INSTITUTE OF CHEMICAL TECHNOLOGY
Ordinances, Regulations and Syllabi relating to the Degree of Master of Technology (Bioprocess Technology) M. Tech. (BPT) – Interdisciplinary course

Admission:

1. **Eligibility:** The candidate should have passed the degree of Bachelor of Chemical Engineering, B. Pharmacy, B.E./B.Tech. in chemical engineering/pharmaceutical/ biotechnology/life sciences/food biotechnology/fermentation technology/Green technology of University of Mumbai OR B. Pharmacy, B.E./B.Tech in Chemical Engineering/pharmaceuticals/biotechnology/life sciences/food biotechnology/ fermentation technology/Green technology of any equivalent examination of a post-H.S.C. 4-year degree course of a University recognized by the UGC/AICTE/DBT and of any national/Indian Institute of Technology, with first class (that is, 60% of the marks in aggregate or equivalent grade average). [55% for the backward class candidates only from Maharashtra State]. Admissions will be done strictly on the basis of merit in the valid GATE/GPAT score and performance at the written test conducted at the UICT/ICT.
2. Design of written test would be such that basic chemical engineering knowledge can be tested in Section-I, while Section-II tests for analytical skills of the candidate.
3. The final merit list would be designed on the basis of 70% weightage to the GATE/GPAT score and 30% weightage to the written test conducted by the Institute.
4. The group of selected candidates, unless selected on a specific project, will be given a presentation for all research activities in the department and available projects for selection of projects / guide. The final allotment of the research guides will be done by the Departmental committee based on the preferences given by the candidates and admissible rules / regulations.

Course Credit System and Structure:

1. The course is conducted on a credit-based 4-semester (2-year) system. There are two semesters in a year: July to December, semester I, and December to May, semester II. Semesters I and II will consist of 15-16 weeks of instructions including a seminar / project, 1-2 weeks of theory examinations and 1-2 weeks of laboratory examinations, wherever applicable.
2. For the first year, the semester I Examination will be held in December / January and semester II Examination will be held in May. The second year will have a research project-based evaluation in each semester carrying equal weightage as that of the first / second semester. The senate-approved schedule of academic activities for the academic year (dates of start and end of classes, dates of final examinations, etc.) will be followed.
3. A certain quantum of work measured in terms of credits is defined for each course. The student acquires credits by passing courses in semesters I and II, whereas the research project-based evaluation in semesters III and IV (second year) will contribute to credits equivalent to that obtained in the first two semesters.
4. Administering of the courses in the first year will mainly consist of Lectures (**L**) and Tutorials (**T**). However, laboratory courses will consist of practical (**P**) hours, wherever applicable.

5. The credit (**C**) for a course will be equal to the number of contact hours (**L+T+P**) per week for that course, that is, for 100 marks it will be 6 and that for 50 marks it will be 3. The research project-based evaluation will be equivalent to 21 credits per semester.

6. For assisting the instructor in conducting tutorials, Teaching Assistants (TA) may be provided. The instructor is expected to inform TA the syllabus covered up to the point of each tutorial and the syllabus to be covered in a particular tutorial. The course instructor is required to provide problem statements and solutions to the TA. The TAs are responsible for administering the problem statements and solutions to the students. The course instructor is also required to be present during the tutorial session.

7. Courses are numbered in an alphanumeric manner as shown in Table 1. Core subject are compulsory. Students have to choose one elective from the list provided herewith and second can be from other department such pharmaceutical, foods and chemical engineering. While choosing the elective subject from department students should check the pre-requisites of that subject.

Attendance:

1. Attendance in all classes (lectures, tutorials, practicals) is compulsory and will be monitored. In general, the Institute expects 100% attendance. 75% attendance is permitted only for health or other emergency situations. A medical certificate from recognised and qualified doctor is necessary for getting sick-leave on health grounds.

(Faculty members are required to submit the attendance sheets to the Chemical Engineering Department office at the end of the semester but before the submission of forms for examination. The office will compile the data and put it on notice board. An early warning will be released to all defaulters by mid-semester examination).

2. A student not having minimum 75 percent attendance for a particular subject may be debarred from appearing in the semester-end examination in that particular subject and given 'FF' grade (grades are described below) in that particular subject.

3. The concerned teacher may condone absence from classes due to unavoidable reasons, for a very short period, provided the teacher is satisfied with the explanation.

4. If the period of absence is for short duration (not more than two weeks), application for the leave shall be submitted to the Head of the Department stating fully the reasons for leave, supported by proper documents. The Head of Department may condone such absence based on the application.

5. If the period of absence is more than two weeks, the application for leave shall be submitted stating fully the reasons for leave, supported by proper documents, to the Dean, (A.P.) forwarded through Head of the Department. The Dean may condone such absence based on the application.

6. Additional leave may be granted to attend conference, workshop, seminar, and also for participating in extra-curricular activities, **with prior permission** from the concerned subject-teacher, research supervisor AND the Head of the Department.

Assessment of students' performance in theory courses:

The assessment of students' performance in a theory course will be based on:

(i) Continuous assessment (60% weightage in overall credit of the course)

The continuous assessment will comprise of: quizzes, surprise tests, class tests (open- or closed-book), home assignments, group assignments, presentations, etc. This consists of overall 30%

weightage and another overall 30% will be mid-semester examination. It is expected that the instructor for a particular course should conduct minimum of 3 evaluations (Including one which has to be an **announced mid-semester test** conducted in 8th to 10th week from the start date). In the very first lecture of the course, the instructor should clearly indicate the methodology of continuous assessment that will be followed for a particular course. In case a particular student is absent for a particular internal evaluation, repeat evaluations will not be conducted. For the benefit of and as a process of learning by the students, the corrected evaluations will be made available within two weeks of conducting the assessment.

(ii) Final examination (40% weightage in overall credit of the course)

The final examination is compulsory for all students. Absenteeism in the final examination will be considered as **Failed** in the examination. The final examination will be conducted as per pre-announced time table. The final examination will be one (1) hour duration for three-credit course and one and half (1½) hours duration for six-credit course. This would be given 60% weightage.

In case, a student is absent for the final examination because of extra-ordinary situations, and supports his application with relevant documents, he will be given a grade 'I' (grades are described below). Such a student will be eligible for appearing for 'Supplementary Examination'. The maximum grade obtainable in such supplementary examinations is '**ONE GRADE LESS'** (described below) than that obtained based on the total marks after the supplementary examination. If 'EE' is obtained in the supplementary examination, then it remains 'EE'.

Assessment of students' performance in Laboratory courses:

The assessment of students' performance in a laboratory course will be based on: (i) Continuous assessment: Turn-to-turn supervision of the student's work, their performance in viva-voce examinations, group discussions, and the quality of their work as prescribed through laboratory journals. This would be given 100% weightage.

Assessment of students' performance in Project I / II / III:

In the first semester, students will be given two projects – Projects I and II. In Project I, they are supposed to critically assess one research publication. In Project II, the students will be required to prepare a critical review of a selected topic in Chemical Engineering and allied subjects. Project I and II will be supervised by a faculty other than the research supervisor. For both these projects, the students need to submit a standard typed report. The students will also be required to make an oral presentation for all these projects. Weightage would be 40% for the presentation and 60% for the report (average of the marks given by internal and external examiners for both presentation and report).

In addition, in the second semester, the students will have to critically analyse literature on their own research area (project III). Project III evaluation will be based on the analysis of existing literature and proposed objectives, methodology, bar chart of activities, and deliverables. Weightage would be 40% for the presentation and 60% for the report (average of the marks given by internal and external examiners for both the presentation and report).

Assessment of students' performance in Second year:

1. Every candidate will give a presentation at the end of the semester III in front of the Research Progress Committee (RPC) formed by the Head of the Department in consultation with the research supervisor, and which will consist of the research supervisor and at least one more faculty member of the Department.

