SCHEME OF EXAMINATION
&
SYLLABUS

for

M.Tech. in Biotechnology
August 2016 onwards
(updated upto 2017)

UNIVERSITY SCHOOL OF BIOTECHNOLOGY
GGS INDRAPRASTHA UNIVERSITY
Sector 16C, Dwarka, New Delhi - 110 078

SCHEME OF EXAMINATION FOR M.TECH. (BIOTECHNOLOGY)

FIRST SEMESTER EXAMINATION (M.Tech)

S.No.	Code	Course title	L	T/P	Credits
		Theory courses (Pick 5 out of the subjects/bundles offered)			
1.	BT 501	Advances in Plant Biotechnology	3	1	4
2.	BT 503	Proteomics	3	1	4
3.	BT 505	Clinical Immunology and Immunotechnology	3	1	4
4.	BT 507	Genomics	3	1	4
5.	BT 509	Pharmaceutical Biotechnology	3	1	4
6.	BT 511	Biotechnology of Functional Foods and Nutraceuticals	3	1	4
7.	BT 513	Advanced Engineering Mathematics	3	1	4
8.	BT 515	Biochemical Engineering	3	1	4
9.	BT 517	Bioprocess Modelling and Control	3	1	4
10.	BT 519	Industrial Biotechnology	3	1	4
11.	BT 521	Biomanufacturing Principles and Practice	3	1	4
12.	BT523	Bioinformatics	2	2	4
13.	BT525	Virology	3	1	4
14.	CT513	Environmental Engineering and waste management	3	0	3
15.	MS101	Management Function and Organizational behaviour	4	0	4
		Laboratory course (Mandatory)			
16.	BT 551	Laboratory Techniques in Biotechnology-I	0	8	4
		Total number of required credits to be taken			**24**

SECOND SEMESTER EXAMINATION (M.Tech)

S.No.	Code	Course title	L	T/P	Credits
		Theory courses (Pick 5 out of the subjects/bundles offered)			
1.	BT 502	Biotechnology in Health care	3	1	4
2.	BT 504	Biodiversity and Biotechnology	3	1	4
3.	BT 506	Biophysics and Structural Biology	3	1	4
4.	BT 508	Epigenetics	3	1	4
5.	BT 510	Food Product Testing and Analysis	3	1	4
6.	BT 512	Stem Cell Biology and Technology	3	1	4
7.	BT 514	Bioethics, Biosafety and Intellectual Property Rights	3	1	4
8.	BT 516	Computational Biology: Algorithms and Applications	3	1	4
9.	BT 518	Multivariate Statistics and Design of Experiments	3	1	4
10.	BT 520	Systems and Synthetic Biology	3	1	4
11.	BT 522	Downstream Processing	3	1	4
12.	BT 524	Bioprocess Plant Design	3	1	4
13.	CT520	Design and analysis of Bioreactors	3	0	3
14.	MS 106	Marketing Research	4	0	4
		Laboratory course (Mandatory)			
15.	BT 552	Laboratory Techniques in Biotechnology-II	0	8	4
		Total number of required credits to be taken			**24**

THIRD SEMESTER EXAMINATION (M.Tech)

S.No.	Code	Course title	L	T/P	Credits
16.	BT651	Journal Club Seminar Presentation		2	2
17.	BT653	Project Progress Report and *viva-voce* through Seminar			14
		Total number of required credits to be taken			**16**

FOURTH SEMESTER EXAMINATION (M.Tech)

S.No.	Code	Course title	L	T/P	Credits
18.	BT652	Journal Club Seminar Presentation		2	2
19.	BT654	Project Dissertation and *viva-voce* through Seminar			14
		Total number of required credits to be taken			**16**

Notes:

1. M.Tech. is delinked from B.Tech.-M.Tech. dual degree and operates as an independent course from 2016-17. The overall number of credits required to qualify for the degree shall remain the same.

2. There shall only be one M.Tech. (Biotechnology) programme in USBT from 2016-17, incorporating several elective subjects under the choice-based credit system. All M.Tech.students are required to take at least 80 credits and obtain at least 75 credits to qualify for the M.Tech. degree.

3. All students admitted into B.Tech.until 2015-16 and meet the eligibility conditions under the B.Tech./M.Tech. dual degree programme shall be admitted and absorbed into the delinked M.Tech. Scheme. Any issues arising during the transition period will be addressed by the Academic Programme Committee.

4. In addition, 10 seats for M.Tech. shall be filled through competition based on GATE score (in Biotechnology) from 2015-16. Following the transition of all students from the dual degree programme to the delinked M.Tech. programme, the entire intake sanctioned by AICTE (currently 20 for GATE fellowship) shall be filled through competition.

5. The eligibility conditions for competitive admission through GATE score include: Four year BE/B.Tech in Biotechnology or Biochemical Engineering or equivalent, OR M.S./M.Sc. in Biotechnology or Life sciences or Biosciences or Biochemistry or Microbiology or Genetics or equivalent discipline as defined by the Academic Programme Committee from time to time.

6. All the approved courses/electives may not necessarily be offered. The Academic Programme Committee is authorized to decide the combination of courses/electives offered each semester as per the availability of faculty and infrastructure.

7. As per the applicable Ordinance (11), the Internal:External evaluation ratio shall be 25:75 for theory courses and 40:60 for lab courses and projects.

8. Faculty mentors/supervisors shall be essential for the 3rd and 4th semesters, but students may be allotted their mentors/supervisors even earlier by the Academic Programme Committee. The mentor/supervisor/co-supervisor can also be an external person in case the project is carried out entirely outside GGSIPU, especially under overseas/industry training programmes or collaborations. The evaluation of practicals, journal club, project report/dissertation and open viva voce for 3rd and 4th semesters shall be done as per the Internal/External evaluation ratio of 40:60.The internal evaluation of students in all such courses shall be done by internal examiner(s) constituted by the Academic Programme Committee.

Rationale for revised curriculum for M.Tech. (Biotechnology)

The primary motivation for this revision is the unmet need of the biotechnology industry, which is growing at a fairly fast pace, for trained and skilled manpower. The fastest growing segment is in biomanufacturing, which also has the capability of generating employment. The skill set required is an understanding of modern biology coupled with a very strong analytical ability in engineering. This is required since much of the biomanufacturing facilities need to be designed from pilot scale data, executed and run in optimal fashion. Students with M.Sc. and M.Tech. degrees in traditional biotechnology do not currently have this skill set, because of poor training in engineering and therefore have to settle for Ph.D., research and teaching careers.

In order to address the manpower needs for industrial careers, this curriculum has introduced several courses in bioengineering and technology for those opting for industrial careers. The courses focus on various aspects of biochemical engineering, industrial biotechnology and biomanufacturing practices. Given that the background for these subjects may not have been covered (at least not as quantitatively) in the B.Tech. or M.Sc. programmes, they need to be supplemented with engineering mathematics, statistics, modeling, control theory, etc.

This has been done without compromising the analytical research training needed for students opting for higher academic careers through Ph.D. The advanced science subjects offered here build on the previous training in science subjects at the B.Tech. and M.Sc. levels. The core subjects of biochemistry, molecular biology, biophysics, structural biology, bioinformatics etc. are revisited with more depth and analytical rigour. In addition, advanced courses in frontier areas of research like stem cell biology, nanotechnology, genomics and functional genomics, proteomics, bioinformatics, structural biology etc., have been added to provide the student with specialized exposure.

This M.Tech. course structure is premised on lateral entry, designed in such a way that there is some scope for students who may not have particularly strong biology or Engineering background to cope up with the course. This also considers the possibility that some students might like to use this course to cross over from a chemical engineering to biology and vice-versa using this course as a bridge. So, the only compulsory courses are those related to practical training in laboratory techniques (one in each semester), whereas the theory courses are all electives which may be offered in various combinations. Students will be required to pick five electives from those offered in each semester.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-501	**Advances in Plant Biotechnology**	**3**	**1**	**4**	**40**

Objective: This course is meant to familiarize students with the advances in plant and crop biotechnology, including the various agronomically important traits that have been addressed towards crop improvement. In addition, the students appreciate the use of plants as biofactories for nutraceutical, biomedical, industrial and other products. By building further on the knowledge gained through this course and the skills imparted in other laboratory courses, the student should be able to make a career in plant biology or crop biotechnology.

1. Molecular breeding: Role of molecular markers in accelerating crop improvement, need to develop diverse types of marker systems for various crops, marker assisted selection and breeding; role of QTLs and their mapping. Case studies. **(5)**

2. Molecular and biochemical basis of plant resistance to biotic stresses, engineering plants for resistance to viruses, fungi, bacteria, weeds etc their commercialization and success stories and limitations. **(5)**

3. Molecular and biochemical basis of plant resistance to various abiotic stresses like drought, salinity, heavy metals, extreme temperatures (low/high) along with approaches to engineer plants to tolerate them, commercialization and success stories of the efforts so far. **(5)**

4. Genetic Engineering Strategies in plants for quality traits, herbicide resistance, modification of nitrogen fixing capability, and achievements so far versus role of alternate strategies. **(5)**

5. Chloroplast genetic engineering: Chloroplast transformation methods and design of vectors, applications in engineering herbicide resistance, production of biopharmaceuticals, edible vaccines, and success achieved so far along with limitations. **(5)**

6. Molecular farming: Advantages and scope of plants for production of nutraceuticals, edible vaccines, plantibodies, enzymes, oils and other desirable metabolites at industrial scale, development of different types of bioreactors, commercial products available and success stories so far. **(5)**

7. Plant Microbe interaction: Host-pathogen interaction, host-symbiont interaction, host-*Agrobacterium* interaction, scope of their exploitation for benefiting plants and mankind. **(5)**

8. Ensuring World Food Security: Efforts for sustainable food production, causes of food insecurity, consumer acceptance of GM food items, social economic issues involved, limitations in ensuring food security. Current status of food security in India. Current status of GM Crops in India compare to global level. **(5)**

Books/ References:

1. Slater, S, Scott, NW & Fowler, MR. (2008). Plant Biotechnology: the genetic manipulation of plants, second edition, Oxford.
2. Purohit, SD.(2013). Introduction to plant cell, tissue and organ culture, PHI Learning PVT Ltd, Delhi
3. Ramawat, KG and Goyal, S. (2014). Comprehensive Biotechnology, S Chand and Co. Pvt Ltd, Delhi
4. Articles from journals like Nature Biotechnology, Current Opinion, Trends and Annual Reviews.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-503	**Proteomics**	**3**	**1**	**4**	**40**

Objective: This course provides knowledge of the use of high throughput techniques to study the entire range of proteins present in any cell/tissue/organism under specific conditions, to obtain a global view of cellular processes at the protein level. Its various aspects include protein diversity, abundance, structure, function and regulation, including post-translational modifications and interactions with other biomolecules and the various associated techniques from a functional genomics perspective. This knowledge should help the students to absorb and retain the related practical skills better when the opportunity arises in academia/industry.

1. **Introduction:** Protein strcuture and function, Evolution of Proteomics from protein chemistry, the proteome and the genome, functional protein families, need for proteomics, scope and challenges of proteomics, systems biology in proteomics. **(4)**

2. **Abundance-based proteomics:** Sample preparation for proteomics, challenges associated with low- and high-abundant protein, Gel-based proteomics (2-DE, DIGE, BN-PAGE), Modifications in gel-electrophoresis techniques,Applications, Merits and Demerits of Gel-based proteomics, Gel-free proteomics [two dimensional and multidimensional liquid chromatography including MudPIT, Isotope based techniques like Isotope-Coded Protein Label (ICPL), COmbined FRActional DIagonal Chromatography (COFRADIC)], Applications, Merits and Demerits of Gel-free proteomics. **(5)**

3. **Detection of proteins in polyacrylamide gels and on electroblot membranes:** Organic dyes and silver stains, reverse stains, colloidal dispersion stains, organic fluorophore stains, metal chelate stains, electroblotting and recent advances in electroblotting. **(3)**

4. **Mass spectrometry in proteomics:** Overview, protein identification using MS data, protein identification using MS/MS data, introduction of Ionization source, Mass analyzer, Ion detector, Different types of mass spectrometers and modifications, Mass spectrometry applications, Merits and demerits of different types of mass spectrometers, Mass spectrometry data analysis, Search engines for MS protein identification.**(3)**

5. **Quantitative and Functional Proteomics:**Stable Isotope Labeling by Amino acids in Cell culture (SILAC), Isotope Coded Affinity Tag (ICAT), Isobaric Tagging for Relative and Absolute Quantitation (iTRAQ), SELDI, Immunoprecipitation (IP),different types of protein chips, detection and quantification of proteins bound to protein chips,emerging protein chips technologies. **(6)**

6. **Structural proteomics and Protein-Protein Interaction:**X-ray crystallography, Nuclear Magnetic Resonance (NMR), Application, merits and demerits of structural proteomics, Yeast-2-hybrid, Co-immunoprecipitation (Co-IP), Pull-down assays, Tandem Affinity Purification (TAP), Surface Plasmon Resonance (SPR), Atomic Force Microscopy (AFM). **(5)**

7. **Protein modification in proteomics:** Introduction, phosphoproteins; glycoproteins, Ubiquitin etc., challenges in PTMs, Techniques for characterization of PTMs. **(4)**

8. **Bioinformatics and proteomics:**Bioinformatics and proteomic technologies, Public protein databases and interfaces, protein expression profiling, identification of protein-protein interactions and protein complexes, data mining in proteomics, Modelling of proteomic networks, Need for model prediction, Generation of models in proteomic studies, Current endeavors and future challenges. **(6)**

9. **Recent advances in Proteomics.** **(4)**

Books /References:

1. Principles of Proteomics by R. M. Twyman. Second edition, *BIOS Scientific Publishers* (2013).
2. Introduction to Proteomics by Daniel C. Liebler. *Humana Press Inc*. (2002)
3. Proteome analysis interpreting the genome. Edited by David W. Speicher. Elsevier (2004)
4. Proteomics: From Protein Sequence to Function. S.R. Pennington and M.J. Dunn. *Viva Books* (2002).

