INSTITUTE OF CHEMICAL TECHNOLOGY
Ordinances, Regulations and Syllabi relating to the
Degree of Master of Technology in Bioprocess Technology
(M. Tech. Bioprocess Technology)
2023-2024

1. Introduction

The Institute is revamping its academic structure especially for the master's courses by way of introducing the compulsory industrial training for a period of six months (to be undertaken in the third semester of the programme). The number of credits in the first two semesters has also been increased and a research component has been included. The total credits in the first two semesters now stand at 27 each instead of the earlier 21. All the courses will continue to be credit based and the evaluation will be grade based.

The departmental administrative committee and academic programme committee periodically proposed the programme outcomes having consistency with the graduate attributes available with NBA. The committee critically analyzed information obtained from graduated students, employers and immediately passed out students. The programme outcomes are as follows:

SR. NO.	PROGRAMME OUTCOMES (POS)
1	The graduates will be able to apply knowledge of basic sciences (Mathematics, Physics, Chemistry, Biochemistry, Microbiology, Biology and Chemical Engineering Sciences) and applied engineering courses in getting solutions to issues pertaining to biotechnology, biochemical, biopharmaceutical and allied industries.
2	The graduates should be able to systematically break up complex processing problems in realizable steps and solve them.
3	The graduates will be able to design and develop a process, a product or a component of a biotech system or provide an engineering and technological solution for a specific task within realistic constraints.
4	The graduates will be able to design and conduct experiments as well as analyze and interpret data.
5	The graduate will be able to use modern tools, software, equipment, etc. to analyze and obtain solutions to the problems.
6	The graduates will be able to study the impact of the bioprocess industry in the global, economic, and societal context.
7	The graduates should practice their profession considering environmental protection and sustainability.
8	Graduates are expected to practice professional skills in an ethical manner.

9	The graduates should have competence to undertake designated task on individual or team basis as per the requirement.
10	The graduates will be able to communicate effectively their points of view.
11	The graduates will acquire attitude for life-long learning.
12	The graduates should actively participate in project and financial management.

SR. NO.	PROGRAM SPECIFIC OUTCOMES (PSOs)
13	Graduates will be acquainted with the latest development in different fields of bioprocessing so as to enable them to take up higher studies, research and developmental work.
14	Graduates will be introduced to industrial bioprocessing and technology managerial subjects, so as to enable them to take up further studies in technology development, technology translation and function effectively as managers.

Credit system is a systematic way of describing an educational programme by attaching credits to its components. The definition of credits may be based on different parameters, such as student workload, learning outcomes and contact hours. It is a student-centric system based on the **student workload** required to achieve the objectives of a programme. It should facilitate academic recognition of the courses and mobility of the students. Credits assignment is based on the principle that credits can only be obtained after successful completion of the work required and appropriate assessment of the learning outcomes achieved. As per the AICTE norms 2L/week of lectures are 2 credits, while 2h/week of practical/seminar/literature review/research work are 1 credit. This has been taken as the basis during the working of the proposed syllabus.

Student workload consists of the time required to complete all prescribed learning activities such as attendance at lectures/practical, seminars, projects, etc. Credits are allocated to all the educational components of a study programme and indicate the quantity of work each component requires to achieve its specific objectives.

Evaluation is an important component of any teaching-learning process. The Institute places emphasis on continuous evaluation with considerable freedom to the teacher in deciding the mode of evaluation of the students. The performance of the student is documented by a **grade** at the end of the semester. The grading scale ranks the students on a statistical basis. Therefore, statistical data on student performance is a prerequisite for applying the grading system.

2. Course Credits

In general, a certain quantum of work measured in terms of **credits** is laid down as the requirement for a particular degree. The student acquires credits by passing courses every semester, the amount

of credit associated with a course being dependent upon the number of hours of instruction per week in that course.

There are mainly two types of courses in the Institute: lecture courses and laboratory courses. Lecture courses consist of lecture (L) and tutorial (T) hours. Laboratory courses consist of practical (P) hours. The credit (C) for a course is dependent on the number of hours of instruction per week in that course, as given below:

(1) 1h/week of lecture (L) or tutorial (T) = 1 credit
(2) 2h/week of Practical (P) = 1 credit
(3) Credit (C) for a theory course = No. of hours of lectures per week + No. of hours of tutorials per week = L + T
(4) Credits (C) for a Laboratory course/Seminar/research work = ½ × No. of hours per week

Credits will be assigned to In-plant, Seminar, Projects and other mandatory course requirements also and these will be mentioned in the respective syllabi. There may be some non-credit requirements. A student is required to earn credits as mentioned in the syllabus.

3. Evaluation

3.1 The weightage of different modes of assessments shall be as under:

	In-Semester evaluation		**End-Semester-Exam**	**Components of continuous mode**
	Continuous mode	**Mid Semester-Exam**		
Theory	20%	30%	50%	Quizzes, class tests (open or closed book), home assignments, group assignments, *viva-voce* assignments, discussions
Practical	50%	-	50%	Attendance, *viva-voce*, journal, assignments, project, experiments, tests
Seminar/ critical review/ Research work	-	-	100%	Continuous evaluation not applicable, End semester evaluation will be based on written report evaluation and presentation in front of the external examiner within the Department

3.2. In-Semester Evaluation:

(a) It is expected that the teacher would conduct at least two assessments (in any form as quizzes, tests, homework, group work etc.) under the continuous mode in a semester.
(b) The teacher will announce at the beginning of the respective course the method of conducting the tests under the continuous mode and the assignment of marks.
(c) In-semester performance of all students should be displayed and sent to the academic office by the teacher at least 15 days before the end-semester examination.
(d) For the theory courses, there will be one mid-semester test for each course to be held as per the schedule fixed in the Academic Calendar.
(e) For mid-semester examinations in theory papers, duration of examination will be 1 hour for 3 credit courses and 2 hours for 4 credit courses.

3.3. End-Semester examination:

a) The semester end examination will cover the full syllabus of the course and will be conducted as per the Institutional timetable at the end of each semester.
b) For end-semester examinations in theory papers, duration of examination will be 1 hour for 3 credit courses and 2 hours for 4 credit courses.
c) For the end semester evaluation of seminar/research work, students will be expected to submit a written report and make a presentation. The evaluation will be based on the quality of the written report and presentation.

3.4 Passes and Fail

(a) The candidates who obtain 40% and more marks of the total marks of a course head shall be deemed to have **passed** the respective course head.
(b) The candidates who obtain marks less than 40% of the total marks of a course head shall be deemed to have **failed** in the respective course head **(Grade FF).**

3.5 Grades:

(a) The performance of a student shall be documented by a **Letter grade.** Each letter grade has a **Grade point** associated with it. The Grades and Grade points shall be assigned to each head of passing and both will be indicated in the mark-list of the semester examination.
(b) The total marks (in-semester + end-semester) of a candidate in a subject head are converted into a letter grade, based on the relative (and sometimes the absolute) performance of the student.

Letter Grade	**Grade Point**
AA	10
AB	9
BB	8
BC	7

CC	6.5
CD	6
DD	5.5
EE	5

(c) For granting class, a grade point of 6.0 and above will be considered equivalent to First class.

(d) The grades to be allotted in the case of students who fail or do not appear at the end-semester examination shall be as under:

Letter Grade	**Grade Point**	**Explanation**
FF	0	The candidate fails in course head. The candidate will be allowed to take end semester repeat or subsequent examinations as per rule.
XX		The candidate has not kept term for the course head due to attendance less than requisite. Further see 3.5(g) below. In the above cases, the candidate has to repeat the respective course by paying the fees.
I	0	The candidate has kept term for the course head, has taken all the internal examinations with satisfactory performance, but has failed to take the end-semester examination or repeat examination due to genuine reasons. The candidate will be allowed to take end-semester repeat or subsequent examinations as per rule.
FR	0	The candidate has exhausted all the permissible chances to clear the end-semester examinations. The candidate has to register for the respective semester again for all the subject heads or will be out of the respective degree course as per the rules.
DR	0	(i) The candidate has not participated in academic programme. (ii) The candidate has taken a drop for the subject head: - provided he/she intimates the same (i or ii) at least 7 days in advance of the commencement of the end-semester examination for the respective year.

(e) Grades **FF** and **I** are placeholders only and do not enter into CPI/SPI calculations directly. These grades get converted to one of the regular grades after the end-semester examination.

(f) A candidate with an **FR** grade is not eligible for any repeat examination in that course and has to re-register for that semester by paying the appropriate fees.

(g) **I** grade will not be continued beyond the permissible number of end-semester/repeat examinations.

(h) **'XX' Grade:** The grade **XX** in a course is awarded if – (i) candidate does not maintain the minimum 75% attendance in the Lecture/Tutorial/Practical classes, (ii) candidate receives less than 20% of the combined marks assigned for continuous assessment and mid-semester examination, and (iii) candidate indulges in a misconduct/uses unfair means in the examination, assignments, etc., of a nature serious enough to invite disciplinary action in the opinion of the teacher.

(**Note:** Award of the **XX** grade in the case of h(iii) above shall be done by Disciplinary Action Committee (DAC)).

(i) The names/roll numbers of students to be awarded the **XX** grade should be communicated by the teacher to the Academic office as per academic calendar before the last date of submission of the application for end semester examination.

3.6. Awarding the grades

The grading scale ranks the students on a statistical basis on the basis of the overall performance of the students of a given class in the given course head. Therefore, statistical data on students' performance is a prerequisite for applying the grading system. While assigning grades in a given course head, it is essential to know the **average marks (AM)** obtained by the students *who have passed the subject head* and the **highest marks (HM)** obtained in the *same subject head*.

3.6.1. If the **average marks (AM)** obtained by the students *who have passed the subject head* is <60%, the interval AM shall be awarded grade CC and the other grades shall be decided as follows:

(i) AA, AB, BB, and BC grades shall be decided between the AM and HM by dividing the range in equal intervals.

(ii) CD, DD and EE grades shall be decided between the AM and minimum marks required for passing the head (i.e. 40%) by dividing the range in equal intervals.

3.6.2. If the **average marks (AM)** obtained by the students *who have passed the subject head* is such that **60% ≤ AM < 70%**, the interval AM shall be awarded grade BC and the other grades shall be decided as follows:

(i) AA, AB, BB grades shall be decided between the AM and HM by dividing the range in equal intervals.