2. The evaluation at the end of semester III will be based on: (i) experimental setup / mathematical model formulation (30%), (ii) analysis of reactants, products / solution strategy (20%), (iii) results and data analysis, including comparison with previous work (50%). The grade for semester III will be awarded by RPC.

3. The cases of plagiarism and data manipulation will be investigated by the concerned committee (PRC) and dealt with sternly. The candidate will be asked to leave the program and the Institute, if proven of charges against him / her.

4. Once the research project approaches completion (tentatively by end of March) as mutually decided by the supervisor and the candidate, the candidate will submit synopsis to RPC. An external examiner will be appointed for thesis evaluation, and a copy of the synopsis will be sent to external examiner.

5. The thesis in soft bound form will be sent to examiner for evaluation, tentatively by end of May. The comments received from the external examiner need to be incorporated in the thesis and discussed with the RPC.

6. The viva-voce examination will consist of open research colloquium in the presence of external examiner and RPC members, and questions and answers will be open to all. Only after successful viva-voce examination, the grade for semester IV will be awarded jointly by the external examiner and RPC. Final copy of the thesis will be submitted to the Institute in hard-bound form.

7. The thesis soft copy will be maintained in PDF format with Institutional library and Chemical Engineering office.

Grading system:

1. As a measure of students' performance the following letter grades and corresponding grade points per credit, shall be followed:

Grade	Grade points per credit
AA	10.0
AB	9.0
BB	8.0
BC	7.0
CC	6.5
CD	6.0
DD	5.5
EE	5.0
FF	0
I	0
T	0

2. Instructor of the course will submit the absolute marks obtained by the candidates (out of 50 or out of 100, as the case may be), in the following heads depending on whether the course is theory or laboratory: (i) Continuous Assessment, (ii) Final Examination, and (iii) Total Marks.

3. Depending on the grace marks (to be decided) by the Results Committee; the absolute marks obtained by the candidates under each subject head will be calculated. These absolute marks will be converted to grades and grade points for each subject for each candidate in the following manner:

a. Candidates who have failed (secured less than 40% of the marks even after considering grace marks) will be given grade 'FF' for that subject.

b. Based on the absolute marks obtained by the successful (passed) candidates in a particular subject, 'CLASS AVERAGE' will be calculated for each subject.

c. If 'CLASS AVERAGE' is less than 65%, then the 'CLASS AVERAGE' is given a grade 'CC'. AA, AB, BB, and BC grades are given between 'CLASS AVERAGE' and 'HIGHEST MARKS' based on equal increments. CD, DD, and EE grades are given between 'CLASS AVERAGE' and the minimum passing marks based on equal increments (40%).

d. If 'CLASS AVERAGE' is greater than 65%, but less than 70%, then the 'CLASS AVERAGE' is given a grade 'BC'. AA, AB, and BB grades are given between 'CLASS AVERAGE' and 'HIGHEST MARKS' based on equal increments. CC, CD, DD, and EE grades are given between 'CLASS AVERAGE' and the minimum passing based on equal increments (40%).

e. If 'CLASS AVERAGE' is greater than 70%, then the 'CLASS AVERAGE' is given a grade 'BB'. AA and AB grades are given between 'CLASS AVERAGE' and 'HIGHEST MARKS' based on equal increments. BC, CC, CD, DD, and EE grades are given between 'CLASS AVERAGE' and the minimum passing based on equal increments (40%).

4. A semester Grade Point Average (SGPA) will be computed for each semester as follows:

$$\text{SGPA} = \frac{\left(\sum_{i=1}^{n} c_i g_i\right)}{\left(\sum_{i=1}^{n} c_i\right)}$$

where,
'n' is the number of subjects for the semester,
'ci' is the number of credits allotted to a particular subject, and
'gi' is the grade points awarded to the student for the subject based on his performance as per the above table.
SGPA will be rounded off to the second place of decimal and recorded as such.

5. Starting from the first semester at the end of each semester (S), a Cumulative Grade Point Average (CGPA) will be computed as follows:

$$CGPA = \frac{\left(\sum_{i=1}^{m} c_i g_i \right)}{\left(\sum_{i=1}^{m} c_i \right)}$$

where,

'm' = total number of subjects from the first semester onwards up to and including the semester S,

'ci' = number of credits allotted to a particular subject, and

'gi' = grade points awarded to the student for the subject based on his performance as per the above table.

CGPA will be rounded off to the second place of decimal and recorded as such.

6. The CGPA would indicate the cumulative performance of the student from the first semester up to the end of the semester to which it refers.

7. The CGPA, SGPA and the grades obtained in all the subjects in a semester will be communicated to every student at the end of every semester / beginning of next semester.

8. Candidate will be considered to have passed the course if he / she secures grade 'EE' or higher (AA, AB, BB, BC, CC, CD, DD).

Supplementary Examinations:

1. For those candidates who fail (Grade 'FF') in one or more subjects, another examination called 'Supplementary Examination' (50% weightage) will be held after one month of the declaration of the result for the particular semester.

2. The marks obtained by the candidate during the semester in the Continuous Assessment will be carried forward and added to the marks obtained in the Final Examination.

3. The total marks will be considered for award of grades and grade points. The grades are to be calculated based on the grading scheme discussed in point **No. 3** under the heading '**Grading System**'. However, the maximum grade obtainable after such supplementary examination is **'ONE GRADE LESS'** than that obtained after the supplementary examination. If 'EE' is obtained in the supplementary examination, then it remains 'EE'.

Grade the candidate would have got after Supplementary Examination	Grade actually given	Grade Point per Credit
AA	AB	9.0
AB	BB	8.0
BB	BC	7.0
BC	CC	6.5
CC	CD	6.0
CD	DD	5.5
DD	EE	5.0
EE	EE	5.0
FF	FF	0
I	I	0
T	T	0

4. When a student gets the grade 'FF' or 'I' in any subject during a semester, the SGPA and CGPA from that semester onwards will be tentatively calculated, taking only 'zero point' for each such 'FF' or 'I' grade. After the 'FF' grade(s) has / have been substituted by better grades after the supplementary examination or subsequent semesters, the SGPA and CGPA will be recomputed and recorded to take this change of grade into account.

5. The candidate can continue for the research project in semester III and IV with whatever grade obtained in the previous semesters. However, the candidate must clear all the courses where is has FF and/or I before getting the passing certificate.

6. The records of all candidates will have to be maintained in the Institute for the grade point average calculations.

7. A candidate who remains absent for the regular final examinations and supplementary examinations for **ALL SUBJECTS** will be considered to have dropped out / terminated from the course and will be given a grade 'T'.

M. Tech. BPT Syllabus Details: Prerequisites and Expected Learning

No.	Subject	Credit	Hr/Week			Marks			
			L	T	P	Continuous Assessment	Mid-Semester examination	Final examination	Total
SEMESTER - I									
BST 2101	Bioreaction Engineering	**3**	2	1	0	15	15	20	50
BST 2102	Unit operations in Bioprocessing	**3**	2	1	0	15	15	20	50
	Elective – I	**3**	2	1	0	15	15	20	50
	Elective – II	**3**	2	1	0	15	15	20	50
BST 2114	Project – I (Critical review of one research paper)	**3**	--	--	3	--	--	30 (Report) + 20 (Presentation)	50
BST 2115	Project – II (Seminar)	**3**	--	--	3	--	--	30 (Report) + 20 (Presentation)	50
CEP 2001	Laboratory - I (Chemical Engineering Lab)	**3**	--	--	3	50	--	--	50
	Total	**21**	8	4	9	110	60	180	350
SEMESTER - I									
BST 2103	Biosystem Engineering	**3**	2	1	0	15	15	20	50
CET 2001	Bioreactor design and control	**3**	2	1	0	15	15	20	50
	Elective – III	**3**	2	1	0	15	15	20	50
	Elective – IV	**3**	2	1	0	15	15	20	50
BST 2116	Project – III (critical literature review of research project)	**3**	--	--	3	--	--	30 (Report) + 20 (Presentation)	50
BSP 2101	Laboratory – II (Biochemistry, microbiology & genetics)	**3**	--	--	3	50	--	--	50
BSP 2102	Laboratory – III (Fermentation and Downstream processing)	**3**	--	--	3	50	--	--	50
	Total	**21**	8	4	9	160	60	130	350
Semester III and IV (Laboratory project work on the title of the thesis registered for the degree of M. Tech) Project Evaluation of 350 Marks in III and IV Semester									
Semester III – 350 marks – 21 credits									
Semester IV – 350 marks – 21 credits									