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-505	**Clinical Immunology &Immunotechnology**	**3**	**1**	**4**	**40**

Objective: This course aims to provide students with an overview of the basic concepts and the principles of immune system. The course provides in depth understanding of the impact of different receptors cell signaling pathways in immune response. They will learn about the latest technologies used in detection of diseases. The students will also gain insight into the immune response to various infectious and noninfectious diseases. The students will be introduced to the recent technologies being employed for production of antibodies used in therapy and diagnosis.

1. **Fundamental concepts and anatomy of the immune system**: Components of innate and acquired immunity; complement and inflammatory responses; organs and cells of the immune system: structure and function of antigens and antibodies; antigen processing and presentation; major histocompatibility complex and immune responsiveness, immunological basis of self–non-self discrimination and immunological memory. **(8)**

2. **Receptors and cell signaling**: Immunoglobulin superfamily; B-cell receptor; T-cell receptor; cytokines, chemokines and their receptors; signal transduction pathways- the JAK/STAT pathway, The Ras-MAPK pathway, phosphatidylinositol pathway; B and T cell activation **(6)**

3. **Principles and applications of laboratory tests in Immunology**: Principles of antigen-antibody interactions; production and purification of polyclonal antibodies; antibody assays - precipitation, agglutination, immunoelectrophoresis and complement mediated immune reactions; advanced immunological techniques - RIA, ELISA, Western blotting, immunofluorescence, immunoelectron microscopy, flow cytometry and ELISPOT assay, surface plasmon resonance; total and differential counts in human peripheral cells, separation of monocytes from peripheral cells; CMI techniques- lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, HLA typing **(9)**

4. **Techniques for generation of antibodies**: Introduction and historical perspective, hybridoma technology, Genetic engineering techniques to make human antibodies- chimeric antibodies & humanized antibodies, therapeutic and diagnostic antibodies, Phage based treatments. **(4)**

5. **Vaccinology**: Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein based vaccines; Peptide vaccines; conjugate vaccines; reverse vaccinology **(4)**

6. **Clinical Immunology**- Immunity to Infection : Bacteria, viral, protozoan infections (with example from each group); Hypersensitivity – Type I-IV; Types of autoimmune diseases and their treatment; Transplantation and immunosuppressive therapy; Tumor immunology – Tumor antigens; Immune response to tumors and tumor evasion of the immune system, Therapeutic uses of cytokines. **(9)**

Books/References:

1. Kuby Immunology By Owen, Punt, & Stranford, 7th, Seventh Edition, 2013, Macmillan press.
2. The Elements of Immunology by FahimHalim Khan, Pearson Education, 2009.
3. Essentials of Immunology: Ivan Riot- Blakswell Scientific Publications, Oxford, 6th Edition.
4. Infection and immunity by John Playfair and Gregory Bancroft, 3rd edition, Oxford Univ.press. 2008.
5. Monoclonal antibodies: Principles and practice by J.W. Goding. 3rd edition, Academic Press.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-507	**Genomics**	**3**	**1**	**4**	**40**

Objective: This course has been designed to introduce students to the structural and functional aspects of genomes across organisms. It also aims to familiarize them with the developments in the experimental approaches used by researchers to understand the complexity and diversity of genomes. Recent advances in genomics have transformed the way in which biologists study cells and biological systems. Furthermore, there is an enormous potential for the future widespread use of genomics in various areas including medicine, pharmacology and agriculture, with implications in prediction, prevention, diagnosis and treatment of human diseases, as well as conservation and sustainable development. This would require qualified and trained manpower who can effectively use the knowledge of genomics for the benefit of humans.

1. **Genome Architecture**: Structure and Organization of prokaryotic and eukaryotic genomes; Organellar genomes; Genome sizes-C-value paradox; Metagenome; Synthetic genome. **(4)**

2. **Sequencing and Annotation of Genome**: Classical approaches to sequencing DNA; Automated sequencing; Genome sequencing approaches-Hierarchical and Shotgun approaches, Genome assembly; Next Generation Sequencing Technologies; Annotation of genome. **(6)**

3. **Comparative Genomics**: Genomes of model organisms-yeast, *C. elegans*, *D. melanogaster*, Zebrafish, Mice, *Arabidopsis*, Rice and others; Synteny; Human Genome Project- Key features, ENCODE project, Ethical, Social and Legal implications. **(6)**

4. **Functional Genomics:**Concept, contribution to system biology and system medicine, socio-ethical aspects of functional genomics in biomedicine and biotechnology.

5. **Genome Variation**: Types of genome variation; Techniques to study variation; Connections to disease, agriculture and evolution. **(4)**

6. **Analysis of Gene Expression**: Northern blot; RNAse protection assays; RT-PCR; Real-time PCR; Subtractive hybridization; DD-PCR; RAP-PCR; Microarray technology; SAGE; RNA-Seq. **(5)**

7. **Genomes to Phenotypes**: Reverse genetics; Genetic interaction screens; Genome-wide mutant libraries; Gene-knockouts; RNA interference screens; Chemical genetics; Genome editing-CRISPR and other genome editing tools. **(6)**

8. **Molecular Interactions**: Pull-down assays; Immunoprecipitation; ChIP; ChIP on chip; Phage-display; TAP-tagging; Yeast two hybrid assay and its variations. **(6)**

9. **Recent Advances in Genomics** **(3)**

Books/References:

1. Systems Genetics Ed.- F. Markowetz and M. Boutros (2015) Cambridge University Press.
2. Bioinformatics and Functional Genomics 3rd Edition (2015) by J. Pevsner, Wiley-Blackwell.
3. Genetics and Genomics in Medicine 1st Ed. (2014) by T.Strachan, J.Goodship, P.Chinnery, Garland Press.
4. An Introduction to Genomics 2nd Edition (2012) by A. M. Lesk, Oxford University Press.
5. Genomics and Bioinformatics: An Introduction to Programming Tools for Life Sciences 1st Edition (2012) by T. Samuelsson, Cambridge University Press.
6. From Genes to Genomes: Concepts and Applications of DNA Technology, 3rd Edition (2011) by J.W. Dale, M.v. Schantz and N. Plant, Wiley-Blackwell.
7. Principles of Genome Analysis and Genomics, 3rd Edition (2003) by S.B. Primrose and R. Twyman, Blackwell publishing
8. Reviews and research articles from journals.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-509	**Pharmaceutical Biotechnology**	**3**	**1**	**4**	**40**

Objectives: The student learns to identify appropriate sources of drugs and latest techniques for the search of new products from natural sources; novel techniques of production, purification and characterization of enzymes, biotechnologically produced biomedicines and pharmaceuticals. This course helps to develop cost and time effective methods to produce safe and quality biomedicines; as well as to develop skills in biotechnological techniques for obtaining and improving the quality of natural products. At the end of the course, the student should be able to apply theoretical bases and practical applications of pharmaceutical biotechnology in concerned industries and organizations. The student should be competent to work in pharmaceutical companies and R & D organizations to develop biomedicines and pharmaceuticals.

1. **Pharmaceuticals, biologicals and biopharmaceuticals:** Overview of pharmaceutical & biopharmaceutical biotechnology, current status and future prospects, pharmaceuticals of animal, plant and microbial origin. **(4)**

2. **The drug development process:** Drug discovery, rational drug design. Delivery of biopharmaceuticals, Pre-clinical trials, and clinical trials. **(4)**

3. **Drug manufacturing process:** International pharmacopoeia, guide to good manufacturing practice, manufacturing facility,sources of pharmaceuticals, production and analysis of final product. **(4)**

4. **Strategies in the search for new lead drugs/compounds:**In Silico and Ultra High-Throughput Screenings (uHTS), Systematic screening, **(4)**

5. **Natural products as pharmaceuticals and source of new lead structure: N**atural products or analogs as pharmaceuticals, Principles of combinatorial chemistry. **(4)**

6. **Production and formulation of Biotech Compounds:** Cultivation, production and Purification, downstream processing, Excipients, microbiological consideration, shelf life, Doses, Therapeutic response, Route of drug administration, Delivery system. **(4)**

7. **Drug metabolism:** pharmacokinetic and pharmacodynamics , Absorption, distribution, metabolism, elimination of drugs , pharmacogenetics and pharmacogenomics **(4)**

8. **Post-production handling and delivery:** Preparation, storage, handling and administration principles, physiologic and mechanistic approaches, approaches using devices, molecular approaches. **(4)**

9. **Pharmaceutical biotechnology product in clinical use:** Hematopoietic Growth Factors, Interferons and Interleukins, Insulin, Growth Hormones, Recombinant Coagulation Factors and Thrombolytic Agents, Monoclonal Antibodies, Follicle-Stimulating Hormone **.** **(6)**

10. **Regulatory Issues and Drug Product Approval for Biopharmaceuticals**. **(2)**

Books/ References:

1. Biopharmaceuticals and industrial prospective. Gray Walsh & B. Murphy, *Kluwer publishers* (2004).
2. Pharmaceutical Biotechnology: Concepts and Applications. by Gary Walsh (2007) Wiley
3. Biopharmaceuticals. Gray Walsh, *Wiley John & Sons, Inc*. (2003).
4. The practice of Medicinal chemistry. Camille G. Wermuth, Academic Press, (2003).
5. Pharmaceutical Biotechnology by Dann, J.A, Crommelin & Robert D., Sindelar, 2008, *Taylor & Francis.*
6. Pharmaceutical Biotechnology: Fundamentals and Applications. Crommelin**,** Daan J. A., Sindelar**,** Robert D., Meibohm**,** Bernd (Eds.).2013 Springer-Verlag
7. Pharmaceutical Biotechnology: Drug Discovery and Clinical Applications by Oliver Kayser (Editor), Rainer H. Müller (Editor).Wiley-Blackwell; (2004)
8. Handbook of Pharmaceutical Biotechnology by Shayne Cox Gad (Editor) Wiley-Interscience; (2007)

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-511	**Biotechnology of functional foods and nutraceuticals**	**3**	**1**	**4**	**40**

Objective: To understand various nutraceuticals and functional foods, their types, mechanisms of action, clinical testing and toxicity aspects, as well as the role of biotechnology in their production; national and international regulatory framework and growth potential in the world market.