(ii) CC, CD, DD and EE grades shall be decided between the AM and minimum marks required for passing the head (i.e. 40%) by dividing the range in equal intervals.

3.6.3. If the **average marks (AM)** obtained by the students *who have passed the subject head* is **≥ 70%** , the interval AM shall be awarded grade BB and the other grades shall be decided as follows:

(i) AA and AB grades shall be decided between the AM and HM by dividing the range in equal intervals.

(ii) BC CC, CD, DD and EE grades shall be decided between the AM and minimum marks required for passing the head (i.e. 40%) by dividing the range in equal intervals.

4. SPI and CPI

(a) **Semester Performance Index (SPI):** The performance of a student in a semester is indicated by **Semester Performance Index (SPI),** which is a weighted average of the grade points obtained in all the courses taken by the student in the semester and scaled to a maximum of 10. (SPI is to be calculated upto two decimal places.) 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 courses for the semester,
'c_i' is the number of credits allotted to a particular course, and
'g_i' is the grade-points awarded to the student for the course based on his performance as per the above table.
SGPA will be rounded off to the second place of decimal and recorded as such.

(b) **Cumulative Performance Index (CPI):** An up to date assessment of the overall performance of a student from the time he entered the Institute is obtained by calculating **Cumulative Performance Index (CPI)** of a student. The CPI is weighted average of the grade points obtained in all the courses registered by the student since he entered the Institute. CPI is also calculated at the end of every semester (upto two decimal places).

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' is the total number of courses from the first semester onwards up to and including the semester S,

'c_i' is the number of credits allotted to a particular course, and

'g_i' is the grade-points awarded to the student for the course based on his performance as per the above table. CGPA will be rounded off to the second place of decimal and recorded as such.

(c) 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 the next semester.

(d) **When** a student gets the grade 'FF', or I' in any subject head during a semester, the SGPA and CGPA from that semester onwards will be tentatively calculated, taking only 'zero' grade point for each such 'FF' or 'I' grade. When the 'FF' grade(s) has / have been substituted by better grades after the repeat examination or subsequent semester examination, the SGPA and CGPA will be recomputed and recorded.

5. Repeat End-Semester Examination

5.1. For those candidates who fail in a subject head or are eligible for appearing at the repeat examination, **Repeat End-Semester Examination** will be conducted within one month from the declaration of the results of regular end-semester examination, as per **Regulation R.14**.

5.2. The marks obtained by candidates in the in-semester examinations (continuous assessment and Mid Semester Examination) will be carried forward in such cases.

5.3. Grading the performance in the Repeat Examination: The grades will be assigned as per 3.5 and 3.6 above. However, for a candidate taking any repeat examination or subsequent regular semester examination or performance improvement examination shall be awarded **one grade lower** than that decided on the basis of the actual marks obtained; provided 'EE' grade obtained in such an examination shall remain 'EE'. For reference see the table below.

Grade obtained in repeat or subsequent end-semester examination	Grade to be assigned	Grade point
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

5.4. Revaluation of end-semester and repeat examination: Candidate's performance in these examinations will be displayed on proper notice board and after 3 days of such display the marks will be sent to the Academic Office. No revaluation of these examinations will be allowed.

6. Passing of a Semester examination

A candidate shall be declared as **'PASSED'** any semester examination if he/she has

(a) Cleared all heads of passing by securing grades EE or higher in all the heads;
(b) Passed all the heads of passing such as project, seminar, training, etc as per the rules;
(c) Satisfactorily completed all the mandatory requirements of the course;
(d) paid all the Institute dues;
(e) No case of indiscipline pending against him/her.

7. Eligibility for the Award of a Degree

A candidate shall be declared eligible for the award of a degree, if he/she has cleared all the semester examinations as given in (6) above.

8. Allowed to keep terms (ATKT)

8.1 A candidate who has I grade in one or more heads of passing of an odd semester of an academic year shall be allowed to keep terms for the respective even semester.

8.2. A candidate shall be allowed to keep terms for the subsequent academic year if he/she has FF or I grade in not more than two heads of passing from all the heads of passing of the two

terms of the previous academic year taken together. Such a candidate shall be declared as **FAILED, ATKT**.

9. Repeating a course

9.1 A student is required to repeat the course under the following situations:

(a) A student who gets an **XX, FR, or DR** grade in a course; or

(b) A student has exhausted all permissible chances to clear the course.

9.2 A candidate from first year who remains absent for the regular end-semester examination of a semester and the corresponding repeat examination for **ALL SUBJECTS** shall have to take fresh admission for the corresponding year; unless the candidate has dropped out / terminated from the course.

9.3 If a candidate at the Second, fails to pass any semester examination in not more than 4 consecutive examinations, including the repeat examinations, from the date of registering for the respective year, the candidate shall have to take readmission for the corresponding year again in which the failure has occurred, provided the course is not changed.

10. Improvement of performance

A candidate will be allowed to appear at the **entire examination** after the regular end-semester examination as per the respective rules to improve the performance. In such a case if the result of the examination repeated –

1. Is better than the previous one, the previous result shall be declared null and void;
and 2. Is worse than the previous one, the result of the subsequent examination shall not be declared.
3. However, awarding of final grade will be made under the provision of sub clause 5.3 above.

11. Exit rules for poorly performing students

A candidate shall be excluded from a course under the following conditions:

(a) If he/she fails to pass any semester examination of the any year of the course in not more than four consecutive attempts (Examination conducted by Institute) from the date of joining the course.

(b) If he/she does not keep two consecutive terms without giving any reasonable justification (as prescribed by the institute) for doing so.

(c) If a candidate fails to fulfill all the requirements of his/her respective degree within the prescribed period from the date of taking admission to the course, the candidate shall be excluded from the course.

12. Miscellaneous

(a) Although CPI will be given in the Semester grade report, the final degree certificate will not mention any **Class** whatsoever.

(b) Not with standing anything said above if a course is revised /restructured then transient provisions applicable at the time of revision /restructuring shall be applicable.

Syllabus Details for the degree of
Master of Technology (Bioprocess Technology) Program

Subject code	Subject	Credit	Hr/Week			Marks			
			L	T	P	Continuous Assessment	Mid-semester Examination	Final Examination	Total
SEMESTER I									
BST 2101	Core I: Bioreaction Engineering	3	2	1	0	20	30	50	100
BST 2114	Core II: Cell Culture and Biosystem Engineering	3	2	1	0	20	30	50	100
BST 2107	Core III: Analytical Methods in Bioprocessing	3	2	1	0	20	30	50	100
	Elective I	3	2	1	0	20	30	50	100
	Elective II	3	2	1	0	20	30	50	100
BSP 2101	Bioprocess Engineering Laboratory	3			6	50	-	50	100
BSP 2102	Seminar and Critical Review	3	---	---	6	-	-	60 (Report) 40 (Presentation)	100
BSP 2103	Research Project-I	6	---	---	12	-	-	60 (Report) 40 (Presentation)	100
	TOTAL:	27	10	5	24				800
SEMESTER II									
BST 2103	Core V: Industrial Biocatalysis	3	2	1	0	20	30	50	100
BST 2112	Core VI: Adsorptive, Chromatographic and Membrane separations	3	2	1	0	20	30	50	100
BST 2102	Core VII: Unit Operation in Bioprocessing	3	2	1	0	20	30	50	100

	Elective III	3	2	1	0	20	30	50	100
	Elective IV	3	2	1	0	20	30	50	100
BSP 2104	Biosciences and Bioprocess Technology Laboratory	3			6	20	30	50	100
BSP 2105	Research Project-II	9	---	---	18	-	-	60 (Report) 40 (Presentation)	100
	TOTAL:	27	10	5	24	-	-	-	700
SEMESTER III									
BSP 2106	RP-III	30	-	-	40			60 (Report) 40 (Presentation)	100
SEMESTER IV									
BSP 2107	Final Thesis	30	-	-	40	-	-	60 (Report) 40 (Presentation)	100

Note: Semester III and Semester IV evaluation will be conducted at end of IV semester.

Brief Overview of Syllabus

SEMESTER I

	Course Code: BST2101	**Course Title: Bioreaction Engineering**	**Credits =**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**3**	**1**	**0**
List of Prerequisite Courses					
	1. Biological sciences [For Engineering Students]				
	2. Transport Phenomenon [For Interdisciplinary and Pharmacy Students]				
	3. Differential and integral calculus, Solution of differential equation [For Interdisciplinary and Pharmacy Students]				
	4. Numerical methods, Computer programming [For Interdisciplinary and Pharmacy Students]				
	5. Kinetics of chemical reactions, Physical Chemistry [For Interdisciplinary and Pharmacy Students]				
List of Courses where this course will be prerequisite					
	1. Biocatalyst engineering				
	2. Bioreactor design				
	3. Enzyme engineering				
	4. Industrial biocatalysis				
Description of relevance of this course in the M.Tech.(BPT) Program					
Bioreaction engineering deals with the design, analysis and optimization of biological processes involving microorganisms, enzymes or cells. It combines principles from chemical engineering, microbiology, biochemistry and systems biology to create efficient and sustainable bioprocesses for various applications. The focus of the Bioreaction Engineering course is to provide students with the knowledge needed to understand and apply reaction kinetics and engineering principles to the industrial production of bioproducts by means of isolated enzymes and microbial cells. This course will provide an introduction to the important principles and techniques that are used in the design and analysis of reactors conducting enzymatically modulated reactions. It will also develop students' knowledge and understanding of industrial processing, analytical abilities and problem solving methodologies in this area.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Introduction to biochemical industry, Basic Principles of biochemical reactions and Thermodynamics and kinetics of bioreactions, feasibility and efficiency of bioreactions[1].		2		
2	Biocatalysis *versus* chemical catalysis; Advantage and disadvantage of biocatalyst compared to traditional chemical reactions		1		