Total credits **21 (Sem I) + 21 (Sem II) = 42**
21 (Sem III) + 21 (SEM IV) = 42

CORE SUBJECTS

Sem I	Subject Code BST 2101	Bioreaction Engineering	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Material and Energy Balance Computations, Basic Biochemistry, Basic Microbiology and Basic Molecular Biology, Principles of biochemical reactions and kinetics; Thermodynamics of bioreactions and biotransfromations; Unstructured and simple structured models, Mechanistic models and morphologically structured models.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Basic thermodynamics and chemical kinetics, Simple design methods, graphical procedures, and comparison of capabilities of the major reactor types.	
	Expected Learning	After this course, students should: - have a basic knowledge on enzymatic and microbial kinetics - have basic knowledge of biochemistry, microbiology and molecular biologoy	
	Reference Books	1. Chemical Reaction Engineering: Levenspiel O 2. Chemical Engineering Kinetics: Smith J. 3. Elements of Chemical Reaction Engineering: H.Scott, Fogler. 4. Basic Biotechnology, edited by Colin Ratledge and Bjorn Kristiansen, Cambridge University Press 2003. 5. Biochemical Engineering Fundamentals, Bailey, and Ollis, McGraw Hill Book Co.1986. 6. Bioreacation Engineering, K. Schergeri, Vols 1 & 2, John Wiley. 1985. 7. Bioprocess computations in Biotechnology, T.K. Ghosh, Ellis Horwood Publications, 1988. 8. Advanced Biochemical Engg., ' Henry R. Bugay Georgs Belforj, John Wiley & Sons.' 9. Lehninger, Biochemistry, 4th edition, 2005 10. M.J. Pelczar, E.C.S. Chase and N.R. Kreigh, "Microbiology", 4th Edition, Tata McGrawhill, India. 11. P.A. Ketchum, "Microbiology", John Wiley and Sons, New York, 1984. 12. Freifelder D., "Molecular Biology", Jones and Bartlett Publishers Inc., 1987	
	Departments	DBT-ICT-CEB	

Sem I	Subject Code BST 2102	Unit Operation in Bioprocesses	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Downstream Processing in Biotechnology, Selection of unit operation with due consideration of physical, chemical and biochemical aspect of biomolecules, basic review of bioprocess designing. Primary separation and recovery processes: Cell disruption methods for intracellular products, removal of insolubles, biomass (and particulate debris) separation techniques, flocculation and sedimentation, centrifugation and filtration methods. Enrichment operations: Membrane – based separations (micro and ultrafiltration, precipitation methods, extractive separation, aqueous two-phase extraction, supercritical extraction, insitu product removal, integrated bioprocessing. Product resolution / fractionation: Adsorptive chromatographic separations processes, electrophoretic separations, hybrid separation technologies (electrochromatography). Product finishing: precipitation/crystallization, mixing, dialysis, distillation and drying. Ultracentrifugation as a separation technique for fractionation of cells and proteins. Introduction to Process Analytical Technology (PAT) and Quality by Design (QbD). Scale down, monitoring and Validation of bioprocesses	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Physicochemical Properties of biochemical's, Transport phenomenon, sedimentation	
	Expected Learning	Students will be able to describe theory, principle, design, application and possible integrations of unit operations in bioprocessing	
	Reference Books	1. Encyclopedia of Bioprocess Technology, Vol. 1-5, 1999 2. Scopes Ak, Protein Purification, IRL Press, 1993 3. Biotechnology: Bioprocessing, Rhem and Reed, Vol. 3, 1993 4. Separation and purification techniques in biotechnology, Fredreich Dechow, 1989 5. Coulson J.M. and Richardson, J.F. "Chemical Engineering, Vol.2 Unit Operations, Ed.3, Pergamon Press (1978).	
	Departments	DBT-ICT-CEB	

Sem II	Subject Code BST 2103	Biosystem Engineering	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Thermodynamics of Biosystems, Principles of Cellular Metabolism and Principles of Metabolic flux analysis, Elementary Mode Modeling, Cybernetic principles of optimal growth modeling, Biochemical pathway engineering, Rational manipulation of biosystems through metabolic and genetic engineering techniques to provide new biocatalysts/bioproducts/value added products. New approaches for design of cellular systems: Integration of recombinant technology and process design, as well as bioinformatics and process systems engineering. Basic principles of System and Synthetic biology and modeling of bioreactors.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Biochemical reactions, enzyme catalysis, nucleic acid, proteins, and metabolites	
	Expected Learning	After this course students should have - knowledge of genetic and metabolic engineering for improvement of biosystem/s - knowledge of molecular aspects in designing of new systems for upstream processing	
	Reference Books	1. Ahindra Nag, Biosystems Engineering, 1 edition, McGraw-Hill, Inc, 2009 2. Biosystem Engineering Journal, Elsevier	
	Departments	DBT-ICT-CEB	

Sem II	Subject Code CET 2001	Bioreactor Design and Control	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Background of bioreactors, Modeling and Design of bioreactors: batch, fed-batch, and continuous flow types (Airlift bioreactors, Airlift pressure cycle bioreactors, Loop bioreactor, Stirred tank bioreactors, Fluidized bed bioreactor, Packed-bed reactors, Trickle bed bioreactor, Bubble column fermenter, Multiphase bioreactors, Disposable bioreactors and Wave bioreactor). Design of Stirrers and impellers. Design, development and scale up of bioreactors and photobioreactors for production of antibiotics, enzymes, vaccines, therapeutic products and biofuels. Reactors with non ideal mixing. Immobilized enzyme/cell reactors. Mass and Heat Transfer, Shear effects in cell cultures, Pontryagin maximum principle for the determination of optimal flow rate to fed batch reactors, optimization for the production of primary and secondary biological products. Bioremediation and Waste treatment, Microbial reactors with and without cell recycle. Bioreactor operations for industrial-important biological products and for biological treatment of wastewater. Design of activated sludge and fixed-film systems. Solid state, Surface, submerged and anaerobic fermentation, Sterilization and asepsis. Principles and Strategies for Control of Bioreactors (feedback, feedforward, adaptive and statistical control, fuzzy logic control), of bioreactors and ancillary equipment.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Basic knowledge of biological processes, cellular metabolism, enzyme and microbial kinetics, and basic mathematics	
	Expected Learning	Students should be able to design and analyze batch, continuous flow, and fed batch reactors with specific instrumentation required for the efficient monitoring and control of simple bioreactor, ancillary equipment required for the aseptic feeding, sampling and processing of bioreactor fluids. Design biological reactors with cell recycle streams. Students should be able to apply the reactor optimization principles for the design of bioreactors for industrially important biological products, primary and secondary metabolites.	
	Reference Books	1. Najafpour, G. D., "Biochemical Engineering and biotechnology", Elsevier, 2007. 2. Doran, P.M., "Bioprocess Engineering Principles", Academic Press, 2005. 3. Walker, J.M. and Rapley, R., "Molecular Biology and Biotechnology", 4th Edition, Royal Society of Chemistry, 2000. 4. Blanch, H. W. and Clark, D. S., "Biochemical Engineering",	