1. Biotechnology of plant-based functional foods: Biofortification with essential micronutrients, phytochemicals, modification of macronutrients; production of hypoallergenic foods; reduction of antinutrients. Biotechnology of animal-based functional foods: meat products, dairy foods etc. **(4)**

2. Improving the bioavailability of polyphenols and flavonoids, factors affecting bio availability, strategy to improve bio availability of flavonoids. Function of next generation polyphenol "Oligonol". **(4)**

3. Increased production of nutriments by genetically engineered bacteria (Glutathione, Ala-Gln, Hydroxyproline, Hyaluronic Acid, N-Acetylglucosamine, Cystidine 5 – Diphosphate Choline). Improved and enhancement of phyto-ingredients using new technology of genetic recombination. **(4)**

4. Pro-biotics and Pre-biotics : Health benefits, Efficacy & Safety. Designers food, specialty foods, substitutes (eg. Milk replacers, low sodium slat, sugarless sweet meats, food for sports, geriatric). Nutraceuticals with reference to Indian Context and Ayurveda. **(4)**

5. Solubility and Product Recovery in super critical fluid separation process. Super fluid technology for extraction of bio active components. **(4)**

6. Dehydration technologies to retain bio-active components (artificial drying, drug drying, spray drying, freeze drying, vacuum drying, micro-wave vacuum drying, membrane separation in processing bioactive components (pre-concentration, fractionation, hybrid process, new membrane processes). **(4)**

7. Packaging technologies for functional foods: fruits & vegetables (processed plant products, fresh plant products), probiotics (yogurt, dried cultures), intermediate moisture products, oils and fats. choice of packaging materials. active packaging. Microencapsulation and nano emulsion technology for delivery of nutraceuticals and functional foods. **(4)**

8. Application of nanotechnology to functional foods and nutraceuticals to enhance their bioactivities: nanonisation of functional foods and nutraceuticals (functional foods, nutraceuticals, medicines). improvements in the bioactivity of functional foods and nutraceuticals (hepato-protective, antioxidant), nanotechnology functional foods and drug delivery systems. **(4)**

9. Microalgal biotechnology in the production of nutraceuticals: microalgae in food chain, scale of microalgal nutraceutical production, health concerns with microalgal products, lipid, carotenoids, production with microalgae. **(4)**

10. Future strategies for the development of biotechnology- enhanced functional foods and their contribution to human nutrition. US-FDA and FASSI regulatory aspects. **(4)**

Books/References:

1. Advances in food research by G.F.Stewart, 1966
2. Functional foods: Designer foods, pharma foods and nutraceuticals by Goldberg, 1994
3. Advances in food and nutrition research by Steve L. Taylor, 2007
4. Functional food Ingredients &Nutraceuticals by John Shi, Taylor & Francis 2007
5. Biotechnology in functional foods & nutraceuticals by Debasis Bagchi, Francis C. Lau and Dilip K. Ghosh, CRC Press, Boca Raton, 2010

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-513	**Advanced engineering mathematics**	**3**	**1**	**4**	**40**

Objective: To provide students with high order mathematical skills required for solving engineering problems in biotechnology. These skills are essential for modeling, design and optimization problems, which form the basis for design and operation of bio-manufacturing facilities. The students are expected to have prior exposure and training in basic analytical geometry, calculus, coordinate geometry etc. At the end of the course, the student should have developed familiarity with a wide range of mathematical tools and their applications, and also have the ability to use mathematical tools to solve complex modeling problems.

1. ORDINARY DIFFERENTIAL EQUATIONS **(4)**
   - 1.1. Order and degree of differential equations
   - 1.2. First order differential equations
   - 1.3. Second order differential equations
   - 1.4. Linear differential equations
   - 1.5. Simultaneous differential equations

2. SOLUTION BY SERIES **(4)**
   - 2.1. Infinite series
   - 2.2. Power series
   - 2.3. Method of frobenius
   - 2.4. Bessel's equation and properties of bessel functions
   - 2.5. Legendre polynomials

3. COMPLEX ALGEBRA **(7)**
   - 3.1. The complex number and argand diagrams
   - 3.2. Principal values
   - 3.3. Algebraic operations on the argand diagram
   - 3.4. Conjugate numbers
   - 3.5. De moivre's theorem
   - 3.6. Trigonometrical – exponential identities
   - 3.7. The complex variable
   - 3.8. Derivatives of a complex variable
   - 3.9. Analytic functions
   - 3.10. Singularities
   - 3.11. Integration of functions of complex variables, and cauchy's theorem
   - 3.12. Theory of residues

4. FUNCTIONS AND DEFINITE INTEGRALS **(3)**
   - 4.1. The error function
   - 4.2. The gamma function
   - 4.3. Other tabulated functions which are defined by integrals
   - 4.4. Evaluation of definite integrals

5. THE LAPLACE TRANSFORMATION **(6)**
   - 5.1. The laplace transform
   - 5.2. The inverse transformation
   - 5.3. Properties of the laplace transformation
   - 5.4. The step functions
   - 5.5. Convolution
   - 5.6. Inversion by elementary integration
   - 5.7. Inversion of the laplace transform by contour integration
   - 5.8. Application of the laplace transform to automatic control theory

6. VECTOR ANALYSIS **(6)**
   - 6.1. Tensors
   - 6.2. Addition and subtraction of vectors
   - 6.3. Multiplication of vectors
   - 6.4. Differentiation of vectors
   - 6.5. Hamilton's operator, ∇
   - 6.6. Integration of vectors and scalars
   - 6.7. Standard identities
   - 6.8. Curvilinear coordinate systems
   - 6.9. Applications

7. MATRICES **(7)**
   - 7.1. The matrix
   - 7.2. Matrix algebra
   - 7.3. Determinants of square matrices and matrix products
   - 7.4. The transpose of a matrix
   - 7.5. Adjoint matrices
   - 7.6. Reciprocal of a square matrix
   - 7.7. The rank and degeneracy of a matrix
   - 7.8. The sub-matrix
   - 7.9. Solution of linear algebraic equations
   - 7.10. Matrix series
   - 7.11. Differentiation and integration of matrices
   - 7.12. Lambda-matrices
   - 7.13. The characteristic equation
   - 7.14. Sylvester's theorem
   - 7.15. Quadratic form
   - 7.16. Application to the solution of differential equations
   - 7.17. Solutions of systems of linear differential equations

8. MODELLING **(3)**
   - 8.1. Examples from biological systems
   - 8.2. Applications in engineering design

Books/References:

1. Mathematical methods in Chemical Engineering, by V.V. Jenson and G.V. Jeffreys, Indian Reprint, 2012, Elsevier-Academic Press (Acc. 660.0151 JEN)
2. Advanced Engineering Mathematics by Erwin Kreyzig
3. Advanced Engineering Mathematics by Jaggi and Mathur

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-515	**Biochemical Engineering**	**3**	**1**	**4**	**40**

Objective: To introduce the students to the abiotic phase interactions in a biological system from an engineering point of view. This would primarily deal with developing a basic understanding of transport phenomena, with emphasis on heat and mass transfer. These are critical for modeling and scale up of biological processes, since they link the micro environment of the cell with the measurable macro environment. In addition, enzyme engineering is included, with a focus on its applied aspects. A prior exposure of the student to fundamentals of biochemical engineering is desirable, though not essential. However, a background in mathematics such as calculus is essential. At the end of the course, the student should be able to construct an abiotic phase model of various biological systems like fermentation modeling and ancillary processes. The student should also be able to design enzyme-catalyzed reactors and do scale-up. This course is complementary to the bioprocess modeling course, which deals with biotic phase modeling.

1. PRINCIPLES OF PHYSICAL TRANSFER PROCESSES **(6)**
   - 1.1. Heat conduction and molecular diffusion
   - 1.2. Fluid flow and momentum transfer
   - 1.3. Laminar vs. Turbulent flow
   - 1.4. Transfer phenomena in turbulent flow
   - 1.5. Film coefficients of heat and mass transfer and their estimation

2. TRANSPORT PHENOMENA IN BIOPROCESS SYSTEMS **(12)**
   - 2.1. Gas-liquid mass transfer in cellular systems
     - 2.1.1. Basis mass-transfer concepts
     - 2.1.2. Rates of metabolic oxygen utilization
   - 2.2. Determination of oxygen transfer rates
     - 2.2.1. Measurement of $k_l a$ using gas-liquid reactions
   - 2.3. Mass transfer for freely rising or falling bodies
     - 2.3.1. Mass-transfer coefficients for bubbles and bubbles swarms
     - 2.3.2. Estimation of dispersed phase interfacial area and holdup and correlations
   - 2.4. Forced convection mass transfer
     - 2.4.1. General concepts and key dimensionless groups
     - 2.4.2. Correlations for mass-transfer coefficients and interfacial area related to sauter mean (d_{sm}) bubble or droplet diameter
   - 2.5. Overall $k_l a$ estimates and power requirements for sparged and agitated vessels
   - 2.6. Mass transfer across free surfaces
   - 2.7. Other factors affecting $k_l a$
     - 2.7.1. Estimation of diffusivities
     - 2.7.2. Ionic strength
     - 2.7.3. Surface active agents
   - 2.8. Non-newtonian fluids
     - 2.8.1. Models and parameters for non-newtonian fluids
     - 2.8.2. Suspensions
     - 2.8.3. Macromolecular solutions
     - 2.8.4. Power consumption and mass transfer in non-newtonian fluids
   - 2.9. Scaling of mass-transfer correlations
   - 2.10. Heat transfer
     - 2.10.1. Heat transfer correlations
     - 2.10.2. Overall coefficients and film coefficients
     - 2.10.3. Forced flow of fluids in tubes and tube banks
     - 2.10.4. Liquids in jacketed or coiled vessels

3. THE KINETICS OF ENZYME-CATALYZED REACTIONS **(7)**
   - 3.1. The enzyme-substrate complex and enzyme action
   - 3.2. Simple kinetics with one and two substrates
     - 3.2.1. Michaelis-menten kinetics
     - 3.2.2. Evaluation of parameters in the Michaelis-menten equation
     - 3.2.3. Kinetics for reversible reactions, two-substrate reactions, and cofactor activation
   - 3.3. Determination of elementary-step rate constants
     - 3.3.1. Relaxation kinetics
     - 3.3.2. Investigation of transient-kinetics
   - 3.4. Patterns of substrate concentration dependence
     - 3.4.1. Substrate activation and inhibition
     - 3.4.2. Multiple substrates reacting on a single enzyme
   - 3.5. Modulation and regulation of enzymatic activity
     - 3.5.1. The mechanisms of reversible enzymatic activity
     - 3.5.2. Analysis of reversible modulator effects on enzyme kinetics
   - 3.6. Other influences on enzyme activity
     - 3.6.1. The effect of pH on enzyme kinetics in solution
     - 3.6.2. Enzyme reaction rates and temperature
   - 3.7. Enzyme deactivation
     - 3.7.1. Mechanisms and manifestations of protein denaturation
     - 3.7.2. Deactivation models and kinetics
     - 3.7.3. Mechanical forces acting on enzymes
     - 3.7.4. Strategies for enzyme stabilization
   - 3.8. Enzyme reactions in heterogeneous systems

4. APPLIED ENZYME CATALYSIS **(5)**
   - 4.1. Applications of hydrolytic enzymes
     - 4.1.1. Hydrolysis of starch and cellulose
     - 4.1.2. Proteolytic enzymes
     - 4.1.3. Esterase applications
     - 4.1.4. Enzyme mixtures, pectic enzymes etc.
   - 4.2. Other applications of enzymes in solution
     - 4.2.1. Medical applications of enzymes
     - 4.2.2. Nonhydrolytic enzymes in industrial technology
   - 4.3. Immobilized-enzyme technology
     - 4.3.1. Enzyme immobilization
     - 4.3.2. Industrial processes
     - 4.3.3. Medical and analytical applications of immobilized enzymes
     - 4.3.4. Utilization and regeneration of cofactors

5. IMMOBILIZED ENZYME KINETICS **(5)**
   - 5.1. Effects of external mass-transfer resistance
   - 5.2. Analysis of intraparticle diffusion and reaction and estimation of parameters
   - 5.3. Simultaneous film and intraparticle mass-transfer resistances
   - 5.4. Effects of inhibitors, temperature, and ph on immobilized enzyme catalytic activity and deactivation

6. ENZYME REACTOR DESIGN; ANALYSIS OF DATA **(2)**

7. SCALE UP PRINCIPLES **(3)**

Books/References:

1. Biochemical Engineering Fundamentals. By J.E. Bailey, D.F. Ollis, 2nd Ed. 1986, Mc.Graw Hill
2. Biochemical Engineering. By S. Katoh, J Horiuchi, F. Yoshida, 2nd Ed., 2015, Wiley-VCH

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-517	**Bioprocess Modelling and Control**	**3**	**1**	**4**	**40**

Objective: This course is complementary to the biochemical engineering course, which deals with abiotic phase modeling, while this course is focused on the biotic phase modeling. The emphasis is on quantitative analysis of cell growth, product formation, stoichiometry, energetic and kinetics, as well as on the implementation of biotic phase models in different modes of bioreactor operations, like batch, fed-batch and continuous systems. The course moves beyond black box models to structured models in order to get a better understanding of cell behavior. Students are also introduced to control theory, with emphasis on bioprocess control. A prior exposure of the student to fundamentals of bioprocess engineering and process control is desirable, though not essential. However, a background in mathematics such as calculus is essential. At the end of the course, the students should be able to develop comprehensive models of cellular behavior in bioreactors, in order to predict their performance as well as optimize and control operations.