3	Material and Energy Balance Computations of biochemical reactions, Elemental and redox balances: how to account for the mass and energy conservation in bioreactions	2
4	Enzyme kinetics, Factors affecting rates of enzyme catalyzed reactions, Inhibition and co-factor activation of enzymes, Regulatory mechanisms,	3
5	Thermostabilizing and immobilization of enzymes	2
6	Enzymatic reactors, Batch time for enzymatic batch reactors, Packed and stirred reactors, mass transfer limitations of immobilized enzyme reactors, process design	4
7	Microbial kinetics, factors affecting microbial kinetics, Growth kinetics of cell cultures: how to characterize the growth behavior and productivity of microbial populations	4
8	Unstructured and simple structured models, Biochemical reaction networks, Mechanistic models and morphologically structured models	4
9	Transport phenomena in bioreactors Process design of fermenters	4
10	Batch, semi-batch and continuous fermenters, Monod's Chemostat, Productivity of bioreactors, mass transfer aspects of biochemical reactors,	4
List of Reference Books		
	1. James E. Bailey and David F. Ollis, Biochemical Engineering Fundamentals, McGraw Hill 1986	
	2. Biotransformations and Bioprocesses, M. Doble, Anil and VG Gaikar, Marcel Dekker	
	3. James M. Lee, Biochemical Engineering, Prentice Hall, 1992	
	4. Bioreaction Engineering Principles, Jens Nielsen, John Villadsen, Springer, Boston, MA	
Course Outcomes		
Sr. No	Upon successful completion of this course, the students will be able to….	Level
1	Understand, categories and describe the quantitative terms of the rates of enzyme catalyzed reactions at given process operations.	K4
2	Understand and calculate the data analysis and evaluation parameters by performing various numerical calculations using the process data	K3
3	Apply and analyze the unsteady-state mass and energy balance concepts to batch, fed batch and continuous bioreactors.	K4
4	Design and interpret the process design of various bioreactors	K5
5	Prepare an estimate, material and energy balance for virous operations in bioprocessing	K6

	Course Code: BST2114	Course Title: Cell Culture and Biosystems Engineering (Marks 100)	Credits =		
			L	T	P
	Semester: I	Total contact hours: 60	3	1	0
List of Prerequisite Courses					
	BST2108 Applied Molecular and Synthetic Biology				
List of Courses where this course will be prerequisite					
	1. Unit Operation in Bioprocessing 2. Biosciences and Bioprocess Technology Laboratory				
Description of relevance of this course in the M.Tech. Bioprocess Technology Programme					
The focus of the Biosystems Engineering course is to introduce students to advanced concepts of biological engineering. Engineering of whole cells, rather than working with individual genes, will be emphasized. Mathematical modeling of metabolic pathways will also be covered.					

	Course Contents (Topics and subtopics)	Reqd. hours
	Cell Culture	
1	Historical and modern perspective of Fermentation Synthesis methods from chemical (petrochemicals and natural products) and biotechnology routes (fermentation and cell culture technology). Introduction to High value-Low volume and Low value-High volume chemicals	4
2	Strain construction and strain improvement, Nutritional requirements of Microorganisms in fermentation process, Microbial Growth, product and substrate kinetics. Statistical methods for nutrient optimization for Biochemical production	6
3	Aerobic and anaerobic fermentation, surface, submerged and solid state fermentation technology, high cell density and high performance bioreactors	4
4	Fermentation design (for example based on agitation and aeration), cost consideration. Design considerations for aseptic fermentation, Modern Experimental techniques: Batch, fed batch, continuous, Efficiency of fermentation process	6
5	Scale-up Automation, optimization and control of fermentation processes	2
6	Cell culture engineering and technology, Plant and mammalian cell culture for production of Bio-based products	8
	Biosystems Engineering	
7	Engineering biological systems: an overview	2
8	Principles of metabolic regulation	4
9	Engineering and characterisation of chassis organisms	6
10	Building synthetic pathways: combinatorial engineering	4
11	Cell-free metabolic engineering	2
12	Semisynthetic cells	4

13	Modeling pathways; genome scale modeling; flux balance analysis	6
14	Design principles of genetic circuits	2
List of Text Books/Reference Books		
1	Principles of Fermentation Technology by Peter F. Stanbury, Allan Whitaker and Stephen J hall	
2	Biochemical Engineering Fundamentals by James E. Bailey and David F. Ollis	
3	Systems and Synthetic Biology (edited by Vikram Singh and Pawan Dhar), Springer	
4	Fundamentals of Systems Biology (by Markus Covert), CRC Press	
5	Articles from the primary scientific literature	
Course Outcomes		
Sr. No	Upon successful completion of this course, the students will be able to….	Level
1	Understand and apply in qualitative and quantitative terms the operation of a variety of bioprocess operations and design a new	K3
2	Apply and analyze microbial fermentation process to a variety of bioprocesses	K4
3	Analyze and evaluate the methods and technologies used for animal and plant cell cultivation for bio-based chemical production	K5
4	Analyze and evaluate the principles of metabolic engineering	K3
5	Evaluate and Engineer the entire pathways in a facile and combinatorial manner	K6

	Course Code: BST2107	Course Title: BST2104 Analytical Techniques in Bioprocessing (Marks 100)	Credits = 3		
			L	T	P
	Semester: I	Total contact hours: 60	2	1	0
List of Prerequisite Courses					
	Basics of biochemical analysis, spectroscopic techniques, organic chemistry, functional groups, electromagnetic radiation.				
List of Courses where this course will be prerequisite					
	Bioreaction Engineering, Unit operations in bioprocessing, Industrial Biocatalyst Adsorptive chromatographic & membrane separation, Bioprocess Equipment Design and Industrial Process Automation				
Description of relevance of this course in the M. Tech BPT Program					
	The focus of the Analytical Techniques in Bioprocessing course is to provide individuals with the knowledge needed to understand and apply sound analytical principles to develop qualitative, quantitative and in process analysis techniques for various biomolecules, organic molecules, protein, polysaccharides, natural products, APIs etc., for industrial applications of bioprocess technology and bioprocess development. This course will provide important insights to various advanced and hybrid analytical tools that are widely used in the process design, development, in-process monitoring, analysis and characterization of various bioprocess and biomolecules. It will also help to develop analytical and experimental problem-solving ability of learners in the area of bioprocess technology.				
Module	**Course Contents (Topics and subtopics)**				**Reqd.hrs**
1	**Qualitative and quantitative analysis techniques and their applications**: Qualitative and quantitative analysis of proteins, nucleic acids, polysaccharides, and small molecules such as antibiotics, vitamins, natural products etc. **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. **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.				6
2	**Spectroscopic techniques**: **UV-Spectroscopy:** Instrumentation, principle, Beers and lambert law, shift of absorption maxima and intensity, chromophore,				12

	auxochrome, electronic transitions, woodward-fieser rules, applications of UV-spectroscopy. **IR-Spectroscopy:** Instrumentation, principle, different mode of vibrations, vibrational transitions, IR-active and IR-inactive bands, classification of IR-active bands, Hook's law, types of molecular vibration in IR, applications of IR-spectroscopy. **NMR-spectroscopy:** History of NMR, Instrumentation, principle, Chemical shift, factors influencing chemical shift, deshielding, chemical shift values and correlation for protons bonded to carbons (aliphatic, olefinic, aldehydic, aromatic) and other nuclei (alcohols, phenols, enols, acids, amides and mercaptans), chemical exchange, effect of deuteration (Driving force), spin-spincoupling, (n+1) rule, complex spin-spin interaction, factors effecting coupling constant, applications of NMR-spectroscopy. **Mass Spectrometry:** Introduction, ion production-EI, CI, FD and FAB, factors affecting fragmentation, ion analysis, ion abundance. Mass spectral fragmentation of organic compounds, common functional groups, molecular ion peak, metastable peak, McLafferty rearrangement. Nitrogen rule, example of Mass fragmentation of organic compounds with respect to their structure determination. High resolution mass spectrometry – ESIMS and MALDI-TOF.	
3	**Surface analytical techniques:** **Scanning electron microscopy (SEM) and Transmission electron microscopy (TEM)**: Instrumentation, principle, Electron beam interactions with solids, Specimen preparation, Image formation, detectors, and contrast, Imaging modes, resolution, Energy dispersive spectrometry and qualitative analysis, Quantitative EDS analysis, Compositional imaging, High-resolution SEM, low voltage SEM **X-Ray diffraction analysis (XRD)**: Instrumentation, principle, X-ray beam interactions with solids, Specimen preparation, Unit cell, Brag angle, crystal lattice, application of XRD	6
4	**Hybrid Techniques**: High performance liquid chromatography (HPLC) and Gas chromatography (GC), Principle and instrumentation, types of detectors, 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	6

	detection (ICP- MS). Applications to proteomics, metabolomics, Impurity identification and profiling.	
List of Textbooks/ Reference Books		
	1. Spectroscopy of Organic Compounds, P S Kalsi, New AGE International Publication	
	2. Elementary Organic Spectroscopy, Principles and Chemical Applications, Y.R Sharma, S. Chand.	
	3. Handbook of analytical separations, vol. 4, by Ian Wilson, 2003	
	4. Encyclopedia of spectroscopy and spectrometry, vol. 1-3, 2000	
	5. Methods of biochemical Analysis, Vol. 35, Clarence Suelter, 1991	
	6. Methods of biochemical Analysis, Vol. 36, Clarence Suelter, 1992	
Course Outcomes		
r. No	Upon successful completion of this course, the students will be able to….	Level
1	Able to understand the basics of bioanalytical instrumentation and its applicability in bioprocessing and to appraise these techniques during their research work.	K4
2	Evaluate quality control for natural products, proteins, APIs organic compounds, biopharmaceuticals and biochemical etc.	K5
3	Analyze and interpret the analysis data of various biotech and biobased products by using spectroscopic, qualitative, and quantitative analysis tools.	K4
4	Understand, compare, and evaluate the raw material, in process and finished product quality control for biotech and biobased products	K5
5	To find out the applications of various analytical techniques in process automation, process control and various biotech products as well as their formulations/stability etc.	K6

	Course Code: **BSP 2101**	**Course Title: BSP 2101** Bioprocess Engineering Laboratory **(Marks 50)**
	Semester: I	**Total contact hours: 30**
Module	**Course Contents (Topics and subtopics)**	
1	Flow through pipes, coils and fittings. Flow meters, orifice, venturi, rotameter and turbine meter. Flow through packed beds. Two phase flow. Sedimentation. Fluidization. Solid-liquid separation. Mixing. Evaporators. Absorption in a packed column. Adsorption isotherms. Drying characteristics. Study of spray nozzles, impellers, tower packings, dryers, filters, evaporators. Demonstration of some phenomena, particularly in mixing, fluid mechanics, etc.	
2	Absorption with and without chemical reactions in packed columns. Distillation in packed and/or plate column. Spray, packed and mechanically agitated extraction columns. Absorption/ion exchange in fixed beds. Separation by membranes. Flow of non-Newtonian fluids. Dynamics of feedback control systems. Level and pH control. Demonstration of some important phenomena in bioprocess Engineering, notably coalescence, foaming, internal circulations in drops and bubbles, two and three phase fluidization, aggregative and particulate fluidization, mixing, crystallization etc.	
3	Suitable number of experiments from the above list will be performed. In addition to these experiments, students will also undertake demonstration experiments related to advanced analytical instruments such as GC, HPLC, GC-MS, LC-MS, SEM, FTIR, UV-Vis Spectrophotometry, NMR, TEM, ICP, particle size analyzer etc. In this student will work in groups on these instruments to make a report on theory, working principle, standard operating procedure and one case study as well as live demonstration at the end of laboratory session.	