		Marcel Dekker, Inc., 1999. 5. Dunn, I.J., Heinzle, E., Ingham J. and Prenosil, J.E., "Biological Reaction Engineering: Dynamic Modeling Fundamentals with Simulation Examples", 2nd Edition, Wiley-VCH, 2003.	
	Departments	Chemical Engineering Department	

Projects

Sem I	Subject Code BST 2114	Project I (Critical review of one research paper)	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	Nil	
	Tutorial Hours	Nil	
	Instruction for candidates	In this project, the candidate is expected to review single research publication either published or manuscript in preparation as decided by the faculty/research advisor. In general a written report on similar guidelines as given for project II later needs to be submitted but the distribution of the content should be as follows: **(a)** 5% weightage (1 page) should be given to important features of the paper in own words of the candidate. **(b)** 45% weightage should be given to literature survey including significance of the area of research discussed in the paper. **(c)** Remaining part should focus on the detailed analysis of the paper. Some general guidelines for the critical analysis of a research publication include: **ORIGINALITY (5 marks):** Are the facts and ideas new, or have they been covered before by this author or other authors? Is there enough useful information to warrant this paper and whether the length of the paper is justified? If you feel the material is not new, please cite references in which it has already been reported. **TECHNICALLY CORRECT (20 marks):** Is the paper technically correct; are assumptions reasonable; is the reasoning logical? If you think it is not, specify what you think is incorrect and suggest the correct approach. Are the methods used in the work appropriate? Are there any internal contradictions or computational errors and are there any loopholes in the observations? If so, please explain. **CLARITY (5 marks):** Is the paper reasonably easy to follow and understand, complete but not verbose, and does it stick to the subject? If not, please comment. **BIBLIOGRAPHY (5 marks):** Does the author cite all the references in the text and vice versa? Are the references complete and as per guidelines? Does the manuscript accurately represent statements in cited references and do not reproduce? **TITLE/ABSTRACT (5 marks):** Is the title suitable and adequate? Does the Abstract (normally 50-150 words) bring out the main points of the paper? **ILLUSTRATIONS AND TABLES (5 marks):** Is there material	

		that could be better covered in a table? Is there needless duplication between text illustrations and tables? Are there too many 9 of 20 illustrations or tables? Are the illustrations clear and legible? Are the experiments/results & discussion/illustrations/tables same/similar to other papers in similar area? **ALTERNATIVE INTERPRETATIONS (5 marks):** Are there other valid interpretations of the observations? If so, please elaborate.	
	Departments	Chemical Engineering	

Sem I	Subject Code BST 2115	Project II (Seminar)	No. of Hours
	Credits	3 (report submission and oral presentation)	
	Lecture/ Practical = Hours	Nil	
	Tutorial Hours	Nil	
	Instruction for candidates	1. ***Note:*** Seminar report should be prepared using the Times Roman font (size 12) using 1.5 spacing leaving 1-inch margin on all sides except left hand side where it should be 1.5 inch, producing approximately 29 lines per page. The report should be typed on one side of the paper and need not be bound in a hard cover binding. Please write your text in good English (American or British usage is accepted, but not a mixture of these). The Seminar work is concerned with a detailed and critical review of an area of interest to bioprocess technology including both upstream and downstream processing. Typically, the report should contain and will be evaluated based on the following points: ***1. Title.*** Concise and informative. Avoid abbreviations and formulae where possible. ***2.*** **Abstract**: A concise and factual abstract is required. The abstract should state briefly the theme of the topic, the published principal results and major conclusions. References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself. ***3.*** **Keywords:** Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, "and", "of"). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible ***4. Introduction*** - State the objectives of the topic and provide an adequate background, avoiding a detailed literature survey or a summary of the results. Maximum 2 pages. **5**. ***Main body of the seminar***: Exhaustive review of literature (including figures): 10 – 12 pages: 50% Weightage. Divide this	

		section your seminar into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to "the text". Any subsection may be given a brief heading. Each heading should appear on its own separate line. Bold or bold and italic fonts can be used to differentiate the headings and subheadings. Non-Bold italic font can be used to indicate any subsequent headings. This section should also contain critical analysis of the literature and comments on the analysis. Critical analysis should also contain quantitative comparison of observations, results, and conclusion amongst the various papers. 6.***Conclusions*** **-**The main conclusions of the seminar topic may be presented in a short. Conclusions section, which may stand alone or form separate section of the seminar report. 7.***Figures and Tables captions*****-** Figures and tables should be shown as a part of the running text. Each figure should be drawn inside a rectangular box of 12 cm width and 10 cm height. The figures must be sufficiently clear and hand drawn figures will be acceptable. Particular care must be taken if a figure is photocopied from source. Each figure must have a sequence number and caption below. Each table must have a sequence number and title at the top. Number figures and tables consecutively in accordance with their appearance in the text. Ensure that each illustration has a caption. A caption should comprise a brief title (**not** on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used. **Tables** - Place footnotes to tables below the table body and indicate them with superscript lowercase letters. Avoid vertical rules. Be sparing in the use of tables and ensure that the data presented in tables do not duplicate results described elsewhere in the article. 8. **Symbols, abbreviations and units**: Widely accepted symbols, abbreviations and units (SI) should be used. For all other symbols and abbreviations, the full expression followed by the abbreviation should be given at the first time it appears in the text. Abbreviations used in tables and figures should be explained in the captions. In general, the recommendations of the	

International Union of Pure and Applied Chemistry (IUPAC) should be followed (see http://www.iupac.org). [For SI system - Ref: Ind. Chem. Engr., 24, 32, 3 (1983)]. Units used in the literature (if not SI) should be correctly converted.

9.**Reference Style**

Text: All citations in the text should refer to:

1. ***Single author****:* the author's name (without initials, unless there is ambiguity) and the year of publication; e.g. (i) The flow pattern in gas-liquid-solid fluidized bed has been reported in the published literature (Murooka et al., 1982).

OR

(ii) Murooka et al. (1982) have measured flow patterns in gas-liquid-solid fluidized beds. The title of the article should also be included.

2. ***Two authors****:* both authors' names and the year of publication;

3. ***Three or more authors****:* first author's name followed by "et al." and the year of publication.

Citations may be made directly (or parenthetically). Groups of references should be listed first alphabetically, then chronologically. Examples: "as demonstrated (Allan, 1996a, 1996b, 1999; Allan and Jones, 1995). Kramer et al. (2000) have recently shown ...."

List: References should be arranged first alphabetically and then further sorted chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters "a", "b", "c", etc., placed after the year of publication.

Examples:

(a) Reference to a journal publication or articles from periodicals:

Murooka S., Uchida K. and Kato Y., Recirculation Turbulent Flow of Liquid in Gas-Liquid-Solid Fluidised Bed", J. Chem. Engg. Japan, 15, 29-34 (1982).

(b) Format for listing references of Books:

Constant R.F.,"Crystallization, Academic Press, New York, pp. 89-90, 1968.

(c) ***Reference to a chapter in an edited book:***

Mettam, G.R., Adams, L.B., 1999. How to prepare an electronic version of your article, in: Jones, B.S., Smith , R.Z. (Eds.), Introduction to the Electronic Age. E-Publishing Inc., New York, pp. 281-304.

(d) Format for listing Thesis:

Niranjan K., "Hydrodynamic and Mass Transfer Characteristics

of Packed Columns", Ph.D. (Tech.) Thesis, University of Mumbai, 1983.

(e) Format for listing references of Patents in Chemical Abstracts:
Cananaush R.M., U.S.Patent 2,647,141, Cf. C.A. 48, 82636 (1954).

(f) Format for listing Handbooks, Tables, Symposia etc.:
Kumar R and Kuloor N.R., "Formation of Drops and Bubbles", in Advances in Chemical Engineering, Vol.8, T.B. Drew et.al. (Eds.) New York, Academic Press, pp.256-364 (1970).