1. MACROSCOPIC THEORY FOR OPEN SYSTEMS **(2)**
   - 1.1. Conserved and non-conserved quantities
   - 1.2. Balance equations for the chemical state vector of a system
   - 1.3. Elemental mass balancing
   - 1.4. Balance of energy and entropy

2. STOICHIOMETRY AND ENERGETICS OF MICROBIAL GROWTH AND PRODUCT FORMATION **(4)**
   - 2.1. Elementary balance equations for biomass
     - 2.1.1. Growth without product formation
     - 2.1.2. Anaerobic growth without external e^- acceptors or with e^- acceptors other than o_2
   - 2.2. Thermodynamic treatment of the energetic of growth
     - 2.2.1. Enthalpy and free energy changes during growth
     - 2.2.2. Thermodynamic efficiency
     - 2.2.3. Aerobic and anaerobic growth
     - 2.2.4. Energy availability in various oxidation/reduction reactions

3. THE LINEAR EQUATION FOR SUBSTRATE CONSUMPTION **(4)**
   - 3.1. The concept of maintenance energy
   - 3.2. Aerobic growth without product formation with maintenance
   - 3.3. Anaerobic growth with maintenance
   - 3.4. Calculation of true yields and maintenance during anaerobic and aerobic growth
   - 3.5. Biochemically structured balances of microbial metabolism
   - 3.6. Concept of ATP yield of growth
   - 3.7. Aerobic growth, the p/o ratio
   - 3.8. Biochemically structured model of aerobic growth on one substrate
   - 3.9. Growth on mixed substrates
   - 3.10. Growth with formation of product under anaerobic and partially aerobic conditions

4. KINETICS OF SUBSTRATE UTILIZATION, PRODUCT FORMATION, AND BIOMASS PRODUCTION IN CELL CULTURES **(5)**
   - 4.1. Ideal reactors for kinetics measurements
     - 4.1.1. The ideal batch reactor
     - 4.1.2. The ideal continuous-flow stirred-tank reactor (CSTR)
   - 4.2. Kinetics of balanced growth
     - 4.2.1. Monod growth kinetics
     - 4.2.2. Kinetic implications of endogenous and maintenance metabolism
     - 4.2.3. Other forms of growth kinetics
     - 4.2.4. Other environmental effects on growth kinetics

4.3. Transient growth kinetics
4.3.1. Growth-cycle phases for batch cultivation
4.3.2. Unstructured batch growth models
4.3.3. Growth of filamentous organisms

5. STRUCTURED KINETIC MODELS **(4)**
5.1. Compartmental models
5.2. Metabolic models
5.3. Modeling cell growth as an optimum process

6. PRODUCT FORMATION KINETICS **(4)**
6.1. Unstructured models
6.1.1. Parameter estimation for a simple batch fermentation
6.2. Chemically structured product formation kinetics models
6.3. Product formation kinetics based on molecular mechanisms: genetically structured models
6.4. Product formation kinetics by filamentous organisms
6.5. Segregated kinetic models of growth and product formation

7. DESIGN AND ANALYSIS OF BIOREACTORS **(6)**
7.1. Ideal and non-ideal reactors
7.2. Mixing time and residence time distributions in reactors
7.3. CSTRS with wall growth, with recycle and in-series
7.4. Fed-batch reactor operation and design of feeding profiles

8. INSTRUMENTATION AND CONTROL **(6)**
8.1. Physical and chemical sensors for the medium and gases
8.1.1. Sensors of the physical environment
8.1.2. Medium chemical sensors
8.1.3. Gas analysis
8.2. On-line sensors for cell properties
8.3. Off-line analytical methods
8.3.1. Measurements of medium properties
8.3.2. Analysis of cell population composition
8.4. Data analysis
8.4.1. Data smoothing and interpolation
8.4.2. State and parameter estimation
8.5. Process control
8.5.1. Direct regulatory control
8.5.2. Cascade control of metabolism
8.6. Advanced control strategies
8.6.1. Programmed batch bioreaction
8.6.2. Design and operating strategies for batch plants
8.6.3. Continuous process control

9. LAPLACE-DOMAIN ANALYSIS OF ADVANCED CONTROL SYSTEMS **(5)**
9.1. Cascade control
9.1.1. Series cascade
9.1.2. Parallel cascade
9.2. Feed-forward control
9.2.1. Linear feed-forward control
9.2.2. Nonlinear feed-forward control

9.3. Open loop-unstable processes
    9.3.1. Simple systems
    9.3.2. Effects of lags
    9.3.3. Pd control
    9.3.4. Effect of reactor scale-up on controllability
9.4. Processes with inverse response
9.5. Model-based control
    9.5.1. Direct synthesis
    9.5.2. Internal model control

Books/References:

1. New Directions in Bioprocess Modeling and Control: Maximizing Process Analytical Technology, 2006, Michael A. Boudreau , Gregory K. McMillan
2. Bioprocess Technology: Kinetics and Reactors Anton Moser

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-519	**Industrial Biotechnology**	**3**	**1**	**4**	**40**

Objective: This course combines industrial microbiology (isolation, preservation and improvement of microorganisms for the production of primary and secondary metabolites) with practical aspects of fermentation like media design, sterilization, inoculum development etc. No prior background in engineering is essential, but a background in microbiology would be useful. At the end of this course, the students should have learnt the basic techniques of handling microbes and their upstream development in industry, as well as the practical aspects of bioreactor operation to be able to optimize them in an industrial set up.

1. THE ISOLATION OF INDUSTRIALLY IMPORTANT MICRO-ORGANISMS **(3)**
   - 1.1. Isolation methods utilizing selection of the desired characteristic
     - 1.1.1. Enrichment liquid culture
     - 1.1.2. Enrichment cultures using solidified media
   - 1.2. Isolation method not utilizing selection of the desired characteristic
   - 1.3. Screening methods/high throughput techniques

2. THE PRESERVATION OF INDUSTRIALLY IMPORTANT MICRO-ORGANISMS **(3)**
   - 2.1. Storage at reduced temperature
     - 2.1.1. Storage on agar slopes
     - 2.1.2. Storage under liquid nitrogen
   - 2.2. Storage in a dehydrated form
     - 2.2.1. Dried cultures
     - 2.2.2. Lyophilization
   - 2.3. Quality control of preserved stock cultures

3. THE IMPROVEMENT OF INDUSTRIAL MICRO-ORGANISMS
   - 3.1. Products of primary metabolism **(6)**
     - 3.1.1. The selection of induced mutants synthesizing improved levels of primary metabolites
     - 3.1.2. Modification of the permeability
     - 3.1.3. The isolation of mutants which do not produce feedback inhibitors or repressors
     - 3.1.4. Examples of the use of auxotrophs for the production of primary metabolites
     - 3.1.5. The isolation of mutants that do not recognize the presence of inhibitors and repressors
     - 3.1.6. The isolation of auxotrophic mutants
     - 3.1.7. The isolation of resistant mutants
   - 3.2. Products of secondary metabolism **(8)**
     - 3.2.1. Mutants resistant to the analogues of primary metabolic precursors of secondary metabolites
     - 3.2.2. Mutants resistant to the feedback effects of the secondary metabolite
     - 3.2.3. The isolation of mutants resistant to the toxic effects of the secondary metabolite in the trophophase
     - 3.2.4. The isolation of mutants in which secondary metabolite synthesis gives resistance to toxic compounds
     - 3.2.5. The isolation of revertant mutants
     - 3.2.6. The isolation of revertants of mutants auxotrophic for primary metabolites which may influence the production of a secondary metabolite
     - 3.2.7. The isolation of revertants of mutants which have lot the ability to product the secondary metabolite
     - 3.2.8. The use of recombination systems for the improvement of industrial micro-organisms
     - 3.2.9. The application of the parasexual cycle
     - 3.2.10. The application of protoplast fusion techniques
   - 3.3. The application of recombinant DNA techniques **(4)**
     - 3.3.1.The production of heterologous proteins
     - 3.3.2.The use of recombinant DNA technology for the improvement of native microbial products

4. THE IMPROVEMENT OF INDUSTRIAL STRAINS BY MODIFYING PROPERTIES OTHER THAN THE YIELD OF PRODUCT **(3)**
   - 4.1. The selection of stable strains
   - 4.2. The selection of strains resistant to infection
   - 4.3. The selection of non-foaming strains
   - 4.4. The selection of strains which are resistant to components in the medium
   - 4.5. The selection of morphologically favourable strains
   - 4.6. The selection of strains which are tolerant of low oxygen tension
   - 4.7. The elimination of undesirable products from a production strain
   - 4.8. The development of strains producing new fermentation products

5. INOCULUM DEVELOPMENT IN BIOREACTORS **(2)**

6. STERILIZATION **(4)**
   - 6.1. Reactor sterilization
   - 6.2. Media sterilization principles
   - 6.3. Kinetics of microbial death; effect on media quality
   - 6.4. Aseptic operation and air sterilization

7. MEDIA OPTIMIZATION AND DESIGN **(7)**
   - 7.1. Media types and constituents
   - 7.2. Role of macro and micro nutrients
   - 7.3. Factorial design of experiments
   - 7.4. Placket Burman design
   - 7.5. Box-wilson design and related fractional factorial design search algorithms

Books/References:

1. Principles of Fermentation Technology. By P.F. Stanbury, A. Whittaker and S.J. Hall, 2nd Edition, 1995, Pergamon.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-521	**Biomanfacturing Principles and Practice**	**3**	**1**	**4**	**40**

Objective: Students develop conceptual clarity and knowledge about systems which brings and guarantee quality in products (Biopharmaceuticals, diagnostics and foods) manufactured for human use. The knowledge of GMP and GLP requirements is critical for students who opt for careers in biomanufacturing.

1. BIOMANUFACTURING PRINCIPLES: **(12)**
   - 1.1 Overview and design of biomanufacturing, quality by design approach, technical considerations, phases and scale up: life cycle of manufacturing, raw material considerations, compliance and quality in biomanufacturing , lean biomanufacturing
   - 1.2 Process analytical technology (PAT) duringbiomanufacturing: background and need tools for data acquisitions (softwares in fermenters, flow filtrations, chromatography, analysis and designprocess analyzers, process control tools and continuous improvement and knowledge management.
   - 1.3 Standard manufacturing operating procedures of biotechnology, including upstream and downstream processing of proteins, and quality control of protein production, and final fill and finish of product.
   - 1.4 Two case studies to be included at least: therapeutic protein, monoclonal antibodies, human vaccine.

2 QUALITY SYSTEM: **(4)**
   - 2.1 Introduction to quality system, main elements of a quality system
   - 2.2 Essential of quality system
   - 2.3 Practical implementation of a quality system
   - 2.4 Structure of quality manual, correlation between GMP requirements (WHO) and ISO 9001:2000

3. PRINCIPLES AND PRACTICE OF (GOOD MANUFACTURING PRACTICE) GMP **(20)**
   - 3.1 Personnel: Principles of human resource management, duties of senior management, organizational structures, qualification and profiles requirement, workplace and job descriptions, health monitoring and occupational health safety, training, functions owners subject to public law
   - 3.2 Premises: Official requirements, material & personnel flow and layout, air cleanliness classes and grades, construction elements, barrier systems, isolators and safety cabinets, building services, heating ventilation air conditioning (HVAC), process gases, qualification of premises and HVAC systems, pharma monitoring of HVAC systems, particle monitoring.
   - 3.3 Facilities and Equipment: Facility planning, materials, hygienic design in solids handling, system controllers and process control systems, technical documentation, calibration, maintenance, cleaning of facilities, containment (personnel protection) in solids handling
   - 3.4 Pharmaceutical water: Water qualities, generation of pharmaceutical water, distribution and storage of pharmaceutical water, qualification of water supplies, operation of water supplies, pure steam systems
   - 3.5 Qualification: Official requirements, preparation of the qualification, qualification documentation, design qualification (DQ), Installation qualification (IQ), operational qualification (OQ), Performance qualification (PQ), special cases of qualification
   - 3.6 Process Validation: Official requirements, Validation - a key element of quality management, validation planning and procedure, validation documentation, process validation and product lifecycle
   - 3.7 Cleaning Validation: Official requirements, how to validate cleaning procedures, cleaning validation master plan, establishing the scope of validation, acceptance criteria and limit calculation, sampling procedures, analytical procedure, documentation, maintenance of the validated status, cleaning validation documentation
   - 3.8 Computer system Validation: Introduction and terminology, legal aspects, system life cycle, system classification and risk management, validation of computerised systems, operation of computerised systems, external service providers
   - 3.9 Quality Risk Management: Principles and requirements, Potential applications and uses of quality risk management, the quality risk management process, methods and tools of quality risk management