<table>
<tr><td rowspan="2"></td><td>Course Code:
BSP2102</td><td>Course Title: BSP2102
Seminar and Critical Review
(Marks 50)</td><td colspan="3">Credits = 3</td></tr>
<tr><td></td><td></td><td>L</td><td>T</td><td>P</td></tr>
<tr><td></td><td>Semester: I</td><td>Total contact hours: -</td><td>-</td><td>-</td><td>6</td></tr>
<tr><td colspan="6">List of Prerequisite Courses</td></tr>
<tr><td></td><td colspan="5">Literature Survey, In-depth reading of Research and review article</td></tr>
<tr><td colspan="6">List of Courses where this course will be prerequisite</td></tr>
<tr><td></td><td colspan="5">1. Research Project-I, Research Project-II, Research Project-III, Thesis</td></tr>
<tr><td colspan="6">Description of relevance of this course in the M. Tech BPT Program</td></tr>
<tr><td></td><td colspan="5">The focus of the Seminar is to understand the given research area throughout in-depth literature survey and summarize the understanding to evaluate scientific findings, strength, weakness, and future scope of research. Suitable potential topics for the seminar shall be provided or selected through discussion with a research guide. The focus of critical review is to analyze the given research article to evaluate the strengths and weaknesses of an idea and content. The critical review can be of a book, a chapter, or a journal article. It will also help to develop critical and analytical think of learners in the area of bioprocess technology.</td></tr>
<tr><td colspan="6">Instructions for Seminar report</td></tr>
<tr><td>General Instructions</td><td colspan="5">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:</td></tr>
<tr><td>Instructions for drafting report</td><td colspan="5">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</td></tr>
</table>

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 a 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 the 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.

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   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.

   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 (seehttp://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**

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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.
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"

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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.

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).

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(g) Format for listing Private Communications and other categories:

Sharma, M.M., Private Communication (1984).

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

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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. 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
	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,

Referencing	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.
Instructions for Critical Review report	
	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 (size12) 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,

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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.
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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.	
List of Textbooks/ Reference Books		
	1. Available literature on the given topic.	
Course Outcomes		
Sr. No	Upon successful completion of this course, the students will be able to….	**Level**
1	Develop critical thinking regarding the research paper, review article given for the analysis.	K5
2	Analyze different literature sources about a certain topic	K4
3	Comment on others' work in terms of the scientific content, novelty, and correctness of published work	K5
4	Evaluate the research methodologies, data analysis and interpretation	K5
5	Develop skills for presentation and writing scientific documents	K6

	Course Code: BSP2103	Course Title: BSP2103 Research Project-I (Marks 100)	Credits = 3		
			L	T	P
	Semester: I	Total contact hours: -	-	-	6
List of Prerequisite Courses					
	Seminar, Critical Review, Literature Survey, In-depth reading of Research and review article				
List of Courses where this course will be prerequisite					
	2. Research Project-II, Research Project-III, Thesis				
Description of relevance of this course in the M. Tech BPT Program					
	The Research Project-I enable learners to identify and discuss the importance of research in the given area. It provides detailed understanding of research gap, challenges, issues, scientific and technical merits of important points associated with the given topic. It will provide a brief overview of the methodologies, analysis, characterization techniques and tools required for conducting research on the given topic. It will also help to develop novel problem-solving ability by applying the fundamental of bioprocess technology.				
Instructions for Seminar report					
General Instructions	***Note:*** The Research Project-I 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 Research Project-I work is concerned with a detailed literature review of an area provided by research supervisor for the project work which can be undertaken in RP-II, RP-III and final thesis submission. The topic should be within the scope of bioprocess technology including both upstream and downstream processing aspects. Typically, the report should contain and will be evaluated based on the following points:				
Instructions for drafting report	***8. Title.*** Concise and informative. Avoid abbreviations and formulae where possible. ***9.*** **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. ***10.*** **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				

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10. 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.

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

5. ***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:

(d) 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).

(e) Format for listing references of Books:

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

(f) 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.

Format for listing Thesis: Niranjan K., "Hydrodynamic and Mass Transfer Characteristics of Packed Columns", Ph.D. (Tech.) Thesis, University of Mumbai, 1983.

(h) Format for listing references of Patents in Chemical Abstracts:

Cananaush R.M., U.S.Patent 2,647,141, Cf. C.A. 48, 82636
(1954).

(i) 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).

	(j) Format for listing Private Communications and other categories: Sharma, M.M., Private Communication (1984). ***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**:**	8.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. 9.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. 10. 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. **11. The total number of pages, including tables, figures but excluding references should not exceed 30.** 12. 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. 13. The time allotted for the oral presentation of seminar is 30 minutes (20 minutes oral presentation and additional 10 minutes for questions and answers. 14. INCOMPLETE AND CARELESSLY WRITTEN REPORT IS LIABLE TO BE REJECTED. The last date for submission will NOT be extended on any grounds whatsoever. 14. There must not be any acknowledgment about the guidance by the faculty in the Seminar. 15.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. 16. Word-to-word copying from the published article is not permitted. Flowery language is not to be used. 17. Schedule for delivering presentation will display after submission of reports. 18. 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.	
List of Textbooks/ Reference Books		
	2. Published literature related to given topic e.g., scientific research articles, review articles, letters, perspectives, conference papers, thesis etc.	
Course Outcomes		
Sr. No	Upon successful completion of this course, the students will be able to….	**Level**
1	Develop critical thinking to identify the research gap for the project	K5
2	Formulate a scientific question and approach to solve it	K6
3	Plan the experimental methodology for the project	K5
4	Develop skills to communicate the research plan effectively	K6
5	Develop skills for writing scientific documents	K6

SEMESTER II

	Course Code: BST2103	Course Title: Industrial Biocatalysis	Credits =		
			L	T	P
	Semester: II	Total contact hours: 60	3	1	0

List of Prerequisite Courses

Introduction to Biological Sciences and Bioengineering, Biochemical Engineering, Fermentation Technology, Enzyme Technology

List of Courses where this course will be prerequisite

1. **BST 2105** Bioprocess Equipment Design and Industrial process Automation
2. **BST 2104** Bioprocess and Biosystem Engineering

Description of relevance of this course in the M. Tech BPT Program

The focus of Industrial Biocatalysis is to provide individuals with the applied knowledge needed to understand the biocatalysis, mechanism of enzymatic action, synthesis of enzymes at industrial scale. This course will introduce enzyme immobilization techniques for the recycling and reusability of biocatalysts. It will also develop students' knowledge and understanding of the use of biocatalyst over the chemical catalyst for several reactions. This course will also help students to understand enzyme kinetics, and factors influencing enzyme activity. This course will also highlight the advanced/modern biotechnology techniques for the improvement in biocatalyst design and improvement.

	Course Contents (Topics and subtopics)	Reqd. hrs
1	Introduction to Biocatalysis/Enzymes: • What are biocatalysts/enzymes? • Mechanism of enzymatic action. • Nomenclature and classification of enzymes. • Enzyme Units	4
2	Enzyme Kinetics: • Factors affecting enzyme activity (concentrations, pH, temperature, thermal deactivation of enzymes) • Kinetics of a single-substrate enzyme catalyzed reaction • Michaelis-Menten Equation (K_m & V_{max}) • Lineweaver Burk Plot • Turnover number (K_{cat})	6
3	Biocatalyst vs Chemical Catalyst: • To understand when to use biocatalyst over chemical catalyst. • Advantages/disadvantages of biocatalyst over chemical catalyst. • Homogeneous and heterogenous catalysis. • Isolated enzyme systems vs. whole cell as a biocatalyst.	4
4	Enzyme production: • Biocatalysis using natural enzymes.	6

	• Synthesis of enzymes (Fermentation techniques) • Purification of enzyme (different techniques involved in purification)	
5	Industrial and clinical applications of Enzymes: • Specific examples- Oxidoreductase, Transferases, Hydrolases, Lyases, Isomerases, Ligases • Industrial enzymes- Cellulase, protease, lipase, amylase, pectinase, etc. • Clinical enzymes- Asparaginase, Isoenzymes like CK and LDH, Transaminases, nucleases, etc.	6
6	Enzyme Recycling and Recovery: • Immobilization of enzymes using various techniques (Biocatalyst recycling and recovery) • Factors influencing enzyme immobilization. • Advantages and disadvantages of immobilized enzymes.	4
7	Immobilized enzymes: • Industrial applications of immobilized enzymes. • Multi-enzymatic cascade reactions and applications- Use of multi-enzyme system for industrial applications, enzyme co-immobilization, etc.	6
8	Biocatalysis in organic solvents/media: • Enzyme formulation in organic media • Enzyme inactivation in organic solvents • Green chemistry • Oxidation catalysis • Catalysis in water	4
9	Modern Biotechnology for Biocatalyst Design Improvement • Synthetic biology for biocatalyst engineering • Enzyme engineering strategies • Chassis selection and host cell engineering • Enzyme production and scale-up challenges	6
10	Enzyme structure and function relationship: • Determination of enzyme structure • Modelling of enzymes • Molecular simulation as a tool for enzyme design	4
List of Text Books/ Reference Books		
	1. Price and Lewis Stevens. Fundamentals of Enzymology	
	2. Ashok Pande, Colin Webb, Carlos Richard, Cristian Larroche. Enzyme Technology.	
	3. Lehninger- Principles of Biochemistry by Nelson and Cox – W. H. Freeman and Company Pub.	
Course Outcomes (students will be able to…..)		