(g) Format for listing Private Communications and other categories:
Sharma, M.M., Private Communication (1984).

(h) Web references: As a minimum, the full URL should be given and the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list.

Other instructions:

1. Two typed copies of the report on thesis size bond paper (A4 size) are to be submitted to Coordinator on **time to be decided by the coordinator.** The detailed timetable for the presentation would be communicated.
2. Name of the student, title of the problem and year of examination must be indicated on the top cover. THE NAME OF THE SUPERVISOR (ONLY INITIALS) MUST APPEAR ON THE BOTTOM RIGHT CORNER OF THE TOP COVER.
3. The report must be precise. All important aspects of the topic should be considered and reported. Chapters or subsections need not be started on new pages, while getting the report typed.
4. **The total number of pages, including tables, figures but excluding references should not exceed 30.**
5. Typographical errors in the report must be corrected by the student. The student will be discredited for any omission in the report. All the symbols used in the text should be arranged in an alphabetical order and given separately after conclusions.
6. The time allotted for the oral presentation of seminar is 30 minutes (20 minutes oral presentation and additional 10 minutes for questions and answers.
7. INCOMPLETE AND CARELESSLY WRITTEN REPORT IS LIABLE TO BE REJECTED.
8. The last date for submission will NOT be extended on any

		grounds whatsoever. 9. There must not be any acknowledgment about the guidance by the faculty in the Seminar. 10. The Seminar will be evaluated on the basis of (i) rational approach to the problem, ii) correctness and completeness of the written text and iii) performance in the oral presentation. 11. Word-to-word copying from the published article is not permitted. Flowery language is not to be used. 12. Schedule for delivering presentation will display after submission of reports. 13. Font size of should be readable. Slides should not be shabby with lot of written matter. Appropriate color combination to be used. Diagrams, figures, tables, pictures should not be copied from literature (this is also applicable for written report). These should be redrawn to make it prominent enough	
	Referencing	e.g. Scientific literature sites, such as http://sciencedirect.com/, http://onlinelibrary.wiley.com/, *www.**springer**.com/* , *www.**informaworld**.com/* -, *www.**informahealth**care.com/* , www.ncbi.nlm.nih.gov/**pubmed,** www.**scopus**.com/**scopus**/home.url, http://pubs.acs.org/action/showPublications?display=journals, http://ieeexplore.ieee.org/xpl/periodicals.jsp?reload=true, http://www.nature.com/siteindex/index.html, *www.niscair.res.in/* and other to collect the scientific literature. Other research or scientific article, general reviews, economics and market reviews and review papers, books from library to be used for writing report and making ppt.	
	Departments	Chemical Engineering	

Sem II	Subject Code BST 2114	Project III (Critical review of one research paper)	No. of Hours
	Credits	3 (report submission)	
	Instruction for candidates	1. This would be concerned with a **detailed and critical review of the area of the proposed research project to be undertaken in the second year** and will be under the guidance of the research supervisor. The topic should be within the scope of bioprocess technology including both upstream and downstream processing aspects. 2. ***Note:*** report should be prepared using the Times Roman font (size 12) using 1.5 spacing leaving 1-inch margin on all sides except left hand side where it should be 1.5 inch, producing approximately 29 lines per page. The report should be typed on one side of the paper and need not be bound in a hard cover binding. Please write your text in good English (American or British usage is accepted, but not a mixture of these). Typically, the report should contain and will be evaluated based on the following points: 3. ***Title.*** Concise and informative. Avoid abbreviations and formulae where possible. 4. **Abstract**: A concise and factual abstract is required. The abstract should state briefly the theme of the topic, the published principal results and major conclusions. References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself. 5. **Keywords:** Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, "and", "of"). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible 6. ***Introduction*** **-** State the objectives of the topic and provide an adequate background, avoiding a detailed literature survey or a summary of the results. Maximum 2 pages. 7. ***Main body of the seminar***: Exhaustive review of literature (including figures): 10 – 12 pages: 50% Weightage. Divide this section your seminar into clearly defined and numbered	

		sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to "the text". Any subsection may be given a brief heading. Each heading should appear on its own separate line. Bold or bold and italic fonts can be used to differentiate the headings and subheadings. Non-Bold italic font can be used to indicate any subsequent headings. This section should also contain critical analysis of the literature and comments on the analysis. Critical analysis should also contain quantitative comparison of observations, results, and conclusion amongst the various papers. 8. ***Conclusions*** **-**The main conclusions of the seminar topic may be presented in a short. Conclusions section, which may stand alone or form separate section of the seminar report. 9.***Figures and Tables captions*****-** Figures and tables should be shown as a part of the running text. Each figure should be drawn inside a rectangular box of 12 cm width and 10 cm height. The figures must be sufficiently clear and hand drawn figures will be acceptable. Particular care must be taken if a figure is photocopied from source. Each figure must have a sequence number and caption below. Each table must have a sequence number and title at the top. Number figures and tables consecutively in accordance with their appearance in the text. Ensure that each illustration has a caption. A caption should comprise a brief title (**not** on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used. **Tables -** Place footnotes to tables below the table body and indicate them with superscript lowercase letters. Avoid vertical rules. Be sparing in the use of tables and ensure that the data presented in tables do not duplicate results described elsewhere in the article. 10. **Symbols, abbreviations and units**: Widely accepted symbols, abbreviations and units (SI) should be used. For all other symbols and abbreviations, the full expression followed by the abbreviation should be given at the first time it appears in the text. Abbreviations used in tables and figures should be explained in the captions. In general, the recommendations of the International Union of Pure and Applied Chemistry (IUPAC) should be	

followed (see http://www.iupac.org). [For SI system - Ref: Ind. Chem. Engr., 24, 32, 3 (1983)]. Units used in the literature (if not SI) should be correctly converted.

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(c) ***Reference to a chapter in an edited book:***

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8. The last date for submission will NOT be extended on any grounds whatsoever.
9. There must not be any acknowledgment about the guidance by the faculty in the Seminar.

		10.The report will be evaluated on the basis of (i) rational approach to the problem, ii) correctness and completeness of the written text and iii) performance in the oral presentation. 11. Word-to-word copying from the published article is not permitted. Flowery language is not to be used. 12. Schedule for delivering presentation will display after submission of reports. 13. Font size of should be readable. Slides should not be shabby with lot of written matter. Appropriate color combination to be used. Diagrams, figures, tables, pictures should not be copied from literature (this is also applicable for written report). These should be redrawn to make it prominent enough	
	Referencing	e.g. Scientific literature sites, such as http://sciencedirect.com/, http://onlinelibrary.wiley.com/, *www.**springer**.com/* , *www.**informaworld**.com/* -, *www.**informahealth**care.com/* , www.ncbi.nlm.nih.gov/**pubmed,** www.**scopus**.com/**scopus**/home.url, http://pubs.acs.org/action/showPublications?display=journals, http://ieeexplore.ieee.org/xpl/periodicals.jsp?reload=true, http://www.nature.com/siteindex/index.html, *www.niscair.res.in/* and other to collect the scientific literature. Other research or scientific article, general reviews, economics and market reviews and review papers, books from library to be used for writing report and making ppt.	
	Department	Chemical Engineering	

ELECTIVE SUBJECTS

Sem I	Subject Code CEE 2002	Transport Phenomenon	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Basic laws of one-dimensional diffusive transport: momentum, heat and mass transfer and their analogies; characteristics of transport processes; flow equation, simple shear flow and developing flows, entrance effect, two/three phase flows. Multiphase systems and transport coefficients; Convective transport; Transport in turbulent condition; Non-steady state transport; Transport phenomena in bioprocesses and biosystem: interphase, diffusion in biofilm-floc, determination of transport coefficients, agitation power, and evaluation of oxygen transport rate as a function of operating variables. Introduction to microfluidics.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Basic mathematics and Algebra	
	Expected Learning	After this course students should have knowledge of transport processes and its applicability in design and development of bioprocesses	
	Reference Books	1. Biron R. Bird, Warren E. Stewart, and Edwin Lightfoot , "Transport Phenomena" 2. Bennet C.O. and Meyer J.E., "Momentum and mass Transfer" 3. Sission and Pitts "Introduction to Transprot Phenomena" 4. Christie J. Geankoplis, "Transport Processes and Unit Operations", Prentice hall of India, 1997 5. J.C.Slattery, " Momentum, Energy and Mass Transfer in continuum , Kruger Publishing company	
	Departments	Chemical Engineering Department	