3.10 Production: Sanitation, personnel hygiene, production hygiene, sanitation programme. environmental monitoring, GMP in the production process, weigh-in, identification, in-process control prevention of cross-contamination, empty chapter, reworking, warehouse and logistics

3.11 Sterile Production and Packaging: Introduction, Air lock concepts, manufacture of terminally sterilised products, sterilisation processes, sseptic processing, freeze-drying, testing for sterility, testing for endotoxins, testing for leakage and for particles, microbiological monitoring,packaging materials, packaging process, qualification of a servo-controlled blister packaging line, blow-fill-seal technology (BFS technology)

3.12 Laboratory Controls: Sampling, substances used in laboratories, qualifying laboratory instruments, calibration in the lab, validation of analytical methods, stability testing, test results outside defined criteria (OOX), raw data documentation, batch release, microbiological testing, pharmacopoeias, laboratory data management systems (LDMS)

3.13 Documentation: Official requirements, GMP-compliant documentation, batch documentation, standard operating procedures (SOPs), site master file, electronic batch recording and batch release, document management systems

3.14 Research and Development: general conditions and legal requirements, development phases and GMP requirements, interfaces to GLP and GCP, manufacture and control of clinical samples, documentation and recording of changes during development, development report, quality by design (QbD)

3.15 Inspections: Principles, inspection procedures, inspectors, organization of inspections, self-inspection, inspection of contract manufacturers, inspection of suppliers, questionnaire for preparing GMP-inspections, Inspection of API manufacturers

3.16 Active Pharmaceutical Ingredients: Introduction, regulatory principles, marketing authorisation documentation for active substances, GMP certificates, auditing active substance manufacturers, chemical active substances, biotechnological active substances

4. GMP IN REGULATION **(4)**

4.1. Information, national bodies and pharmaceutical associations

4.2. EU directives and guidelines, USA: CFR and FDA guidelines, ICH-guidelines, PIC/S guidelines, GMP of other regions, WHO guidelines

Books/References:

1. Introduction to Biomanufacturing. By Northeast Biomanufacturing Center and collaboration, 2012.
2. Introduction to Biomanufacturing, by Mark Witcher. In Encyclopedia of Industrial Biotechnology.
3. Good Manufacturing Practices for Pharmaceuticals (e-resource): A plan for total quality control. Sidney Willig and James Stoker.
4. Biotechnology Operations: Principles and Practices; by John M. Centanni, Michael J. Roy; CRC press
5. Lean Biomanufacturing, 1st Edition; Author Nigel Smart; Woodhead Publishing
6. GMP manual; Publisher Maas & Peither America, Inc. GMP Publishing

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-523	**Bioinformatics**	**2**	**2**	**4**	**40**

Objective: This course is designed to be run in a workshop mode where the students are given "hands on" practical experience with internet based bioinformatics tools and data. The teacher shall act more like a facilitator who guides and motivates the students to explore the internet based resources by themselves. The teacher will also provide simple projects that require use of the tools and databases. Theoretical knowledge will be provided only to the extent that is required to understand the correct use of the databases and software tools. At the end of this course, student would have developed programming skills and an understanding of the web-based analytical and bioinformatic tools, as well as obtained hands-on training in using them.

1. INTRODUCTION TO COMPUTERS AND INTERNET **(8)**
   - 1.1. Fundamental principles of the Linux operating system
   - 1.2. Basic Linux commands that will allow the student to navigate through files and directories
   - 1.3. Familiarity with at least one text based editor program for Linux (emacs or gedit)
   - 1.4. Concepts of IP address, http, https, sftp etc.
   - 1.5. Use of commands like *wget* for non-interactive downloading of data from the internet.
   - 1.6. Fundamentals of *bash*, *sed* and *awk* scripting. Ability to write simple scripts in these languages.

2. WEB-BASED DATABASES IN BIOLOGY: Navigating through the following websites and understanding the use of software tools and data available in each of them **(8)**
   - 2.1. NCBI (www.ncbi.nlm.nih.gov)
   - 2.2. DDBJ (http://www.ddbj.nig.ac.jp/)
   - 2.3. Expasy Bioinformatics Resource Portal (www.expasy.org)
   - 2.4. The European Bioinformatics Institute Portal (www.ebi.ac.uk)
   - 2.5. Kyoto Encyclopedia of Genes and Genomes (http://www.genome.jp/kegg/)
   - 2.6. UniprotKB (http://www.uniprot.org/)
   - 2.7. PFAM Database (http://pfam.xfam.org/)
   - 2.8. Protein Data Bank (www.pdb.org)

3. FAMILIARITY WITH SEQUENCE ANALYSIS TOOLS **(8)**
   - 3.1. Alignment tools (BLAST, CLUSTAL, etc.)
   - 3.2. Pattern Searching tools
   - 3.3. Domain / Motif Search Tools
   - 3.4. Promoter Analysis Tools

4. FAMILIARITY WITH MOLECULAR MODELLING SOFTWARE **(8)**
   - 4.1. Use of any one modelling and visualization software e.g., VMD, PyMol
   - 4.2. Homology Modelling. Use of any one homology modelling software like MODELLER
   - 4.3. Docking. Use of any one docking software like AUTODOCK-VINA

5. PROGRAMMING FOR BIOINFORMATICS **(8)**
   - 5.1. Perl
   - 5.2. HTML
   - 5.3. Java
   - 5.4. R
   - 5.5. MySQL

Books/References:

1. Fundamental concepts of Bioinformatics, by Dan E Krane and Michel Raymer, Pearson, 2003.
2. Bioinformatics and computational biology in drug discovery and development. William T. Loging, 2016.
3. Bioinformatics: A practical guide to the analysis of genes and proteins. Baxevanis and Ouellette, Wiley Student Edition, 2009.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-525	**Virology**	**3**	**1**	**4**	**40**

Objective: The students learn the principles of virology, virus life cycle and immune responses and its modulation during viral infection.They will also be exposed to development of drugs and vaccines. The course will emphasize the common mechanisms by viruses for successful reproduction, survival and spread within the host. Lastly, the students will get an understanding of the immune responses against viral infections and the prophylactic approaches to deal with viral infections.

1. Introduction to virology: History, taxonomy, Baltimore classification, host specificity of viruses, cell culture and animal models, infectious clones. (4)

2. Plant viruses:Importance of Plant viruses, cell-to-cell movement, vector transmission, virus-resistant transgenic plants. (3)

3. Insect viruses and bacteriophages: Impact, classification and perspectives (2)

4. Virus structure: Viral diversity with respect to structures, symmetry of viruses,triangulation number, factors governing viral capsid assembly and genome packaging. (4)

5. Virus attachment, entry and uncoating: Virus-host interactions in cellular entry, pathways involved in virus entry, uncoating of viral particles, nuclear import.Viral transmission directly from cell to cell. (4)

6. Translation and Replication of viral genomes: Translation strategies- diversity and regulation, genome diversity and replication strategies, host factors influencing viral replication, cellular stress and viral replication. (5)

7. Virus assembly and egress. Intracellular trafficking, assembly within nucleus and at cellular membranes, Assembly of virion components, incorporation of nucleic acid genome, post assembly modification and virus release. (4)

8. Antiviral response and immune-evasion strategies by viruses: Stages of viral life-cycle that trigger immune response, modulation of immune responses, specific examples of viral immune evasion. (6)

9. Viral pathogenesis and evolution. Concepts and mechanisms of pathogenesis, Patterns and processes of viral evolution. (2)

10. Diagnostic tests, antiviral agents and vaccines. Significance of viral detection, methods used in diagnostic virology.History and types of vaccines-live virus vaccines, inactivated virus vaccines and virus-like particle vaccines.Vaccine formulation and delivery, overview and mechanisms of antiviral drugs, drug resistance. (6)

Books/References

1) Fields Virology, 6 edition, 2013,By David M. Knipe and Peter Howley
2) Plant Virology Roger Hull 5th Ed 2014
3) Principles of Virology, Fourth Edition.2015,Jane Flint, Vincent Racaniello, Glenn Rall, Anna Marie Skalka
4) Latest review articles and papers on the subject

Code	Title	Lectures	Lab	Credits/week	Hrs/sem
BT-551	**Laboratory Techniques in Biotechnology-I**	**0**	**8**	**4**	**40**

Objective: To train the students coming from different backgrounds with the various laboratory techniques and practical skills needed to succeed in biotechnology and bring them at par. All the faculty members shall participate in imparting the training and skills associated with the various theory subjects. The actual experiments and training exercises will vary depending on the students' needs, courses being offered and the faculty member concerned, but will ensure non-redundancy within and between semesters. At the end of this course, the students should be able to apply their theoretical knowledge and practical skills towards solving academic/industrial problems.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
CT-513	**Environmental Engineering and Waste Management**	**3**	**0**	**3**	**30**

This course is offered by the School of Chemical Technology as per the course contents/credits approved by the Board of School of Studies of USCT.

1. Ecology and Environment. Source of air, water and solid wastes.

2. Air pollution. Micrometeorology and dispersion of pollutants in environment. Fate of pollutants.

3. Air pollution control technologies, centrifugal collectors, electrostatics precipitator, bag filter and wet scrubbers. Design and efficiencies.

4. Combustion generated pollution, vehicle emission control. Case studies.

5. Water pollution: Water quality modeling for streams. Characterisation of effluents, effluent standards.

6. Treatment methods. Primary methods: setting, pH control, chemical treatment.

7. Secondary methods: Biological treatment. Tertiary treatments like ozonization, disinfection, etc.

8. Solid waste collection, treatment and disposal. Waste recovery system.

Books & Reference:

1. L.Canter "Environment Impact Assessment", McGraw Hill..
2. E.P.Odum "Fundamentals of Ecology "V.B.Saunders and Co. 1974.
3. W.J.Weber "Physico-Chemical Process for water quality control, Wiley-international ed.
4. L.L.Gaccio Water and water pollution Handbook Marcel Dekkar, New York

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
MS-101	**Management Function and Organizational Behaviour**	**3**	**1**	**4**	**40**

Objectives: This course is offered by the School of Management as per the course contents/credits approved by the Board of School of Studies of USMS. It is designed to expose the students to fundamental concepts of management, its processes and behavioral dynamics in organizations.

Introduction to Management: Meaning and Nature of Management, Evolution of Management (in India and Abroad), Managerial Skills, Tasks and Responsibilities of a Professional Manager, Management by Objectives
Management and Society: The External Environment, Social Responsibility, and Ethics: An Overview.

Process of Management: Functions of Management: Planning-Process and Techniques, Organizing-Process and Organizational Structure, Directing-Principles and Process, Controlling-Process and Techniques, Problem Solving and Decision Making.

Fundamentals of Organizational Behaviour: Introduction and Meaning, Models of OB, Emergence of OB as a Discipline, OB Trends, Organizational Culture and Climate, Leadership Theories and Styles, Motivation-Theories and Practices, Managerial Communication, Organizational Change and Development.

Individual & Group Behaviour and Process in Organization: Individual Determinants of OB: Perception, Learning, Emotions, Attitudes, Personality, Stress and Its Implication on Management Practices, Group Dynamics and Work Teams, Power, Politics, Conflict and Negotiation, Interpersonal Behaviour and Relations, Transactional Analysis.

Organizational Behaviour Lab (Optional for Internal Assessment only): Since Organizational Behavior as a subject can be better understood through practical learning of behavioral measurement, so an OB lab can be introduced in the course. The student can be made to perform any two of the following Organizational Behavioral Tests. A practical file should also be prepared by the students.

- 16 PF
- FIRO-B
- Interpersonal Adjectives Scale
- MBTI
- Multidimensional Assessment of Personality
- Conflict Resolution Mode Inventory (Thomas – Kilmann)
- Multi Dimensional self Esteem Inventory
- Assessing Personality & Social Behaviour – The social value & attitude scales

Text Books

1. Robbins, S.P., Judge, T.A., Sanghi, S (2009). *Organizational Behaviour*, Pearson Education.
2. Stoner, R. James A.F., Edward Freeman Daniel R Gilbert Jr., *Management* 6TH Ed, Prentice-Hall of India.