Sr. No	Upon successful completion of this course, the students will be able to….	Level
1	Apply and analyze the basics of enzyme classification and mechanism of enzymatic action	K3
2	Analyze and Categorize and evaluate the structure and function relationship of enzymes	K4
3	Learn enzyme applications in various fields and select different enzymes based on selectivity	K5
4	Compare and calculate enzyme activity using enzyme kinetics to choose different enzyme	K5
5	Evaluate and explain different method of enzyme immobilization and applications	K6

	Course Code: BST2112	**Course Title: BST2112** Adsorptive, Chromatographic and Membrane Separations (**Marks 100)**	**Credits = 3**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 60**	2	1	0
List of Prerequisite Courses					
	Transport phenomenon, plug flow and fluidized bed reactors, Separation and Purification.				
List of Courses where this course will be prerequisite					
	Bioreaction Engineering**,** Unit operations in bioprocessing**,** Industrial Biocatalyst**,** Bioprocess Equipment Design and Industrial Process Automation				
Description of relevance of this course in the M. Tech BPT Program					
	The focus of the Adsorptive, Chromatographic and Membrane Separations course is to provide individuals with the knowledge needed to understand and apply sound principles of adsorption and membrane separation to develop and efficient process for separation of various biomolecules, organic molecules, protein, polysaccharides, natural products, APIs etc., for industrial applications of bioprocess technology. This course will provide in-detail understating to high resolution techniques in bio-separation, purification of small and large biomolecules by uing chromatography, membrane separation or integrated chromatographic operation for clarification, purification, polishing and concentration steps in bioprocessing. It will also help to develop separation and purification related process challenges and problems solving ability of learners in the area of bioprocess technology				
Module	**Course Contents (Topics and subtopics)**				**Reqd.hrs**
1	**Adsorptive chromatographic Separation**: Introduction, Theory, and chemistry of adsorption. Chromatographic Fundamentals: Classification of chromatography, 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;				12
2	**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.				4
3	**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.				4

4	**Membrane Separation**: 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.	10
List of Textbooks/ Reference Books		
	3. Anurag Rathore and Ajoy Velyudhan, Scale-up and optimization in preparative chromatography, 2003.	
	4. Sewell P.A. Clarke B, Chromatographic separations. John Wiley & Sons, 1991	
	5. Lindsay B., High performance Liquid Chromatography, John Wiley & Sons,	
	6. Lecture Notes on short course on Enantiomeric separations, April 28-29,1995.	
Course Outcomes		
Sr. No	Upon successful completion of this course, the students will be able to….	**Level**
1	Able to understand and categorize high resolution techniques in bio-separation, purification of small and large biomolecules by chromatography, polishing and concentration steps in bioprocessing	K4
2	Able to compare and choose the column packing, designing of separation and its scale-up for separation of organic molecules, natural products etc.	K5
3	Able to understand and compare the nature of membranes; membrane transport mechanism, design of membrane modules and plant membrane fouling	K4
4	The ability to choose and classify, adsorbents, membrane processes; determine the nature of adsorbents and membranes; formulate the theory of membrane transport and apply the general membrane theory in specific cases	K6
5	To propose the applications of process chromatography and membrane filtration for processing for various biotech products	K6

	Course Code: BST2102	Course Title: Unit operations in Bioprocessing	Credits = 3		
			L	T	P
	Semester: II	Total Contact Hours: 60	2	1	0
List of Prerequisite Courses					
	Physicochemical Properties of biochemical's, Transport phenomenon, biochemistry				
List of Courses where this course will be Prerequisite					
	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Engineering operations, Pharmaceutical Biotechnology, Bioanalytical				

Description of relevance of this course in the M. Tech. (Bioprocess Technology) Programme

Course objectives

1. To understand the basic physicochemical properties of various biomolecules (K2)
2. To understand the principles of various unit operations in bioprocessing of biomolecules (K2)
3. Describe and demonstrate the process integration of with various unit operations (K3)
4. Describe and demonstrate the process optimization with modern strategies (K3)
5. To apply course concepts in solving problems related to unit operations (K4)

Sr. No.	Course Contents (Topics and subtopics)	Required Hours
1	Upstream and Downstream Processing in Biotechnology, Selection of unit operation with due consideration of physical, chemical and biochemical aspect of biomolecules, basic review of bioprocess designing	5+3
2	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	5+2
3	Enrichment operations: Membrane – based separations (micro and ultrafiltration, precipitation methods, extractive separation, aqueous two-phase extraction, supercritical extraction, in-situ product removal, integrated bioprocessing	6+3
4	Product resolution / fractionation: Introduction to adsorptive chromatographic separations processes, electrophoretic separations, hybrid separation technologies (electrochromatography)	5+3

5	Product finishing: precipitation/crystallization, mixing, dialysis, distillation and drying. Ultracentrifugation as a separation technique for fractionation of cells and proteins.	5+2
6	Introduction to Process Analytical Technology (PAT) and Quality by Design (QbD). Scale down, monitoring and Validation of bioprocesses	4+2
	Total	45

List of Textbooks / 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).	
Sr. No	**Course Outcomes (Students will be able to…..)**	**Level**
1	Apply and describe the basic physicochemical properties of various biomolecules	K3
2	Analyse and apply the principles of various unit operations in bioprocessing of biomolecules	K4
3	Describe, analyse, and demonstrate the process integration of with various unit operations	K4
4	Describe, demonstrate, and evaluate the process optimization with modern strategies	K5
5	To apply course concepts in solving problems related to unit operations and to create the material and energy balance diagrams.	K6

	Course Code: BSP2104	**Course Title: BSP2104** Biosciences and Bioprocess Technology Laboratory (**Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 30**	-	-	6
List of Prerequisite Courses					
	Industrial Biocatalyst**,** Adsorptive chromatographic & membrane separation Analytical techniques in bioprocessing ,Fermentation and cell culture engineering				
List of Courses where this course will be prerequisite					
	Bioreaction Engineering**,** Unit operations in bioprocessing**,** Industrial Biocatalyst Adsorptive chromatographic & membrane separation**,** Bioprocess Equipment Design and Industrial Process Automation				
Description of relevance of this course in the M. Tech BPT Program					
	The objective of this laboratory course is to provide the hands-on training, technical, theoretical, and instrumental understanding to learners in the various areas of bioprocess technology such as microbiological, mammalian cell culture, biochemistry, upstream processing, downstream processing, and bioprocess technology. This course will provide practical training on trouble shouting and industrial application aspects to learners to develop experimental problem-solving ability by applying fundamentals Biosciences and Bioprocess Technology. The basic as well as advanced bioprocessing and bioanalytical methods will be taught for application in academic and industrial research.				
Module	**Course Contents (Topics and subtopics)**				**Reqd.hrs**
1	Technical Microbiology pertaining to strain isolation for pure culture and its maintenance, bacterial growth curve				-
2	Technical Biochemistry pertaining to enzyme activity and kinetics				-
3	Basics of mammalian cell culture				-
4	Fermentation and Bioreactions: fermentation of metabolite at shake flask level, demonstration at fermenter level with control parameters				-
5	Separation and purification: Techniques for separation and purification of biomolecules such as selective crystallization, Liquid-Liquid extraction, adsorptive chromatographic separation, membrane separation etc.				-
6	Adsorptive Chromatographic Separation**:** Study of various chromatographic parameters such adsorption isotherms, band broadening theory, resolution, and selectivity etc. Downstream processing consisting of column packing, column loading, unloading, packed bed adsorption study etc.				-
7	Analytical and Bioanalytical Techniques**:** Analysis biomolecules, organic compounds, proteins, APIs etc., for structural, functional characterization by using analytical and bioanalytical techniques such as UV-spectroscopy, FT-				-

	IR spectroscopy, NMR, GC-MS, LC-MS etc. Qualitative and quantitative analysis techniques such as HPLC, UV-spectroscopy and spectrofluorimetry etc.	
List of Textbooks/ Reference Books		
	7. Spectroscopy of Organic Compounds, P S Kalsi, New AGE International Publication	
Course Outcomes		
Sr. No	Upon successful completion of this course, the students will be able to….	Level
1	Demonstrate the use of different analytical equipment for the qualitative and quantitative analysis of biomolecules, organic compounds, proteins, APIs etc.	K3
2	Isolate and preserve common bacterial organisms, determine enzyme activities, and assess kinetics of different enzymes of industrial interest	K4
3	Apply mammalian cell culture technique for fermentative production of secondary metabolites	K4
4	Design and develop the process strategies for characterization, quantification and in process analysis of various bioprocess.	K5
5	Evaluate, interpret, and analyze the experimental results	K6

	Course Code: BSP2105	Course Title: BSP2105 Research Project-II (Marks 100)	Credits = 3		
			L	T	P
	Semester: II	Total contact hours: -	-	-	6
List of Prerequisite Courses					
	Seminar, Critical Review, Literature Survey, In-depth reading of Research and review article				
List of Courses where this course will be prerequisite					
	3. Research Project-II, Research Project-III, Thesis				
Description of relevance of this course in the M. Tech BPT Program					
	The Research Project-II provides in-depth understanding of research problems with scientific and industrial potential. It provides detailed understanding of solving research gaps, challenges, issues, scientific and technical barriers associated with the given topic. It will provide a detailed overview of the execution methodologies (precise work plan) for experimentation, analysis, and characterization etc. It will also help to develop novel problem-solving ability by applying the understanding of prior art and fundamental of bioprocess technology.				
Instructions for Research Project-II report					
General Instructions	***Note:*** The Research Project-II 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 Research Project-II work is concerned with a detailed literature review of an area provided by research supervisor for the project work which can be undertaken in RP-II, RP-III and final thesis submission. The topic should be within the scope of bioprocess technology including both upstream and downstream processing aspects. Typically, the report should contain and will be evaluated based on the following points:				
Instructions for drafting report	***15.*** ***Title.*** Concise and informative. Avoid abbreviations and formulae where possible. ***16.*** **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. ***17.*** **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

18. 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.

19. 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.

20. Conclusions **-**The main conclusions of the seminar topic may be presented in a short. Conclusions section, which may stand alone or form a separate section of the seminar report.

21. 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 the 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.

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 (seehttp://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.

11. 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.

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

7. ***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:

(g) 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).

(h) Format for listing references of Books:

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

(i) 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.

Format for listing Thesis: Niranjan K., "Hydrodynamic and Mass Transfer Characteristics of Packed Columns", Ph.D. (Tech.) Thesis, University of Mumbai, 1983.

(k) Format for listing references of Patents in Chemical Abstracts:

Cananaush R.M., U.S.Patent 2,647,141, Cf. C.A. 48, 82636
(1954).

