. Crystal Engineering: A textbook, Edited by G. R. Desiraju, J. J.Vittal and A. Ramanan

PA 630 – Stability Testing (1 Credit)

1. **Drug development cycles and stability testing:** Role and types of stability studies duringdifferent stages of drug and product development
2. **Drug stability testing guidelines:** International, Regional, and National drug stability guidelines.
3. **WHO vs. ICH drug stability testing guidelines:** Comparison of different aspects in WHOguideline, and critical comparison with ICH parent guideline Q1A(R2).
4. **Specific discussion on following ICH guidelines:** Q1B, Q1C, Q1D, Q1E and Q5C
5. **Additional topics:**

Stress testing and stability-indicating method development*:* Role, regulatory aspects, protocols/approaches, practical considerations

Stability testing of phytopharmaceuticals*:* Regulatory requirements

Stability test equipment*:* Types of stability chambers (walk-in, stand-alone), design considerations, qualification and other critical issues.

Stability testing for Shipping & Distribution*:* Stability testing during transport

Stability testing of drug delivery systems

Recommended Books:

1. ICH (www.ich.org) and WHO (www.who.int) guidelines
2. Pharmaceutical Stress Testing (Predicting Drug Degradation) by Steven Baertschi and KarenAlsante
3. Drug Stability (Principles and Practices) by S. James, Jens ThurØCarstensen
4. Stability-indicating HPLC Methods for Drug Analysis by Quanyun A. Xu, Lawrence A. Trissel
5. Stability of Drugs and Dosage Forms by Sumic Yoshioka, Valentino Stella
6. Physical Pharmacy and Pharmaceutical Sciences by Patrick Sinko, Alfred Martin
7. New Drug Approval Process (Chapter 7) by Richard Guarino
8. Handbook of Stability Testing in Pharmaceutical Development: Regulations, Methodologies, andBest Practices by Kim Huynh-Ba
9. Stability and Characterization of Protein & Peptide of Drugs by Y. John Wang
10. Peptide and Protein Drug Analysis by Ronald Reid

PC 610 - Drug Metabolism (1 Credit)

1. Biotransformation of drugs.
2. Enzymes responsible for bio-transformations, microsomal a non-microsomal mechanisms
3. Factors influencing enzyme induction and inhibition.

4. Factors effecting drug metabolism.
5. Drug metabolism in fetus and new born.
6. Models of study drug metabolism.
7. Dose-effect relationships.
8. Excretion of drugs, biliary and fecal excretion.
9. Adverse drug reactions and drug interactions; Toxic reactions, allergic reactions, indiosyncracy.
10. Acute poisoning and its treatment

Recommended Books:

1. Introduction to Drug Metabolism, by G. Gordon Gibson and Paul Skett
2. Drug Metabolism Handbook Concepts and Applications Edited by Ala F. Nassar, Wiley

PC 611 - Pharmacological Screening and Assays (1 Credit)

1. Role of pharmacology in drug discovery
2. General principles of pharmacological screening.
3. Animal ethics, regulations for conducting animal experimentation.
4. 3 R's concept, alternatives to animal experimentations, Organs-on-chips
5. Pharmacological screening models.
6. Correlations between various animal models and human situations.
7. Correlation between in-vitro and in-vivo screens
8. Cell- based assay, CaCo-2 cell permeability assay. Single cell gel electrophoresis assay (COMET) assay
9. Zebrafish model to screen pharmaceutical molecules
10. Biochemical assays
11. Introduction to cell culture, role of genomic and proteomic techniques in the process of targetidentification in drug discovery, MALdiTof., microarray
12. High throughput screening and high content screening, transgenic animal model for drug screening
13. Specific use of reference drugs
14. Interpretation of results
15. Pharmacogenomics and Personal medicine

Recommended Books:

1. Drug Discovery and Evaluation: Pharmacological Assays by Vogel & Vogel
2. CPCSEA guidelines (http://cpcsea.nic.in)
3. Scientific journals in the area of pharmacology

GE 611 - Seminar (1 Credit)

Students are required to submit written record and present deta.ls of the project to be pursued in semester-Ill & IV This should include the purpose and basis of the project, stating aims, objectives and probable outcomes, be able to supplement these with necessary information, literature review towards it and process for the project itself

LS 610 - General Laboratory Experience 10 hours/week (2 Credits)

Preparation and evaluation of biomaterials for different DDS, development and evaluation of drug delivery systems, formulation development and evaluation.