Reference Books

1. George, J. M. & Jones, G.R. (2009). *Understanding and Managing Organizational Behaviour* 5th Edition, Pearson Education.
2. Green Berg, J. and Baron, R.A. (2008), *Behaviour in Organization*. Prentice Hall of India.
3. Schermerhorn, J. (2007). *Organizational Behaviour*, 10th Edition, Wiley
4. Mcshane, S.L., Von Glinow, M.A., Sharma, R.R. (2006) Organizational Behaviour. Tata McGraw Hill
5. Pierce, J.L. & Gardner, D.G. (2010). *Management and Organizational Behavior*, Cengage Learning.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-502	**Biotechnology in Health care**	**3**	**1**	**4**	**40**

Objective: This course will enable students to acquire knowledge on the fundamentals of healthcare biotechnology. It enables them to understand emerging and advanced concept in molecular pathogenesis of disease and role of biotechnology in diagnosis, prevention and therapeutics. This programme will facilitate the students to acquire knowledge in fields various aspects and molecular tools used in clinical application in alleviation of human disease. It will also empower the students to have advanced focus on the molecular basis of diseases and development of advanced therapeutics.

1. **Introduction:** Molecular basis of disease, Biotechnology in disease prevention, therapeutics and diagnosis, Personalized Medicine **(4)**

2. **Therapeutic Biomolecules:** Introduction, Nucleic acid, protein, carbohydrate and lipids, Role of biomolecules in diseases **(4)**

3. **Molecular diagnostics**: gene based diagnosis, tools for screening of infectious disease, genetic disease. **(4)**

4. **Immunological products:** Overview, Vaccines, Cancer immunotherapy, Monoclonal Antibodies in Solid Organ Transplantation Monoclonal Antibodies in Anti-inflammatory Therapy **(4)**

5. **Oligonucleotides:** Overview, Gene therapy, Antisense therapy, Ribozyme **(4)**

6. **Oligosaccharides:** Overview, Oligosaccharide synthesis, Heparin, Glycoproteins, Polysaccharide bacterial vaccines, Approaches to carbohydrate based cancer Vaccines **(4)**

7. **Radiological Agents:** Radiosensitizers and Radioprotective agents **(3)**

8. **Cardiovascular Drugs and endocrine drugs:** Myocardial infarction agents, Endogenous vasoactive peptides, Hematopoietic agents, Anticoagulants, antithrombotics and Haemostatics, Sex hormones and analogs **(5)**

9. **Chemotherapeutic Agents:** Synthetic antibacterial agents, antifungal, anti protozoal, Antihelminithic agents Antiamoebic agents, Antiviral agents **(6)**

10. **Drug Targeting:** Basic concepts and novel advances, Brain-specific drug targeting strategies, Pulmonary drug delivery, Cell specific drug delivery. **(5)**

Books/References:

1. Pharmaceutical Chemistry by Christine M. Bladon. *John Wiley & Sons, Ltd.*(2002).
2. Burger's Medicinal Chemistry and Drug Discovery (5th edition) by Manfred E.Wolff. A *Wiley* (2000).
3. Drug Targeting Organ-Specific Strategies by Grietje Molema and Dirk K. F. Meijer. Wiley-*VCH*. (2002).
4. Medical Biotechnology, by Judit Pongracz, Dr. Habil and Mary Keen. Churchill Livingstone (2008).
5. Healthcare Biotechnology: A Practical Guide 1st Edition by Dimitris Dogramatzis. CRC Press (2010)
6. Biotechnology in Healthcare: An Introduction to Biopharmaceuticals. Gavin Brooks, Pharmaceutical Press, (1998)
7. Biotechnology in Medical Sciences,By Firdos Alam Khan, CRC press, Taylor and Francis, (2014)

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-504	**Biodiversity and Biotechnology**	**3**	**1**	**4**	**40**

Objective: This course is meant to develop a perspective among students on the role of biodiversity as the feedstock for biotechnology and also as an essential natural resource for environmental sustainability, ecosystem services and livelihoods. They also learn about biodiversity identification, conservation, bio-prospecting, access and benefit sharing and the related national and international legal and policy regimes to fit into academic and regulatory roles.

1. **Concept and principles:** Origin of biodiversity/evolution, definition of biodiversity, types of biodiversity, levels of biodiversity, genetic resources, conservation of biodiversity, endangered species, impact of pollution on biodiversity, loss of biodiversity. **(4)**

2. **Conservation of biodiversity:** Need for conservation of biodiversity, types of conservation, role of biotechnology in biodiversity conservation, in vitro conservation, application of in vitro conservation, limitation of in vitro conservation. **(5)**

3. **Bio-diversity and germplasm:** Germplasm conservation, classical and new approaches to conservation, collection and exchange of germplasm, cryopreservation, stability of conserved germplasm. **(4)**

4. **Loss of biodiversity:** Causes and consequences of biodiversity loss, habitat loss and alteration, endangered species/exotic species, effect of pollutants on species loss, loss of genetic diversity, preventing biodiversity loss. **(5)**

5. **Management of biodiversity:** Identifying land for natural resources, managing wild life resources, biodiversity in a changing world, wealth of nature. **(4)**

6. **Tools to study bio-diversity:** DNA extraction from difficult species and preserved specimens; *Screening methods:* introduction of different types of molecular markers used for characterization of biodiversity. *DATA analysis:* measure of polymorphisms within and among populations, dendrograms. **(8)**

7. **Economic importance of biodiversity:** Bioprospecting of microbial, animal and plant biodiversity resources of India, scope of new sources of alternative foods, medicine etc. **(4)**

8. **8. Laws:** National environmental policy act, endangered species Act, national biodiversity authority (NBDA), plant variety protection & regulatory authority (PVPRA) Internal, Laws and special problems in developing countries. (**6)**

Books/References:

1. Plant biotechnology and Biodiversity Conservation by U. Kumar and A.K. Sharma published by *Agrobios* (India),(2008)
2. Essentials of conservation Biology 6th Edition by Richard B. Primack; Sinauer Associates, *Inc. Publishers*. W.K.(2014)
3. Molecular tools for Screening Biodiversity Edited by. Angela Karp, Peter G. Isaac and David S. Ingram published by *Chapman & Hall*. (1998)

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-506	**Biophysics and Structural Biology**	**3**	**1**	**4**	**40**

Objective: The students learn the physical principles of structure-function relationships in biological macromolecules such as proteins and nucleic acids, as well as the various approaches, techniques and instrumentation associated with structural biology. At the end of this course, they should be able to apply the biophysical principles and techniques to understand, model and predict biomolecular structures as well as their interactions in various academic and industrial situations.

1. Interactions in Biological Systems **(4)**

1.1. Intra- and intermolecular forces
1.2. van der Waals, Electrostatic, and Hydrogen bonding interactions
1.3. Hydrophobic interactions, Structure of Water and weak interactions

2. Structure of Proteins **(8)**

2.1 Conformational properties of polypeptides and Ramachandran Plot
2.2 Primary and secondary structure
2.3 Super secondary structures, fibrous protein structures
2.4 Tertiary and Quaternary structure
2.5 Structural features of membrane proteins

3. Structure of Nucleic Acids **(8)**

3.1 Conformational parameters of Nucleic acids
3.2 Chargaff's rule, DNA polymorphism,
3.3 Hyperchromicity, DNA supercoiling, and Circular DNA
3.4 Types and structures of RNA, mRNA, rRNA and tRNA
3.5 DNA-Protein interactions

4. Equilibrium and Kinetics **(8)**

4.1 Scatchard and Hill Plots for studying binding equilibrium of macromolecule-ligand complexes
4.2 Folding-Unfolding equilibrium and denaturation of proteins and nucleic acids
4.3 Effect of temperature and solvent conditions on the thermodynamics of folding-unfolding equilibrium
4.4 Kinetics of protein folding

5. Techniques for studying Macromolecular Structure and interactions **(12)**

5.1 Analytical Ultracentrifugation, Sedimentation velocity and equilibrium, determination of mol. weights
5.2 UV-Visible Absorbance and Fluorescence spectroscopy
5.3 Circular Dichroism spectroscopy
5.4 Microcalorimetry (DSC and ITC) and its applications
5.5 X-ray crystallography
5.6 Nuclear Magnetic Resonance (NMR)

Books/References:

1. Proteins: Structure and Molecular Properties by T. E. Creighton
2. Nucleic Acids: Structure, properties and function by V. A. Bloomfield and D. M. Crothers
3. Biophysical Chemistry Part I and II by C. R. Cantor and P. R. Schimmel
4. Physical Biochemistry by K. E. Van Holde
5. Physical Biochemistry by David Freifelder
6. Introduction to Protein Structure by C. Branden and J. Tooze
7. Protein Physics by A. V. Finkelstein and O. B. Ptitsyn

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-508	**Epigenetics**	**3**	**1**	**4**	**40**

Objective: This course has been designed to introduce fundamentals of epigenetic gene regulation to M.Tech. (Biotechnology) students. The curriculum will provide an in-depth look into the genomic landscape and chromatin with specific emphasis on covalent modifications that regulate its existence in different forms in cell/tissue-specific/developmental stage-specific manner. A holistic view of the different epigenetic pathways converging to silence and activate genes during plant and animal development will be taught by a combination of lectures, discussions and introduction to recent reviews on these topics.

1. Basic discoveries on genetic materials, Centromeres and Telomeres, Distribution of repeat and transposable elements (TE), Chromatin structure, Synteny. **(4)**

2. Introduction to histones and histone variants, chromatin packing, transcription factors and gene expression; Non-coding RNAs. **(4)**

3. DNA methylation, Histone modifications, Epigenetic regulators: Eukaryotic cytosine DNA methyltransferases (C5), histone methyltransferases, Histone Acetylases (HAT) and deacetylases (HDAC), Chromatin remodeling factors, DNA methylation and other epigenetic signature patterns across eukaryotic genomes, RNA methylation and hydroxymethylation of DNA. **(6)**

4. Polycomb group complexes in plants and animals, gene silencing mechanisms, RNA-directed DNA methylation: Polymerase IV and Polymerase V complexes, heterochromatin formation; RNA interference (RNAi). **(5)**

5. Regulation of chromatin structure and gene regulation by DNA and histone methyltransferases, methyl DNA binding proteins, TE silencing and its role in genome stability, Genomic Imprinting in Plants and Mammals – Mechanism, Dosage compensation; Epigenetic reprogramming and X-chromosome inactivation; Epigenetics and inheritance. **(6)**

6. Epigenetic regulation of plant developmental processes: flowering time, developmental switches, stress response; position effect variegation, paramutation; DNA demethylation, Emerging functions of histone demethylases **(5)**

7. Methodologies for methylome profiling: Methylation sensitive-insensitive restriction enzymes, Microarray based and Next generation sequencing based methods; Epigenotyping **(5)**

8. Epigenetics and disease: Rett syndrome, ICF syndrome, Cancer; Introduction to Epigenome based therapeutics **(5)**

Books/References:

1. Epigenetics, Second edition (2015) Ed. C. David Allis. Cold Spring Harbor laboratory Press
2. From Genes to Genomes: Concepts and Applications of DNA Technology, 3rd Edition (2011) by J.W. Dale, M.v. Schantz and N. Plant, Wiley-Blackwell
3. The Biology of Plants (Cold Spring Harbor Symposia on Quantitative Biology LXXVII) (2013). Edited by Terri Grodzicker, Rob Martienssen, David Stewart and Bruce Stillman. Cold Spring Harbor laboratory Press.
4. Genome Science: A Practical and Conceptual Introduction to Molecular Genetic Analysis in Eukaryotes (2014). Cold Spring Harbor Laboratory Press.
5. Genetics and Genomics in Medicine 1st Edition (2014) by T. Strachan, J. Goodship, P. Chinnery, Garland Press.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-510	**Food Product Testing and Analysis**	**3**	**1**	**4**	**40**

Objective: To develop familiarity with the various testing and analysis methods for raw materials and finished food products, as well as their associated instrumentation. At the end of this course, the students should be able to choose and applythe appropriatemethods and instruments used in quality control and research and development.