Sem I	Subject Code BSE 2104	Bioanalytical Techniques	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Qualitative and quantitative analysis of proteins, nucleic acids, polysaccharides and small molecules such as antibiotics, vitamins, natural products etc. Development and application of modern analytical instrumentation. Chromatography: HPLC (including ELSD, CAD and DLS detectors), UPLC, GC, HPTLC, Ion chromatography and 2D techniques etc. Mass spectrometry: Fragmentation patterns for molecular analysis. Derivatisation techniques. Sample introduction features for large molecules. Recent developments in applications to proteomics and metabolomics (SELDI, MALDI, Q-TOF, Triple Quad and Ion trap mass analyzers). Immunoassay: radioimmunoassay (RIA); enzyme-multiplied immunoassay technique (EMIT); fluorescence polarization immunoassay (FPIA); closed enzyme donor immunoassay (CEDIA); kinetic interaction of microparticles in solution (KIMS); enzyme-linked immunosorbent assay (ELISA). Bioassay for therapeutic proteins, vitamins and antibiotics Hybrid techniques: Gas chromatography with Fourier transforms infrared spectroscopic detection (GC-FTIR), gas chromatography with mass spectrometric detection (GC-MS), liquid chromatography with mass spectrometric detection (LC-MS and LC-MS/MS), and inductively coupled plasma with mass spectrometric detection (ICP-MS). Applications to proteomics, metabolomics, Impurity identification and profiling. Electrophoresis: PAGE, SDS-PAGE, Zone electrophoresis, Capillary electrophoresis, 2-D techniques, laser ablation, Qualitative and quantitative analysis using image analyzers. PCR and RT-PCR techniques. Particle size analysis, SEM, TEM and their application in bioprocessing and bioproduct characterizations Application of IR and NMR spectroscopy, FT-IR, FT-NMR, X-ray diffraction (XRD, XRPD) and differential scanning calorimetry, Microcalorimetry in bioproducts. Synchrotron radiation and their application in bioprocessing Advanced analytical techniques like automated electrophoresis and lab on chip.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Basic principles and instrumentation techniques like spectroscopy and liquid chromatography.	
	Expected Learning	After this course students should - have knowledge of bioanalytical instrumentation and its	

		applicability in bioprocessing - be able to use these techniques carefully during their research work	
	Reference Books	1. Handbook of analytical separations, vol. 4, by Ian Wilson, 2003 2. Encyclopedia of spectroscopy and spectrometry, vol. 1-3, 2000 3. Methods of biochemical Analysis, Vol. 35, Clarence Suelter, 1991 4. Methods of biochemical Analysis, Vol. 36, Clarence Suelter, 1992	
	Departments	DBT-ICT-CEB	

Sem I	Subject Code BSE 2105	Energy Biotechnology	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Introduction to principles of generation of bioenergy. Classification of bioenergy. First, second and third generation Biofuels. Technologies for the three generation of Biofuels. Biomass to Liquid and Biomass to Gas fuel technologies, Biodiesel and Green Diesel, Algal Biotechnology for Bioenergy, Technologies for Biohydrogen, Biogas. Life cycle assessment of biofuels and biofuel technologies. Microbial fuel cells	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Basic Chemistry, Material and Energy balance calculations	
	Expected Learning	After this course students should have - knowledge of biomass to liquid biofuels - knowledge of various approaches for production of bioenergy and its cost economics as well as its impact on ecosystem	
	Reference Books	1. Biofuel engineering process technology, Caya Drapcho, John Nghiem and Terry Walker, 2008 2. Biofuels: Biotechnology, chemistry and sustainable development by Davd Mousdale, 2008 3. Biofpr journal, Society of Chemical Industry (SCI) and John Wiley & Sons Ltd	
	Departments	DBT-ICT-CEB	

Sem I	Subject Code BSE 2106	Patents and IPR	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Introduction to Patent and other IPRs, Types of IP: Patents, Trademarks, Copyright & Related Rights, Industrial Design, Traditional Knowledge, Geographical Indications. Patent protection for inventions in the field of biotechnology, Patentability requirements, for example, inventive-step, industrial applicability and disclosure requirements, to biological inventions, Assessment of Biotechnological Invention by documentation and Search, Drafting of Patent in field of Biotechnology, Patent filing in India and in abroad, Successful research and commercialization of biotechnological inventions. Precautions while patenting disclosure/non-disclosure, Patent infringement- meaning, scope, litigation, case studies	2 hrs lecture each week for 10 weeks
	Pre-requisite courses	Intellectual property and confidentiality	
	Expected Learning	After this course students should have - knowledge of patent analysis, patent drafting and filing - knowledge of implications of patent infringement	
	Reference Books	1. BAREACT, Indian Patent Act 1970 Acts & Rules, Universal Law Publishing Co. Pvt. Ltd., 2007 2. Kankanala C., Genetic Patent Law & Strategy, 1st Edition, Manupatra Information Solution Pvt. Ltd., 2007. 3. http://www.w3.org/IPR/ 4. http://www.wipo.int/portal/index.html.en 5. http://www.ipr.co.uk/IP_conventions/patent_cooperation_treaty.html 6. www.patentoffice.nic.in	
	Departments	DBT-ICT-CEB	

Sem I	Subject Code BSE 2107	Fermentation and Cell Culture Engineering	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Nature of fermentation processes, Nutritional requirements in fermentation process, Strain Construction and Strain Improvement Modern Experimental Techniques: Batch, Fed-Batch, Continuous and extractive Fermentation, High cell-density and High-Performance Bioreactors, Quantitative Physiological Studies. Aerobic and anaerobic fermentation, surface, submerged and solid state fermentation technology, Statistical methods for fermentation optimization, Instrumentation and Control Systems, Improving the production of recombinant DNA proteins through fermentation development, Automation, optimization and Control of fermentation processes, Fermentation design and Cost, Design considerations for aseptic fermentation, Case studies with respect to antibiotic, enzymes and therapeutics. Cell culture engineering and technology: Plant and mammalian cell culture for production of bioproducts.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	CSTR, Mass and Heat transfer	
	Expected Learning	After this course students should have - knowledge of microbial fermentation, growth kinetic and product formation - knowledge of strain improvement, cell culture and its application for production of various bioproducts	
	Reference Books	1. Wang D. I. C., Cooney C. L., Demain A. L., Dunnil P., Humphrey A. E., Lilly M. D., Fermentation and Enzyme Technology, John Wiles and Sons., 1980. 2. Stanbury P. F. and Whitaker A., Principles of Fermentation Technology, Pergamon Press, 1984. 3. Zubay G., Biochemistry, Macmillan Publishers, 1989.	
	Departments	DBT-ICT-CEB	