(l) 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).

	(m) Format for listing Private Communications and other categories: Sharma, M.M., Private Communication (1984). ***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**:**	15. 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. 16. 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. 17. 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. **18. The total number of pages, including tables, figures but excluding references should not exceed 30.** 19. 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. 20. The time allotted for the oral presentation of seminar is 30 minutes (20 minutes oral presentation and additional 10 minutes for questions and answers. 21. INCOMPLETE AND CARELESSLY WRITTEN REPORT IS LIABLE TO BE REJECTED. The last date for submission will NOT be extended on any grounds whatsoever. 19. There must not be any acknowledgment about the guidance by the faculty in the Seminar. 20.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. 21. Word-to-word copying from the published article is not permitted. Flowery language is not to be used. 22. Schedule for delivering presentation will display after submission of reports. 23. 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.	
List of Textbooks/ Reference Books		
	8. Published literature related to given topic e.g., scientific research articles, review articles, letters, perspectives, conference papers, thesis etc.	
Course Outcomes		
Sr. No	Upon successful completion of this course, the students will be able to….	**Level**
1	Develop critical thinking to identify the research gap for the project	K5
2	Formulate a scientific problem and research objectives with hypothesis	K6
3	Plan the experimental strategy for the execution of project	K5
4	Develop skills to communicate the research plan effectively	K6
5	Develop skills for writing scientific documents	K6

SEMESTER III

<table>
<tr><td rowspan="2"></td><td>Course Code:
BSP2106</td><td>Course Title: BSP2106
Research Project-III
(Marks 100)</td><td colspan="3">Credits = 3</td></tr>
<tr><td></td><td>L</td><td>T</td><td>P</td></tr>
<tr><td></td><td>Semester: III</td><td>Total contact hours: -</td><td>-</td><td>-</td><td>6</td></tr>
<tr><td colspan="6">List of Prerequisite Courses</td></tr>
<tr><td></td><td colspan="5">Seminar, Critical Review, Literature Survey, In-depth reading of Research and review article, Research Project-I and Research Project-II</td></tr>
<tr><td colspan="6">List of Courses where this course will be prerequisite</td></tr>
<tr><td></td><td colspan="5">4. Final Thesis</td></tr>
<tr><td colspan="6">Description of relevance of this course in the M. Tech BPT Program</td></tr>
<tr><td></td><td colspan="5">The Research Project-III provides detailed experimentation on the finalized research objectives in RP-I and RP-II. The learners should conduct full time research projects under the research supervision of the assigned research guide. It enables learners to provide hands-on experience to handle various instruments, reactors, fermenters, sophisticated instruments, and analytical tools etc., to execute the given project. It will also help to develop practical skills, data generation, collection, and interpretation skills. Learners will be able to identify and discuss the concepts and procedures of experimentation, sampling, data collection, analysis, and reporting.</td></tr>
<tr><td colspan="6">Instructions for Research Project-III report</td></tr>
<tr><td>General Instructions</td><td colspan="5">Note: The Research Project-III 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 Research Project-III work is concerned with a detailed experimentation on the research area provided by the research supervisor for the project work which can be undertaken for the final thesis submission. The topic should be within the scope of bioprocess technology including both upstream and downstream processing aspects. Typically, the report should contain and will be evaluated based on the following points:</td></tr>
<tr><td>Instructions for drafting report</td><td colspan="5">22. Title. Concise and informative. Avoid abbreviations and formulae where possible.
23. 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.</td></tr>
</table>

	24. **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 ***25. 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. ***26. 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. ***27. Conclusions*** **-**The main conclusions of the seminar topic may be presented in a short. Conclusions section, which may stand alone or form a separate section of the seminar report. ***28. 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 the 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. **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 (seehttp://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.

12. 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.

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

9. ***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:

(j) 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).

(k) Format for listing references of Books:

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

(l) 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.

Format for listing Thesis: Niranjan K., "Hydrodynamic and Mass Transfer Characteristics of Packed Columns", Ph.D. (Tech.) Thesis, University of Mumbai, 1983.

(n) Format for listing references of Patents in Chemical Abstracts:

Cananaush R.M., U.S.Patent 2,647,141, Cf. C.A. 48, 82636
(1954).

	(o) 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). **(p)** Format for listing Private Communications and other categories: Sharma, M.M., Private Communication (1984). ***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**:**	22. 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. 23. 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. 24. 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. **25. The total number of pages, including tables, figures but excluding references should not exceed 30.** 26. 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. 27. The time allotted for the oral presentation of seminar is 30 minutes (20 minutes oral presentation and additional 10 minutes for questions and answers. 28. INCOMPLETE AND CARELESSLY WRITTEN REPORT IS LIABLE TO BE REJECTED. The last date for submission will NOT be extended on any grounds whatsoever. 24. There must not be any acknowledgment about the guidance by the faculty in the Seminar. 25.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. 26. Word-to-word copying from the published article is not permitted. Flowery language is not to be used. 27. Schedule for delivering presentation will display after submission of reports.

	28. Font size 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.	
List of Textbooks/ Reference Books		
	9. Published literature related to given topic e.g., scientific research articles, review articles, letters, perspectives, conference papers, thesis etc.	
Course Outcomes		
Sr. No	Upon successful completion of this course, the students will be able to….	**Level**
1	Perform experiments systematically to accomplish the set objectives	K5
2	Evaluate critically the experimental data and draw meaningful inferences	K6
3	Develop skills to interpret the data and draw the conclusion	K5
4	Develop skills to correlate the scientific observation with prior art and obtained results	K6
5	Develop skills for writing scientific documents	K6

SEMESTER IV

	Course Code: BSP2107	**Course Title: BSP2107** Thesis (**Marks 100)**	**Credits = 3**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: -**	-	-	6
List of Prerequisite Courses					
	Seminar, Critical Review, Literature Survey, In-depth reading of Research and review article, Research Project-I and Research Project-II, Research Project-III				
List of Courses where this course will be prerequisite					
	5. Open Defense and final evaluation				
Description of relevance of this course in the M. Tech BPT Program					
	The final thesis provides detailed experimentation on the research objectives. The learners should compile all the results with all the scientific and experimental evidence and write the final thesis according to thesis submission guidelines of the Institute of Chemical Technology, Mumbai. It enables learners to correlate scientific observation with prior art and obtained results. The Learners will be able to discuss the concepts, experimentation, analysis, and data interpretation throughout the various segments of the thesis.				
Instructions for Synopsis Submission					
General Instructions	Abstract: Maximum 250 Words Introduction: Maximum 600 words Research Objectives: Maximum 200words Materials and Methods: Maximum 600 words Results and Discussions: Maximum 1000 words Conclusions: Maximum 100 words Schemes/Figures/Schematics: Maximum 10 Tables: Maximum 3 References: Maximum 10				
Format for synopsis writing (If you upload it directly as PDF)	Page size: Use A4-size paper with 1″ left margin, 1″ top and bottom margin, 1″ right margin on each page. Font and Font size: The letter font should “Times New Roman” with font size of 12. Line spacing: should be 1.5 (one and a half). Indented quotations or footnotes where single spacing may be used. Figures: Figures must have figure captions below the figure i.e. Fig. 1: Effect of speed on reaction conversion Tables: Tables must have table captions above the Table i.e. Table 1: Effect of mole ration on conversion				
Instructions for Reference style in text and at the end.	**Text**: Indicate references by number(s) in square brackets in line with the text. The actual authors can be referred to, but the reference number(s) must always be given. Example: '..... as demonstrated [3,6]. Barnaby and Jones [8] obtained a different result ....' **List**: Number the references (numbers in square brackets) in the list in the order in which they appear in the text. Examples: **Reference to a journal publication**: [1] J. van der Geer, J.A.J. Hanraads, R.A. Lupton, The art of writing a scientific article, J. Sci. Commun. 163 (2010) 51–59. Reference to a book:				

	[2] W. Strunk Jr., E.B. White, The Elements of Style, fourth ed., Longman, New York, 2000. **Reference to a chapter in an edited book**: [3] G.R. Mettam, L.B. Adams, How to prepare an electronic version of your article, in: B.S. Jones, R.Z. Smith (Eds.), Introduction to the Electronic Age, E-Publishing Inc., New York, 2009, pp. 281–304. **Reference to a website:** [4] Cancer Research UK, Cancer statistics reports for the UK. http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/, 2003 (accessed 13.03.03). **Reference to a dataset: [dataset]** [5] M. Oguro, S. Imahiro, S. Saito, T. Nakashizuka, Mortality data for Japanese oak wilt disease and surrounding forest compositions, Mendeley Data, v1, 2015. https://doi.org/10.17632/xwj98nb39r.1.
Instructions for Thesis Submission	
General Instructions	***Note:*** The Research Project-III 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 Research Project-III work is concerned with a detailed experimentation on the research area provided by the research supervisor for the project work which can be undertaken for the final thesis submission. The topic should be within the scope of bioprocess technology including both upstream and downstream processing aspects. Typically, the report should contain and will be evaluated based on the following points:
Instructions for drafting report	***29.*** ***Title.*** Concise and informative. Avoid abbreviations and formulae where possible. ***30.*** **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. ***31.*** **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 ***32. 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.

33. 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.

34. Conclusions -The main conclusions of the seminar topic may be presented in a short. Conclusions section, which may stand alone or form a separate section of the seminar report.

35. 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 the 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.

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 (seehttp://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.

13. Reference Style

Text: All citations in the text should refer to:

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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.

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

11. ***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:

(m) 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).

(n) Format for listing references of Books:

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

(o) 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.

Format for listing Thesis: Niranjan K., "Hydrodynamic and Mass Transfer Characteristics of Packed Columns", Ph.D. (Tech.) Thesis, University of Mumbai, 1983.

(q) Format for listing references of Patents in Chemical Abstracts:

Cananaush R.M., U.S.Patent 2,647,141, Cf. C.A. 48, 82636
(1954).

(r) 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).

(s) Format for listing Private Communications and other categories:

Sharma, M.M., Private Communication (1984).