1. Sample preparation. Sampling, homogenization, particle size reduction, particle size measurement & sample storage, etc. **(2)**

2. Determination of moisture, ash content of food & Rheology. Drying & factors affecting rate of drying, methods (direct & indirect methods like GC, IR, NIR, Microwave & Mass Spectroscopy). Dry & wet ashing Texture, Viscosity & Rheology evaluation of solid foods. **(4)**

3. Sensory evaluation testing. Recruitment, screening, detection of basic tests. Test ranking, training, descriptive analysis, performance evaluation, method validation, sensory laboratory, etc. **(4)**

4. Enzymes in food analysis; Supercritical fluid extraction in food analysis; Rapid methods for detection of food pathogens, biosensors, automation and use of computers in food analysis **(4)**

5. Alcohols in foods & beverages. Separation of alcohols & clean up, derivatization, detection & quantitation. Applications in wines & musts, vinegars, beers & malt beverages, dairy products, fruits, vegetables & juices. **(4)**

6. Determinate of fat soluble and water soluble vitamin. Sample preparation, clean-up analysis by HPLC & simultaneous determination of multiple vitamins. **(4)**

7. Analysis of organic acids & organic bases including nitrosamines, volatile amines, & alkaloids. **(2)**

8. Application of modern techniques including spectroscopy, chromatography including GC, GC –MS, HPLC, gel permeation, ion-exchange, HPTLC, NMR, GC-FTIR. **(4)**

9. Identification tests. DNA methods, biological & microbiological methods, chemical methods, lipid method using radio-induced volatile hydrocarbons. thermo luminescence, electron spin resonance. Comparative methods of toxicity testing in (novel) foods. **(6)**

10. PCR based diagnostic techniques, Kit based detections in food analysis. RT-PCR, electrophoresis, electro blotting and capillary blotting; population & evolutionary genetics, gene mapping; microbial gene transfer mechanisms. **(6)**

Books/References:

1. Flavours in food by Voilley, Andre, 2006,
2. Spectral method in food analysis by MagdiMossoba, 1999
3. Sensory evaluation technique by Morton C. Meilgaard, 2007
4. Sensory evaluation of food: Principle & practices by Harry L. Lawless, Hildegarde, Heymann, 1999
5. Food Chemistry by W. Grosch by Belitz, H.D., Grosch, W. 2nd ed., 1999
6. Handbook of Food Analysis (Vol I & II) (1996) by Leo M.L. Nollet Marcel Dekker, USA

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-512	**Stem Cell Biology and Technology**	**3**	**1**	**4**	**40**

Objective: Stem Cell based therapy is becoming a reality. Already BMT is established form of Cell based therapy since 1985. This has helped patients getting freed of cancer, Thalessimia to name a few. Chromosome editing in ESC is under clinical trial. Tissue Engineering is under various stages of development. Quality control of Stem Cell continues to be a challenge. As Stem Cells are considered as a drug, Opportunities for preclinical and clinical trials has opened up a whole new window of future openings in the world of medicine.

1. **Heamatopoiesis and Stem Cell Concept:** Self Renewal and Differentiation based on CFU-S, Stochastic and Deterministic cell lineages. Applications in mouse and human and Cord blood banking. **(5)**

2. **Quality Control and Quality Assurance of Stem Cells:** Direct and indirect assays, Molecular Imaging, Immunological, Biochemical and other markers. **(4)**

3. **Types and Diversity of Stem Cells:** Totipotent, Pluripotent, Multipotent and Unipotent Stem Cells. ESC, Adult, Pluripotent, Induced Pluripotent and other types. Types arising from Ectoderm, Endoderm and Mesoderm, Trafficking of SCs and lineage tracing of differentiated SC. **(4)**

4. **Stemness:** Inducing Pluripotency, Epigenetic Silencing, Role of Microenvironment and their engineering, Cytokines and Growth factors, LlF-STAT pathway for self renewal and differentiation, System Biology. **(7)**

5. **Tissue and Organ Stem Cells:** Neural Stem Cells, Neural Crest Stem Cells, Liver Stem Cells, Pancreatic Stem Cells, Eye Development, Mesenchymal Stem Cells, Brain Development, Blood Stem Cells, Adipose Tissue, Germline Stem Cells, Heart Development. **(17)**

6. **3D Organ Development in Vitro:** Dynamic and Developmental Strategies, Success Stories, Limitations,Tissue Repair from Stem Cells, Future Plan of Action. **(3)**

Books/References:

1. Developmental Biology, Tenth Edition by Scott F. Gilbert.
2. Hematology by William J. Williams, Ernest Beutler, Allan JU Erslev, Marshall A. Lightman (1991).
3. Stem Cell Biology By Daniel R. Marshak, Richard Lavenham Gardner, David I. Gottlieb (2001).
4. www.stembook.org

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-514	**Bioethics, Biosafety and IPR**	**3**	**1**	**4**	**40**

Objective: To apprise the students of the various societal, governance and regulatory issues in biotechnology with special emphasis on ethics, safety and intellectual property rights. Through this course, the students develop a perspective on the importance of these aspects in the success of biotechnology products and services in the market. At the end of the course, they should be able to apply this perspective and the specific principles, laws, regulations etc., in academic and industrial settings for regulatory oversight and enforcement.

1. Biotechnology and Society, perceptions of the consumers, government, industry and civil society. **(3)**
2. Biotechnology and globalization, role of international economic and regulatory regimes. **(4)**
3. Bioethics: Codes of ethics in history, UN Declaration on bioethics and human rights, implications **(4)**
4. Research and regulatory ethics: Responsible Conduct of Research, misconduct, Falsification, fabrication, plagiarism, conflict of interest, regulatory misconduct, implications for public trust in biotechnology **(4)**
5. Biosafety: Concepts, biosafety in the laboratory, institution and outside, regulatory regime through institutional, state and national biosafety bodies, biosafety in rDNA work, hospitals, fields etc. **(4)**
6. International biosafety dimensions: Cartagena Protocol, biological warfare and bioterrorism. **(3)**
7. Food safety and environmental safety evaluation of genetically modified microbes, crops, animals. **(6)**
8. Intellectual Property Rights, their scope and duration of protection, their international harmonisation and transition from national to WTO regime, PCT, TRIPS+, FTAs, current domestic and global scenario **(3)**
9. Patents in biotechnology: Patentable subject matter, procedure of patenting, products and processes, novelty, non-obviousness, utility, enablement, disclosure **(5)**
10. IPR in agriculture: Plant variety Protection, Plant Patents and Utility patents
11. Strategic aspects of patent filing locally and abroad, patent litigation. **(2)**
12. Case studies and recent advances in regulatory affairs of relevance to biotechnology **(2)**

Books/References:

1. Encyclopedia of Bioethics
2. Biotechnology - A comprehensive treatise (Vol. 12). Legal economic and ethical dimensions VCH.
3. Thomas, J.A., Fuch, R.L. (2002). Biotechnology and Safety Assessment (3rd Ed). Academic Press.
4. Fleming, D.A., Hunt, D.L., (2000). Biological safety Principles and practices (3rd Ed). ASM Press.
5. The law and strategy of Biotechnological patents by Sibley. Butterworth publications
6. Recent reviews/articles and websites such as WIPO.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-516	**Computational Biology: Algorithms and applications**	**3**	**1**	**4**	**40**

Objective: This course is meant to develop a perspective among students on the computational approach to sequence analysis and interpretation in biological systems, and an understanding of the underlying algorithms, approaches and their applications. Together with the course on bioinformatics and multivariate statistics, it prepares the student to not only absorb and retain the related practical skills better, but also apply them as needed in academia/industry.

1. SEQUENCE COMPARISON **(7)**
   - 1.1. Concept of Edit Distance between a pair of sequences.
   - 1.2. The construction and use of the PAM and BLOSUM matrices.
   - 1.3. Algorithms for global (Needleman-Wunsch) and local (Smith-Waterman) alignment
   - 1.4. Alignment with gap penalities
   - 1.5. Construction of multiple sequence alignment using the Feng and Doolittle approach.

2. SEARCH FOR A SIGNAL IN A SEQUENCE. **(8)**
   - 2.1. Concept of sequence motifs and searching a protein or DNA sequence for the presence of a motif. PROSITE patterns and their use.
   - 2.2. Generalizing a sequence motif to a weight matrix and its comparison with motif-based searches.
   - 2.3. Principles of Hidden-Markov Models (HMM): Brief descriptions of forward, backward and viterbi algorithms and their use.
   - 2.4. Construction of profile HMMs. brief description of expectation-maximization algorithms. PFAM database.

3. SEQUENCE DATABASE SEARCHING **(8)**
   - 3.1. FASTA and BLAST algorithms.
   - 3.2. Statistical significance of a "Hit". Reliability of search results in protein and DNA sequence searches.
   - 3.3. Description of PSI-BLAST and understanding of situations when it is an improvement over ordinary BLAST and when it is not.

4. COMPUTATIONAL GENOMICS **(10)**
   - 4.1. Algorithms for genome assembly and Annotation: NGS Tools and Algorithm for NGS data analysis, Tools and Algorithm for Bisulfite Sequence data, Tools and Algorithm for small RNA structural variations, Tools and Algorithm for RNA Seq.
   - 4.2. Analysis of Microarray data: Designing of oligo probes; Image processing and normalization, measurement and quantification; Analysis of differentially expressed genes
   - 4.3. Analysis of SNPs and their use in Microbe, Plant and Human Biology.

5. PHYLOGENY **(7)**
   - 5.1. Algorithms for the construction of phylogenetic trees: UPGMA, Neighbor-joining, Maximum Parsimony and Maximum Likelihood approaches.
   - 5.2. Reliability of Phylogenetic Tree based analysis. Concepts of Homoplasy, Long Branch Attraction and other commonly encountered problems with tree construction and interpretation
   - 5.3. DNA barcoding: methods, tools and databases, applications and limitations, CBOL norms, BOLD

Books/References:

1. Algorithms on strings, Trees and Sequences. Dan Gusfield Cambridge
2. Computational Molecular Biology: An Algorithmic Approach. Pavel A. Pevzner PHI
3. Introduction to Bioinformatics Algorithms; Jones & Peuzner; *Ane Books*, India.
4. Microarray Bioinformatics; Dov Stekel; *Cambridge University Press*.
5. Web-resources and suggested reviews/ research papers.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-518	**Multivariate statistics and design of expts**	**3**	**1**	**4**	**40**

Objective: This course is meant to train the student in the statistical principles involved in optimizing multiple parameters/variables that often affect the performance of biological systems in academics/industry. Also this helps to design proper experiments in many areas of biotechnology, agriculture and industry to produce statistically stable data for better interpretation and robust conclusions.

1. MULTIVARIATE NORMAL DISTRIBUTION **(6)**
   - 1.1. The multivariate normal density and its properties
   - 1.2. Sampling from a multivariate normal distribution
   - 1.3. Multivariate normal likelihood
   - 1.4. Maximum likelihood estimation of m and s
   - 1.5. Assessing the assumption of normality.
   - 1.6. Detecting outliers and cleaning data.

2. COMPARISONS OF SEVERAL MULTIVARIATE MEANS. **(4)**
   - 2.1. Paired comparisons
   - 2.2. Comparing mean vectors from two populations.
   - 2.3. Comparing several multivariate population means (One way Manova)
   - 2.4. Two way multivariate analysis of variance.

3. MULTIVARIATE LINEAR REGRESSION **(4)**
   - 3.1. The classical linear regression model.
   - 3.2. Least squares estimation. Sum of squares decomposition
   - 3.3. Likelihood ratio tests for regression parameters.
   - 3.4. Model checking. Does the model fit?

4. PRINCIPAL COMPONENTS ANALYSIS **(2)**
   - 4.1. Methodology and geometric interpretation of PCA

5. FACTOR ANALYSIS **(4)**
   - 5.1. The orthogonal factor model.
   - 5.2. Methodology of factor analysis.
   - 5.3. Factor rotation
   - 5.4. Comparison between PCA and factor analysis

6. CANONICAL CORRELATION ANALYSIS **(2)**
   - 6.1. Canonical variates and canonical correlations.
   - 6.2. Interpretation of population canonical variables.

7. DISCRIMINATION AND CLASSIFICATION **(6)**
   - 7.1. Separation and classification of two populations.
   - 7.2. Classification of two multivariate normal populations.
   - 7.3. Evaluating classification functions
   - 7.4. Fischer's discriminant function
   - 7.5. Classification of several populations
   - 7.6. Fischer's method for discriminating

8. CLUSTERING AND ORDINATION **(6)**
   - 8.1. Similarity measures
   - 8.2. Hierarchical clustering: Single linkage, complete linkage and average linkage methods.
   - 8.3. Non-hierarchical methods: K-means and K-medioids.
   - 8.4. Multidimensional scaling: Euclidean scaling. Kruscal's stress function and its use.
   - 8.5. Correspondence analysis. Algebraic development of method and its interpretation in two dimensions.
   - 8.6. Procrustes Analysis: Methodology. Orthogonal and oblique procrustes.