Sem II	Subject Code BSE 2108	Adsorptive and Chromatographic Separations	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Introduction, Theory and chemistry of adsorption. Chromatographic Fundamentals: Retention, Band Spreading, Resolution; Dynamics of Chromatography: Basic mass transfer equations, Method of moments, Linear dispersion model, Linear staged models for chromatography; Instrument Requirements for Chromatography: System design, Column packing techniques; Fundamentals of Adsorption: Gibbs adsorption isotherm, Adsorption isotherm models, Local equilibrium theory and solute movement plots; Preparative Chromatography: Preparative elution, Frontal, Gradient, Displacement chromatography, Optimization; Hydrodynamic design of adsorbent: Particle size, pore size, surface area and pore volume etc. Thermodynamic design of adsorbent: Ligand design through Molecular modeling, retention mechanisms; Modes of Chromatography: Reversed phase and hydrophobic interaction, Ion exchange and Ion exclusion, Size-exclusion, Group specific and biospecific affinity, IMAC, Supercritical fluid chromatography; Isocratic and Gradient Elution preparative chromatography; Mode of contacting solids with liquid: Packed bed , expanded bed, fluidized bed, moving bed (Simulated moving bed, True moving bed, Liquid-solid circulating fluidized bed, Fluidized moving bed); Novel Chromatographic Morphologies: Continuous annular systems, Radial flow, centrifugal chromatography, Perfusion chromatography, Membrane chromatography and Monoliths; Chromatographic Applications in Biotechnology: Applications of various modes of operation, sequencing of chromatographic operations, Multidimensional separations for proteomics.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Transport phenomenon, plug flow and fluidized bed reactors, Separation and Purification	
	Expected Learning	After this course students should have - knowledge of high resolution techniques in bioseparation - knowledge of purification of small and large biomolecules by chromatography - knowledge of integrated chromatographic operation for clarification, purification, polishing and concentration steps in bioprocessing - knowledge of column packing, designing of separation and its scale-up	

	Reference Books	1. Anurag Rathore and Ajoy Velyudhan, Scale-up and optimization in preparative chromatography, 2003 2. Sewell P.A. Clarke B, Chromatographic separations. John Wiley & Sons, 1991 3. Lindsay B., High performance Liquid Chromatography, John Wiley & Sons, 4. Lecture Notes on short course on Enantiomeric separations, April 28-29,1995.	
	Departments	DBT-ICT-CEB	

Sem II	Subject Code CEE 2003	Environmental Biotechnology	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Environmental impact and control; Biosafety, Biological treatment: stabilization pond, aerated lagoon, activated sludge process, trickling filter anaerobic treatment; Biodegradation of xenobiotic organic chemicals; Biological Detoxification of Hazardous chemicals; Environmental Policy & Legislation; Sampling of air and water pollutants; Monitoring techniques and methodology, pH, Dissolved Oxygen (DO); Chemical oxygen demand (COD); Biological Oxygen Demand (BOD); Speculation of metals, monitoring & analysis of CO, NO_2, CO_2, SO_2; Pesticide residue; Phenols and petrochemicals. Environmental pollution control-Bioremediation, Bioaugmentation and Biostimulation; Biofilms in treatment of waste water; Biofilm development and biofilm Kinetics; Aerobic Biofilms; Bioreactors for waste water treatments	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Introduction to chemical and biochemical engineering, basic biotechnology	
	Expected Learning	After this course, students should: - have a basic knowledge in the biological treatments - have a basic knowledge on the physics, chemistry and biology involved in the classical treatment processes - be able to design and control biological treatment processes	
	Reference Books	1. Martin Alexander, Biodegradation and Bioremediation, 2nd Edition, Academic Press, 1999. 2. Bruce Rittman, Perry L. McCarty. Environmental Biotechnology: Principles and Applications, 2nd Edition, McGraw-Hill, 2000. 3. D.L. Wise, Biotreatment Systems, Volume II. 4. Stanir R.Y., Ingraham J.L., Wheelis M.L., Painter R.R., "General Microbiology", McMillan Publications, 1989. 5. Foster C.F., John Ware D.A., "Environmental Biotechnology", Ellis Horwood Ltd., 1987. 6. Karnely D., Chakrabarthy K.,Omen G.S., "Biotechnology and Biodegradation", Advances in Applied Biotechnology Series, Vol. 4, Gulf Publications Co., London, 1989.	
	Departments	Chemical Engineering Department	

Sem II	Subject Code BSE 2109	Membrane Separations	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Principles of membrane separation, Membrane Materials, Transport phenomena of species, molecular and ionic, in porous or dense, charged or not, membranes. Membrane separation processes: Reverse Osmosis, Ultrafiltration, Microfiltration, Nanofiltration, Dialysis, Electrodialysis, Gas Permeation, Pervaporation, Liquid membranes, Membrane modules and design, cost estimation.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Transport Phenomena, Unit operation in bioprocesses	
	Expected Learning	Knowledge and understanding of nature of membranes; membrane transport mechanism; design of membrane modules and plant; membrane fouling. The ability to: classify membrane processes; determine the nature of membranes; formulate the theory of membrane transport and apply the general membrane theory in specific cases.	
	Reference Books	1. Handbook of membrane separations: chemical, pharmaceutical, food and biotechnological applications by Anil K. Pabby, Syed Rezvi and Anna Satre, CRC press, 2009 2. Filtration and purification in biopharmaceutical industry, second edition by Miak Jornitz and Theodore Meltzer, Informa Healthcare, Vol. 174	
	Departments	DBT-ICT-CEB Chemical Engineering Department	

Sem II	Subject Code CEE 2004	Extractive Separations	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Basic Principles of L-L Extraction processes, Thermodynamics of LLE and Distribution coefficient, Single and multistage extraction, Kinetics and modeling of extraction cycles, Types of extraction processes: Reactive extraction, Aqueous two phase systems, Reverse micellar extraction, Liquid-liquid and solid-liquid extraction, Super critical fluid (CO_2 and water). Design of extraction equipment. Different types of extractors and designing of extractors. Case Studies: Design of selective extraction processes for biomolecules from natural sources and fermentation broth. In-situ product removal.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Basics of Unit operations in Bioprocess, chemical and biochemical reaction kinetics	
	Expected Learning	After this course, students should: - have a basic knowledge of the extraction principles - have a basic knowledge of different mechanisms involved in extraction - be able to design and control of different types of Extractor	
	Reference Books	1. Liquid Liquid Extractions, Treybal 2. Liquid Liquid Extraction, KS Laddha 3. Wankat PC , Rate Controlled separations , Elsevier, 1990 4. Belter PA and Cussler E, Bioseparations, Wiley 1985 5. Product Recovery in Bioprocess Technology, BIOTOL Series, VCH, 1990 6. Asenjo JM, Separation processes in Biotechnology, 1993, Marcel Dekker Inc	
	Departments	Chemical Engineering Department	

Sem I	Subject Code BSE 2110	Biocatalysis and Green Technology	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Catalytic activity of biomolecules – enzymes and ribozymes; Enzyme applications: Hydrolase enzymes – lipases, esterases, proteases etc. with specific examples and mechanism, Lyases – e.g. Aspartase, tyrosine-phenol lyase; Isomerases – e.g. glucose isomerise; Transferases – e.g. aminotransferases, PLP as cofactor; Ligases; Oxidoreductases – dehydrogenases, oxidases, oxygenases, peroxidases. Whole cells as catalysts; Energetically unfavourable reactions at low temperatures and in unfavourable solvents; The Michaelis-Menten model and modes of inhibition; Kinetics of enzyme catalysed reaction; Regulation mechanisms; Mechanisn of enzyme action; Multienzyme systems; Selection and screening of biocatalysts for activity, stability and substrate or product selectivity; Extremozymes – protein catalysts for reactions at extremes of temperature, pressure and pH. Principles of green chemistry (e.g. prevention of waste, less hazardous methods, safer chemicals and solvents, energy efficiency, atom economy, use of catalysis, etc.); the design of "greener" effect chemicals, with examples from the development of crop protection agents; the design of "greener" chemical processes, with examples of the use of biocatalysts.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Bioreaction Engineering	
	Expected Learning	After this course students should have knowledge of enzymes as biocatalysts, its kinetics and applications for green technology.	
	Reference Books	1. Handbook of Industrial biocatalysis by Ching T. Hou, Taylor and Francis, 2005. 2. Biocatalysts and Enzyme technology, by K. Buchholz, V. Kasche and U. T. Bornscheuer, Wiley VCH Verlag GmbH and Co, 2005. 3. Modern Biocatalysis: Stereoselective and environmental friendly reactions by Wolf dieter Fessner and Thorleif Anthonsen, Wiley VCH, 2009.	
	Departments	DBT-ICT-CEB	