	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**:**	29. 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. 30. 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. 31. 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. **32. The total number of pages, including tables, figures but excluding references should not exceed 30.** 33. 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. 34. The time allotted for the oral presentation of seminar is 30 minutes (20 minutes oral presentation and additional 10 minutes for questions and answers. 35. INCOMPLETE AND CARELESSLY WRITTEN REPORT IS LIABLE TO BE REJECTED. The last date for submission will NOT be extended on any grounds whatsoever. 29. There must not be any acknowledgment about the guidance by the faculty in the Seminar. 30.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. 31. Word-to-word copying from the published article is not permitted. Flowery language is not to be used. 32. Schedule for delivering presentation will display after submission of reports. 33. Font size 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.

List of Textbooks/ Reference Books

	10. Published literature related to given topic e.g., scientific research articles, review articles, letters, perspectives, conference papers, thesis etc.	

Course Outcomes

Sr. No	Upon successful completion of this course, the students will be able to….	**Level**
1	Evaluate critically the experimental data and draw meaningful inferences	K6
2	Develop skills to interpret the data and draw the conclusion	K5
3	Develop skills to correlate the scientific observation with prior art and obtained results	K6
4	Develop skills for writing scientific documents	K6
5	Develop skills for presenting the scientific findings with experimental and literature evidences.	K6

ELECTIVES

	Course Code: BST2115	Course Title: Introduction to Biopharmaceutical Manufacturing	Credits =		
			L	T	P
	Semester: I	Total contact hours: 60	3	1	0
List of Prerequisite Courses					
	Biological Sciences				
	Biochemical Engineering				
	Biotechnology				
List of Courses where this course will be prerequisite					
	Fermentation and Cell Culture Engineering				
Description of relevance of this course in the MTech BPT Program					
The focus of the course is to provide individuals with the knowledge needed to understand and apply sound engineering and technology principles to the industrial production of biopharmaceuticals and innovative biologics. This course will introduce the important principles and techniques that are used in the manufacturing of biopharmaceuticals and biologics like monoclonal antibodies, recombinant proteins and biosimilars. It will also develop students' knowledge and understanding of manufacturing processes adopted at Industrial Scale.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Introduction of Biopharmaceutical Manufacturing Process		4		
2	Upstream Operation: Cell Culture		6		
3	Upstream Operation: Bioreactors		4		
4	Upstream Operation: Critical Parameters for Batch Release		6		
5	Downstream Operation: Cell Biomass Clarification, Ultrafiltration and Microfiltration		4		
6	Downstream Operation: Virus Inactivation and Chromatography for purifications		6		
7	C-GMP and Regulatory Control (USFDA, EMEA)		4		
8	Process Analytical Tools for Batch Release		6		
9	Packaging and filling		6		
10	Data Integrity		4		
List of Text Books/ Reference Books					
	Animal Cell Culture ISBN 978-3-319-10319-8				
	Biopharmaceutical Production Technology ISBN: 978-3-527-33029-4				
Sr. No	**Course Outcomes (students will be able to…..)**		**Level**		
1	Describe in qualitative terms the unit operations for biopharmaceutical manufacturing.		K2		

2	Manipulate and perform calculations on process variables with particular emphasis on data analysis and evaluation.	K4
3	Apply knowledge and understanding of biopharmaceutical manufacturing to highly regulated GMP process	K3
4	Describe the upstream and downstream production of mAbs	K2
5	Describe the analytical and regulatory methods used for biologic production	K2

	Course Code: PBT2205	Course Title: Immunotechnology	Credits =		
			L	T	P
	Semester: I	Total contact hours: 60	3	1	0

Description of relevance of this course in the M. Tech Bioprocess Technology Program

The objectives of this course are to learn about structural features of components of immune system as well as their function. Major emphasis will be to make the students aware about the immune mechanisms, to be able to predict nature of immune response that develops against bacterial, viral or parasitic infections and to be able to design experiments to prove the mechanisms and develop vaccines against the same.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Fundamental concepts and anatomy of the immune system: Components of innate and acquired immunity; Important organs and cells of immune responses, complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens - immunogens, haptens; Major histocompatibility complex (MHC) genes, Role of MHC in infectious diseases and disease susceptibility, HLA typing.	4 + 1
2	Immune responses generated by B and T lymphocytes: Immunoglobulins-basic structure, classes & subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self & non-self discrimination; kinetics of immune response, memory; B cell maturation, activation and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses, ADCC; cytokines-properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation.	4 + 1
3	Fundamental concepts and anatomy of the immune system: Components of innate and acquired immunity; Important organs and cells of immune responses, complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens - immunogens, haptens; Major histocompatibility complex (MHC) genes, Role of MHC in infectious diseases and disease susceptibility, HLA typing.	4 + 1
4	Antigen-antibody interactions: Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques - RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosensor assays for assessing ligand–receptor interaction, CMI techniques- lymphoproliferation assay,	4 + 1

	mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs, Hybridoma and monoclonal antibodies, Applications of monoclonal antibodies, design of chimeric and bi-specific antibodies, phage display	
5	Vaccinology: Active and passive immunization; live, killed, attenuated, subunit vaccines; vaccine technology- role and properties of adjuvants, recombinant DNA and protein-based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines; Antibody genes and antibody engineering- chimeric, hybrid monoclonal antibodies; catalytic antibodies and generation of immunoglobulin gene libraries, idiotypic vaccines and marker vaccines, viral-like particles (VLPs), dendritic cell-based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and therapeutic vaccine; Success stories in vaccinologye.g. Hepatitis, Polio, Small pox, DPT. Genetic vaccines	4 + 1
6	Immunology and diseases: Immunity to infection: bacteria, viral, fungal and parasitic infections (Tuberculosis, HIV/AIDS, Schistosomiasis, Kala Azar, Chickungunya, Dengue); hypersensitivity reactions– Type I-IV; autoimmunity; Types of autoimmune diseases; mechanism and role of CD4+T cells; MHC and TCR in autoimmunity; transplantation –immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology – tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency-primary immunodeficiencies, acquired or secondary immunodeficiencies, anaphylactic shock.	4 + 1
7	Antigen-antibody interactions: Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques - RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosensor assays for assessing ligand–receptor interaction, CMI techniques- lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs, Hybridoma and monoclonal antibodies, Applications of monoclonal antibodies, design of chimeric and bi-specific antibodies, phage display	4 + 1
8	Vaccinology: Active and passive immunization; live, killed, attenuated, subunit vaccines; vaccine technology- role and properties of adjuvants, recombinant DNA and protein-based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines; Antibody genes and antibody engineering- chimeric, hybrid monoclonal antibodies; catalytic antibodies and generation of immunoglobulin gene libraries, idiotypic vaccines and marker vaccines, viral-like particles (VLPs), dendritic cell-based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and	4 + 1

	therapeutic vaccine; Success stories in vaccinologye.g. Hepatitis, Polio, Small pox, DPT. Genetic vaccines	
9	Immunology and diseases: Immunity to infection: bacteria, viral, fungal and parasitic infections (Tuberculosis, HIV/AIDS, Schistosomiasis, Kala Azar, Chickungunya, Dengue); hypersensitivity reactions– Type I-IV; autoimmunity; Types of autoimmune diseases; mechanism and role of CD4+T cells; MHC and TCR in autoimmunity; transplantation –immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology – tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency-primary immunodeficiencies, acquired or secondary immunodeficiencies, anaphylactic shock.	4 + 1
Course Outcomes (students will be able to…..)		
1	Evaluate the significance of immune system and immune responses to tackle various disease conditions	K5
2	Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and predict the kind of immune responses in the setting of infections (viral or bacterial)	K3
3	Apply knowledge to design vaccines against various diseases	K3

	Course Code: BST2119	Course Title: Research Methodology	Credits =		
			L	T	P
	Semester: I	Total contact hours: 60	3	1	0

Description of relevance of this course in the M. Tech Bioprocess Technology Program

The objective of this course is to develop a research orientation among students and to familiarize them with fundamentals of research methods. Further, the course will make the students aware of the basic concepts used in research, sampling techniques, design and analysis of research, presenting it through reports and oral presentations and strategies of protecting the intellectual property rights associated with research.

	Course Contents (Topics and subtopics)	Reqd. hours
1	Research Meaning of Research, Purpose of Research, Types of Research (Educational, Clinical, Experimental, Historical, Descriptive, Basic applied and Patent Oriented Research) – Objective of research, choosing a mentor, lab and research question	4 + 1
2	Literature survey – Use of Library, Books, & Journals- Medline- Internet, getting patents and reprints of articles as sources for literature survey.	4 + 1
3	Selecting a problem and preparing research proposal for different types of research mentioned above. Processes of communication and scientific communication	4 + 1
4	Methods and tools used in Research • Qualitative studies, Quantitative Studies • Simple data organization, Descriptive data analysis • Limitations and sources of Error • Inquiries in form of Questionnaire, Opinionnaire or by interview Statistical analysis of data including variance, standard deviation, students 't' test and annova, correlation data and its interpretation, computer data analysis	4 + 1
5	Documentation • "How" of Documentation • Techniques of Documentation • Importance of Documentation, Uses of computer packages in Documentation	4 + 1
6	The Research Report / Paper writing / thesis writing • Different parts of the Research paper • Title – Title of project with author's name • Abstract – Statement of the problem Background list in brief and purpose and scope • Key-words- • Methodology-Subject, Apparatus / Instrumentation, (if necessary) and procedure • Results – tables, Graphs, Figures, and statistical presentation • Discussion – Support or non- support of hypothesis – practical & theoretical implications, conclusions	4 + 1

	• Acknowledgements • References • Errata • Importance of spell check for Entire project • Use of footnote	
7	Presentation (Specially for oral) • Importance, types, different skills • Content of presentation, format of model, Introduction and ending • Posture, Gestures, Eye contact, facial expressions stage fright • Volume- pitch, speed, pauses & language • Visual aids and seating • Questionnaire	4 + 1
8	Protection of patents and trademarks, Designs and copyrights • The patent system in India – Present status Intellectual property Rights (IPR), Future changes expected in Indian Patents • Advantages • The Science in Law, Turimetrics (Introduction) • What may be patented • Who may apply for patents • Preparation of patent proposal • Registration of patent in foreign countries and vice-versa	4 + 1
9	Sources for procurement of Research Grants	4 + 1
Course Outcomes (students will be able to…..)		
1	Demonstrate knowledge of research processes (reading, evaluating, and developing)	K3
2	Conduct literature reviews using print and online databases	K4
3	Identify, explain, compare and prepare the key elements of a research proposal or report	K5
4	Compare and contrast quantitative and qualitative research	K5
5	Describe, compare, and contrast descriptive and inferential statistics	K2