9. DESIGN AND OPTIMIZATION **(6)**
    9.1. Modelling; differences between hard and soft modeling
    9.2. Error estimation and estimation of model parameters
    9.3. Factorial design, Partial factorial designs
    9.4. Optimisation techniques (steepest descent etc).
    9.5. Factor Analysis.
    9.6. Partial least squares modeling

Books/References:

1. Applied Multivariate Statistical Analysis. By Richard A. Johnson and Dean W. Wichern, PHI
2. Design and Optimisation in Organic synthesis, by Rolf Carlson

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-520	**Systems and Synthetic Biology**	**3**	**1**	**4**	**40**

Objective: To develop an understanding on gene functions, intracellular flux and cellular networks in cells. It will also help in understanding how cellular functioning can be utilized and modified for developing commercial products from microbial fermentation. At the end of the course, the student shall have an overview of what can be achieved by metabolic engineering of the microbe by systems and synthetic biology approaches, which have significant impacts on fermentation and downstream processing**.**

1. REVIEW OF CELLULAR METABOLISM AND COMPREHENSIVE MODELS FOR CELLULAR REACTIONS **(3)**

2. MATERIAL BALANCES AND DATA CONSISTENCY **(4)**

3. REGULATION OF METABOLIC PATHWAYS AND EXAMPLES OF PATHWAY MANIPULATIONS **(4)**

4. METABOLIC PATHWAY SYNTHESIS, FLUX ANALYSIS, METHODS FOR THE EXPERIMENTAL DETERMINATION OF METABOLIC FLUXES BY ISOTOPE LABELING **(4)**

5. METABOLIC CONTROL ANALYSIS AND ANALYSIS OF STRUCTURE OF METABOLIC NETWORKS **(4)**

6. COMPUTATIONAL MODELLING OF BIOLOGICAL NETWORKS **(8)**
    1. Flux balance analysis, elementary modes, extreme pathways, thermodynamic constraints, use of different optimizer functions
    2. Integration of transcriptomic, proteomic and metabolomic data in networks, iFBA, dFBA
    3. Signalling networks
    4. Evolutionary design principles
    5. Epigenetic regulation and applications

7. APPLICATIONS OF METABOLIC FLUX ANALYSIS **(4)**

8. EXAMPLES / CASE STUDIES **(5)**
    1. Reversal of NAD(P)H cofactor dependence by protein engineering.
    2. High isoprenoidflux *Escherichia coli* as a host for carotenoid production.
    3. Mutagenic inverted repeats assisted genome engineering (MIRAGE)in *Saccharomyces cerevisiae*: Deletion of gal7.
    4. Creation of new metabolic pathways or improvement of existing metabolic enzymes by in vivo evolution in escherichia coli.
    5. Recombination-based DNA assembly and mutagenesis methods for metabolic engineering.
    6. Metabolic engineering of antibiotic-producing actinomycetes using in vitro transposon mutagenesis.
    7. Using flux balance analysis to guide microbial metabolic engineering.
    8. Metabolic engineering for acetate control in large scale fermentation.

9. ENGINEERING GENETIC CIRCUITS IN BACTERIA **(4)**
    1. Biological logic gates and oscillators
    2. Modular assembly and design using biobricks (IGEM)

Books/References:

1. Metabolic Engineering. By Stephanopoulous
2. Systems Biology and Synthetic Biology Pengcheng Fu, Sven Panke

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-522	**Downstream Processing**	**3**	**1**	**4**	**40**

Objective: This course is meant to develop an understanding on the various aspects of product recovery with a special focus on industrial scale processes in biotechnology and the relevant theory, techniques and equipment involved, from an engineer's perspective. It equips the student with the basic tools and training for an industrial career.

1. PROPERTIES OF BIO-MOLECULES AS BASIS OF SEPARATION **(3)**
   1.1. Design of batch & continuous systems

2. PRINCIPLES OF SOLID LIQUID SEPARATION; **(4)**
   2.1. Filtration
   2.2. Centrifugation
   2.3. Membrane based separation

3. THEORY & DESIGN OF EQUIPMENT **(11)**
   3.1. Extractive separation
   3.2. Solvent based separation
   3.3. Design of multistage equipment based on partition coefficient,
   3.4. Aqueous 2-phase separation
   3.5. Chromatographic separation
   3.6. Equilibrium theory & column design
   3.7. Non-linear & mass transfer effects
   3.8. Loading effects
   3.9. Non-linear absorption isotherms and scale up

4. CONTINUOUS CHROMATOGRAPHY & SMB TECHNOLOGY **(4)**
   4.1. Theoretical and Practical aspects
   4.2. Industrial applications

5. CELL DISRUPTION METHODS
   5.1. Handling intracellular & extracellular products of fermentation **(3)**

6. CRYSTALLIZATION **(3)**
   6.1. Principles
   6.2. Scale up
   6.3. Equipment design

7. DRYING **(3)**
   7.1. Principles
   7.2. Equipment design

8. QBD PRINCIPLES & PRACTICE **(3)**

9. INTEGRATED PROCESS DESIGN **(6)**
   9.1. Sequencing & interfacing of unit operations
   9.2. Flow sheets with mass & energy balances
   9.3. Examples: Rec-protein purification from IB & Intracellular soluble fraction

Books/References:

1. Bioseparation science and engineering. Roger Harrison, Paul Todd etal, Oxford Univ. Press.
2. Transport processes and separation process principles. 4th Ed. Christie John Geankoplis, PHI-EEE
3. Handbook of downstream processing, by Goldberg, Springer.
4. Downstream processing in b iotechnologty (2013). By Wisselingh and Krijgsman Duff. Academic Press.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
BT-524	**Bioprocess Plant Design**	**3**	**1**	**4**	**40**

Objective: This course is designed to apply biochemical engineering knowledge gained in earlier courses to the complete design of a bioprocess plant for the production of biotech products arising out of life science discoveries. Such products would typically include biopharmaceutical products like primary and secondary metabolites, enzymes, antibodies, drugs etc. No prior background in engineering is essential, though basic exposure to IT skills would be helpful. At the end of the course, the student should be able to make plant layouts, design process flowcharts for various products with material and energy balances and also perform economic evaluations.

1. ENGINEERING DRAWING **(7)**
   1.1 Introduction to graphics communication. The engineering design process, drawing tools, Sketching and lettering, visualization for design, engineering geometry fundamentals, three-dimensional modeling, multi-view drawings, plans, sections and perspectives, standard graphics and flowsheeting practice, dimensioning and tolerances, working drawings, mechanical drawings, piping drawings, welding drawings, computer drawing, extensive training on a suitable software package (e.g. DesignCAD)

2. PROCESS FLOWSHEETING AND SIMULATION **(7)**
   2.1 Flowsheet synthesis and decomposition, modelling and analysis of flowsheets, flowsheet simulation, heat-exchanger networks and other examples of flowsheet analysis, analysis of process alternatives, use of computer-aided process design and simulation packages such as ASPEN, CHEMSHARE, CHEMCAD and SPEEDUP, Flowsheet optimization

3. PROCESS ECONOMICS AND COSTING **(7)**
   3.1 Estimation of capital and operating costs. Time value of investments, profitability analysis, selection of alternatives, optimization, elements and types of contracts, project management and scheduling, critical path analysis

4. EQUIPMENT DESIGN AND SPECIFICATION **(14)**
   4.1 Tanks and vessels. Agitators, pumps, valves, compressors, heat exchange equipment, evaporators, crystallizers, dryers, freeze and spray dryers, distillation columns, packed towers, cooling towers, gas–liquid contactors, centrifuges, sedimentation tanks, depth □lters, membrane □lters, liquid–liquid extraction equipment, cell disruption equipment, chromatography equipment, size reduction equipment, materials of construction, hygienic design of process machinery, containment and biosafety, preparation of bids, plant layout

5. EXAMPLES OF PLANT DESIGN FOR SPECIFIC PRODUCTS **(5)**
   5.1 Plant design details for primary metabolites, secondary metabolites, recombinant products

Books/References:

1. Software: CAD simulation packages ASPEN, CEMSHARE PROCEDE CHEMCAD, Batch Pro designer, Enviro Pro Designer, Bio Pro Designer
2. Plant design and economics for chemical engineers. Peters and Timmerhaus
3. Bioprocess engineering – systems, equipment and facilities. Bjorn K.L and Nancym, A.D. Wiley Interscience.

Code	Title	Lectures	Lab	Credits/week	Hrs/sem
BT-552	**Laboratory Techniques in Biotechnology-II**	**0**	**8**	**4**	**40**

Objective: To train the students coming from different backgrounds with advanced laboratory techniques and practical skills needed to succeed in biotechnology and bring them at par. All the faculty members shall participate in imparting the training and skills associated with the various theory subjects. The actual experiments and training exercises will vary depending on the students' needs, courses being offered and the faculty member concerned, but will ensure non-redundancy within and between semesters. At the end of this course, the students should be able to apply their theoretical knowledge and practical skills towards solving academic/industrial problems.

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
CT-520	**Design and Analysis of Bioreactors**	**3**	**0**	**3**	**30**

This course is offered by the School of Chemical Technology as per the course contents and credits approved by the Board of School of Studies of USCT.

1. Ideal Bioreactors: Fed-Batch Reactor, Enzyme-catalysed reactions in CSTRs, CSTR reactors with recycle and wall growth, The ideal plug-flow tubular reactor.

2. Reactor Dynamics: Dynamics model, Stability

3. Reactors with non-ideal mixing: Mixing time in agitated tanks, Resident time distributions, Models for no-ideal reactors, Mixing-Bio reaction interactions.

4. Sterilization Reactors: Batch Sterilization, Continuous Sterilization

5. Immobilized Bio Catalysits: Formulation and characterization of immobilized cell bio catalysts, Application of immobilized cell bio catalysts

6. Multiphase Bio reactors: Conversion of heterogeneous substrates, Packed bed reactors, Bubble column Bio-reactors, Fluidised bed Bio-reactors, Trickle bed reactors

7. Fermentation Technology: Medium formulation, Design and operation of a typical aseptic, alrobic fermentation process, Alternate bio reactor configuration.

8. Animal & Plant Cell Reactor Technology: Environmental requirements for animal cell cultivation, Reactor for large-scale production using animal cells, Plant cell cultivation.

Books/References:

1. Biochemical Engineering Fundamentals by James E. Bailey & David F.Ollis, McGrew-Hill.
2. Bioprocess Engineering by Shuler & Kargi, Prentice Hall
3. Encyclopedia of Chemical Engineering by Kirk & Othmer,

Code	Title	Lectures	Tutorials	Credits/week	Hrs/sem
MS-106	**Marketing Research**	**4**	**0**	**4**	**40**

Objectives: This course is offered by the School of Management as per the course contents and credits approved by the Board of School of Studies of USMS. The course aims at making students understand concepts, philosophies, processes and techniques of managing the marketing operations of a firm.

1. **Introduction to Marketing**: Meaning and Scope of Marketing; Marketing Philosophies; Marketing Management Process-An Overview; Concept of Marketing Mix; Understanding Marketing Environment; Consumer and Organization Buyer Behavior; Demand Forecasting; Market Segmentation, Targeting and Positioning.

2. **Product and Pricing Decisions**: Product Concept; Types of Products; Product Levels; Major Product Decisions; Brand Management; Product Life Cycle, New Product Development Process; Pricing Decisions: Determinants of Price; Pricing Process, Policies and Strategies.

3. **Promotion and Distribution Decisions**: Communication Process; Promotion Tools-Advertising, Personal Selling, Publicity and Sales Promotion; Emerging Channels of Distribution, Distribution Channel Decisions-Types and Functions of Intermediaries; Channel Design; Selection and Management of Intermediaries.

4. **Emerging Trends and Issues in Marketing**: Consumerism, Rural Marketing, Social Marketing; Direct Marketing; Online Marketing, Green Marketing.

Text Books

1. Kotler,P., Keller, K.L. Koshy, A. and Jha, M., (2009). Marketing Management: A South Asian Perspective, 13th Edition, Pearson Education, New Delhi.
2. Etzel, M., Walker, B., Stanton, W. and Pandit, A (2009) Marketing Management, Tata McGrawHill, New Delhi

Reference Books

1. Ramaswamy, V.S and Namakumari, S. (2009) Marketing Management: Global Perspective Indian Context, 4th Edition, Macmillan Publishers India Ltd., New Delhi
2. Saxena, Rajan (2009), Marketing Management, Fourth Edition, Tata McGraw Hill Education Pvt. Ltd. New Delhi.
3. Louis E. Boone and David L. Kurtz (2007). Principles of Marketing, 12 th Edition, Cengage Learning.
4. Pride, William, M., and O.C. Ferrell (2010). Marketing Planning, Implementation and Control, Cengage Learning, New Delhi.