Sem II	Subject Code BSE 2111	Biocatalysis and Enzyme Technology	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Protein and Enzyme Engineering and Thermodynamics, Structure-Activity relationship of enzymes and their modeling/visualization, Modelling of enzymes using MM, QM and hybrid techniques; Molecular simulations as a tool for rational enzyme design; Chemometrics and QSAR for prediction of enzyme selectivity. Enzymes in organic synthesis, Enzymes in novel media, Green chemistry, Oxidation catalysis, Catalysis in water, Homogeneous catalysis, Heterogeneous catalysis, Asymmetric catalysis Biocatalysis versus chemical catalysis; Understanding when to use a biocatalyst for a chemical problem; Advantages/disadvantages of biocatalysts compared to traditional chemical reactions and heterogeneous/ homogeneous catalysis; Mild reaction conditions, excellent stereo- chemo- and regio- selectivity versus substrate specificity, product inhibition, lack of catalysts robustness, cofactor recycling; Isolated enzyme systems and whole cell systems. Free and immobilized enzymes for biocatalysis. Water versus organic solvent; Reactor and process technology: types, mass balances and their modes of operation; Biocatalyst recycling and recovery; Enzyme immobilization.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Bioreaction engineering, Biocatalysis	
	Expected Learning	After this course students should have knowledge of different enzyme catalytic reactions, reuse of enzymes, selectivity and specificity of enzymes.	
	Reference Books	1. Biocatalysts and Enzyme technology, by K. Buchholz, V. Kasche and U. T. Bornscheuer, Wiley VCH Verlag GmbH and Co, 2005 2. Enzymes: A Practical Introduction to Structure, Mechanism,and Data Analysis, Second Edition, Robert A. Copeland, Wiley VCH, 2000. 3. Modern Biocatalysis: Stereoselective and environmental friendly reactions by Wolf dieter Fessner and Thorleif Anthonsen, Wiley VCH, 2009.	
	Departments	DBT-ICT-CEB	

Sem I	Subject Code BSE 2112	Protein and Enzyme Engineering	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Protein structure and chemistry, Protein database analysis, methods to alter primary structure of protein, examples of engineered proteins, protein design, principles and examples. Thermodynamics of peptide/protein folding and substrate binding. Tools for the manipulation of DNA (endonucleases, ligases, DNA polymerases); Modification of proteins by enzymetic, chemical, physical and biological (site-directed mutagenesis) methods; Optimisation of biocatalysts by directed evolution; Introduction of non-canonical and synthetic amino acids into proteins; Strategies for introduction of genetic diversity – random mutagenesis, recombination, gene shuffling and semi-synthetic shuffling. Enzyme Immobilization: Physical and Chemical techniques for enzyme immobilization – adsorption, matrix entrapment, encapsulation, cross linking, covalent binding etc. Characterization of immobilized biocatalysts. Advantages and disadvantages of different immobilization techniques, overview of application of immobilized enzyme systems.	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Bioreaction engineering, Biocatalysis	
	Expected Learning	After this course students should have knowledge of physicochemical and biological approaches for modifications of proteins and enzymes.	
	Reference Books	1. Biocatalysts and Enzyme technology, by K. Buchholz, V. Kasche and U. T. Bornscheuer, Wiley VCH Verlag GmbH and Co, 2005 2. Enzymes: A Practical Introduction to Structure, Mechanism,and Data Analysis, Second Edition, Robert A. Copeland, Wiley VCH, 2000	
	Departments	DBT-ICT-CEB	

Sem II	Subject Code BSE 2113	Bioinformatics and Statistical Methods	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	2 0 2	
	Tutorial Hours	1	
		Diagrammatic and graphical representation of numerical data: formation of frequency distribution, histogram, cumulative frequency distribution, polygon and Ogives, measures of central tendencies – mean, median, mode. Measures of dispersion – mean deviation, standard deviation, variance, quartile deviation and coefficient variance, Moments (up to 4^{th}), Measures of skewness and kurtosis for grouped and ungrouped data. Correlation and regression analysis: product moment and rank correlation coefficient, simple regression, method of least squares for estimation of regression coefficients, concept of sampling and sampling distribution, sampling from nominal distribution, standard error, test of significance, large sample test for population mean and proportions, Test of population means-single, two sample, and paired t-test, chi square test. ANOVA; Multiple way classification of variables and Design of Experiments	2 hrs lecture each week for 15 weeks
	Pre-requisite courses	Mathematics or similar course (college level algebra or higher)	
	Expected Learning	After this course students should have knowledge of statistical analysis of numerical data and its interpretation.	
	Reference Books	1. Snedecor G. W. and Chochran W. G., Stastical Methods, 1989. 2. Higher Engineering Mathematics, B.S.Grewal, Khanna Publishers 3. Engineering Mathematics, Vol.2, S.S.Sastry, Prentice Hall of India(P)Ltd. 4. Complex Variables Theory And Applications, H.S.Kasana, Prentice Hall of India(P)Ltd 5. Advanced Engineering Mathematics, Michael D Greenberg, Pearson Education	
	Departments	DBT-ICT-CEB	

Laboratory Work

Sem I	Subject Code CEP 2001	Laboratory – I (Chemical Engineering Lab)	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	0 3 3	
	Tutorial Hours	0	
		Flow through pipes (coils, horizontal and pipe fittings), venture meter, liquid-liquid Extraction, adsorption isotherms, uptake kinetics and breakthrough curve.	3 hrs practical each week for 15 weeks
	Pre-requisite courses	Mathematics or similar course	
	Expected Learning	After this course students should have knowledge and hands on skill of transport processes, adsorption equilibria and kinetic, and extraction	
	Reference Books		
	Departments	Chemical Engineering Department	

Sem II	Subject Code BSP 2101	Laboratory – II (Biochemistry, Microbiology and Genetics)	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	0 3 3	
	Tutorial Hours	0	
		Qualitative and quantitative methods of proteins and metabolite estimation, enzyme kinetics, isolation of nucleic acids, isolation of pure culture, identification of different microorganisms/cultures. Plasmid isolation and transformation	3 hrs practical each week for 15 weeks
	Pre-requisite courses	Basic biochemistry, Microbiology and Molecular biology	
	Expected Learning	After this course students should have knowledge and hands on skill of - qualitative and quantitative methods of analysis of proteins, enzymes and other biomolecules. Should also have - isolation and quantification of nucleic acid and transformation	
	Reference Books		
	Departments	DBT-ICT-CEB	

Sem III	Subject Code BSP 2102	Laboratory – III (Fermentation and Downstream processing)	No. of Hours
	Credits	3	
	Lecture/ Practical = Hours	0 3 3	
	Tutorial Hours	0	
		Preparation of fermentation media, Sterilization, Isolation and purification of biomolecules (protein/s or enzyme) from crude source/fermentation broth using membrane filtration and adsorption chromatography. Solid-liquid extraction of natural product and subsequent purification. Assessment of recovery and purity of the isolated product.	3 hrs practical each week for 15 weeks
	Pre-requisite courses	Unit operation in bioprocesses, Transport phenomenon, Bioreaction engineering, Basic biochemistry and Microbiology	
	Expected Learning	After this course students should have knowledge and hands on skill of - microbial fermentation - recovery and purification of bioproducts	
	Reference Books		
	Departments	DBT-ICT-CEB	

Note: Following two electives will be offered by DBT-ICT-CEB as cross-departmental electives for semester I and II

SEMSTER I

BSE-2104-Bioanalytical Techniques

SEMESTER II

BSE-2108 - Adsorptive and Chromatographic Separations