	Course Code: BST2121	Course Title: Microbial Technology	Credits =		
			L	T	P
	Semester: II	Total contact hours: 60	3	1	0
List of Prerequisite Courses					
	Biological Science				
	Basic Microbiology				
List of Courses where this course will be prerequisite					
Description of relevance of this course in the M. Tech Bioprocess Technology Program					
The objectives of this course are to introduce students to developments/ advances made in the field of microbial technology for use in human welfare and solving problems in society. So that on completion of this course, students would develop a deeper understanding of microbial technology and its applications.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	**Introduction to microbial technology:** Microbial technology in human welfare; Isolation and screening of microbes important for industry – advances in methodology and its application; Advanced genome and epigenome editing tools (e.g., engineered zinc finger proteins, TALEs/TALENs, and the CRISPR/Cas9 system as nucleases for genome editing, transcription factors for epigenome editing, and other emerging tools) for manipulation of useful microbes/ strains and their applications; Strain improvement to increase the yield of selected molecules, e.g., antibiotics, enzymes, biofuels.		12		
2	**Environmental applications of microbial technology**: Environmental application of microbes; Ore leaching; Biodegradation - biomass recycle and removal; Bioremediation - toxic waste removal and soil remediation; Global Biogeochemical cycles; Environment sensing (sensor organisms/ biological sensors); International and National guidelines regarding use of genetically modified organisms in environment, food and pharmaceuticals		12		
3	**Pharmaceutical applications of microbial technology:** Recombinant protein and pharmaceuticals production in microbes – common bottlenecks and issues (technical/operational, commercial and ethical); Attributes required in industrial microbes (*Streptomyces* sp., Yeast) to be used as efficient cloning and expression hosts (biologicals production); Generating diversity and introduction of desirable properties in industrially important microbes (Streptomyces/Yeast); Microbial cell factories; Downstream processing approaches used in the industrial production process (*Streptomyces* sp., Yeast).		12		
4	**Food applications of microbial technology**: Application of microbes and microbial processes in food and healthcare industries - food processing and food preservation, antibiotics and enzymes production, microbes in targeted delivery application – drugs and vaccines (bacterial and viral vectors); Nonrecombinant ways of introducing desirable properties in Generally recognized as safe (GRAS)		12		

	microbes to be used in food (e.g., Yeast) - exploiting the existing natural diversity or the artificially introduced diversity through conventional acceptable techniques (mutagenesis, protoplast fusion, breeding, genome shuffling, directed evolution etc.)	
5	**Advances in microbial technology**: Microbial genomics for the discovery of novel enzymes, drugs/ antibiotics; Limits of microbial genomics with respect to use in human welfare; Metagenomics and metatranscriptomics – their potential, methods to study and applications/use (animal and plant health, environmental clean-up, global nutrient cycles & global sustainability, understanding evolution), Global metagenomics initiative - surveys/projects and outcome, metagenomic library construction and functional screening in suitable hosts – tools and techniques for discovery/identification of novel enzymes, drugs (e.g., protease, antibiotic) etc.	12
List of Text Books/ Reference Books		
1	Lee, Y. K. (2013). Microbial Biotechnology: Principles and Applications. Hackensack, NJ: World Scientific.	
2	Moo-Young, M. (2011). Comprehensive Biotechnology. Amsterdam: Elsevier.	
3	Nelson, K. E. (2015). Encyclopedia of Metagenomics. Genes, Genomes and Metagenomes: Basics, Methods, Databases and Tools. Boston, MA: Springer US.	
4	The New Science of Metagenomics Revealing the Secrets of Our Microbial Planet. (2007). Washington, D.C.: National Academies Press.	
5	Research Journals: (a) Nature, (b) Nature Biotechnology, (c) Applied microbiology and biotechnology, (d) Trends in Biotechnology, (e) Trends in Microbiology, (f) Current opinion in Microbiology, (g) Biotechnology Advances, (h) Genome Research)	
6	Websites: http://jgi.doe.gov/our-science	
Course Outcomes (students will be able to…..)		
1	Students will be able to isolate and screen industrially important microbes.	K3
2	Understand advanced microbial genome editing tools	K2
3	Apply microbes for toxic waste removal and soil remediation.	K3
4	Knowledge of International and National guidelines regarding use of genetically modified organisms in the environment, food, and pharmaceuticals	K1
5	Apply microbes and microbial processes in food and healthcare industries	K3

	Course Code: BST2108 (Elective)	Course Title: Applied Molecular and Synthetic Biology (Marks 100)	Credits =		
			L	T	P
	Semester: I	Total contact hours: 45	3	1	0
List of Prerequisite Courses					
	Biochemistry, molecular biology and genetics courses				
List of Courses where this course will be prerequisite					
1	BST2104 Bioprocess and Biosystems Engineering				
Description of relevance of this course in the M.Tech. Bioprocess Technology Programme					
The focus of the Applied Molecular and Synthetic Biology course is to provide individuals with the knowledge needed to understand and apply principles of molecular and synthetic biology to design, build and test genetic circuits and machines. This course will provide an introduction to the important principles and techniques that are used in the design and characterization of genetic parts and higher order circuits. It will also develop students' knowledge and understanding of gene cloning, genome engineering and generation of novel constructs for industrial applications.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Gene expression and regulation in *Escherichia coli*		4		
2	Tools for genetic engineering of prokaryotes		6		
3	Tools for genetic engineering of eukaryotes, with a focus on *Saccharomyces cerevisiae*		4		
4	Genome engineering strategies, including genome minimization		6		
5	Synthetic biology principles and the Design-Build-Test-Learn paradigm		4		
6	Genetic parts, BioBricks, 3A Assembly, Synthetic Biology Open Language (SBOL)		6		
List of Text Books/Reference Books					
1	Molecular Biology of the Gene (by James Watson et al.), CSHL Press				
2	Synthetic Biology: Parts, Devices and Applications (edited by Christina Smolke), Wiley				
3	Synthetic Biology: Tools and Applications (edited by Huimin Zhao), Elsevier				
4	Synthetic Biology: A Primer (edited by Paul Freemont and Richard Kitney), Imperial College Press				
Course Outcomes (students will be able to…..)					
1	Design gene expression strategies in model prokaryotic and eukaryotic organisms.		K6		
2	Choose appropriate cloning techniques to express genetic constructs		K6		
3	Modify/edit the genome		K3		
4	Develop fluency in contemporary synthetic biology approaches		K5		
5	Apply synthetic biology approaches to design, construct, and analyse new biological functions and systems not found in nature		K3		

	Course Code: BST2106	Course Title: BST2111 Intellectual Property Rights (Marks 100)	Credits =		
			L	T	P
	Semester: I	Total contact hours: 60	3	1	0
List of Prerequisite Courses					
List of Courses where this course will be prerequisite					
Description of relevance of this course in the M.Tech. Bioprocess Technology Programme					
The focus of the Intellectual Property Rights course will be on understanding and applying the concepts of intellectual property rights. Knowledge of IPR is essential for science and technology researchers, as it allows them to safeguard their inventions and other intellectual property and benefit from them.					

	Course Contents (Topics and subtopics)	Reqd. hours
1	OVERVIEW OF INTELLECTUAL PROPERTY	2
2	PATENTS: Patent document, How to protect your inventions, Granting of patent, Rights of a patent, How extensive is patent protection, Why protect inventions by patents, Searching & Drafting of a patent, Filing of a patent, The different layers of the international patent system	4
3	COPYRIGHT : What is copyright, What is covered by copyright, How long does copyright last, Why protect copyright,	4
4	RELATED RIGHTS : What are related rights, Distinction between related rights and copyright, Rights covered by copyright.	2
5	TRADEMARKS : What is a trademark, Rights of trademark, What kind of signs can be used as trademarks, types of trademark function does a trademark perform How is a trademark protected, How is a trademark registered, How long is a registered trademark protected for, How extensive is trademark protection, What are well-known marks and how are they protected	2
6	GEOGRAPHICAL INDICATIONS: What is a geographical indication, How is a geographical indication protected, Why protect geographical indications	2
7	INDUSTRIAL DESIGNS: What is an industrial design, How can industrial designs be protected, What kind of protection is provided by industrial designs,How long does the protection last, Why protect industrial designs	2
8	NEW PLANT VARIETIES : Why protect new varieties of plants, How can new plants be protected,What protection does the breeder get, How long do the breeder's rights last, How extensive is plant variety protection	2
9	ENFORCEMENT OF INTELLECTUAL PROPERTY RIGHTS : Infringement of intellectual property rights ,Enforcement Measure	4

10	INTELLECTUAL PROPERTY : Overview of Biotechnology and Intellectual Property Biotechnology Research and Intellectual Property Rights	4
11	Case studies of patents in other areas	2
List of Text Books/Reference Books		
	As suggested by the instructor.	
Course Outcomes (students will be able to…..)		
1	Understand the theory behind IPR protection	K2
2	Analyze patent specifications and claims	K4
3	Apply knowledge of IPR to different situations	K3
4	Select ideal IPR protection for inventions	K5
5	Create IPR strategies for inventions	K6

	Course Code: BST2123	Course Title: BST2112 Industrial Biotransformations (Marks 100)	Credits =		
			L	T	P
	Semester: II	Total contact hours: 60	3	1	0
List of Prerequisite Courses					
	Biochemistry, enzymology courses				
List of Courses where this course will be prerequisite					
	Biochemical engineering, bioreactor engineering, bioreaction engineering.				
Description of relevance of this course in the M.Tech. Bioprocess Technology Programme					
The focus of the Industrial Biotransformations course will be on introducing students to whole cell- and enzyme-mediated transformation. Students will learn how biocatalysts are selected, how biocatalyst activity can be enhanced, and how biotransformations are carried out at large scales. Case studies will be used to demonstrate principles of biotransformations,					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Introduction to biotransformations		2		
2	Whole cell-mediated biotransformations (examples of bacterial, yeast and fungal biotransformations)		4		
3	Enzyme kinetics and mechanisms		2		
4	Commercial enzyme-mediated biotransformations		2		
5	Isolation of enzymes for biotransformation		2		
6	Recombinant enzymes: cloning and engineering for enhanced biotransformations		4		
7	Retrosynthetic biotransformations		2		
8	Basics of bioreactor engineering		2		
9	Design of enzyme reactors		4		
10	Case studies of enzyme-mediated biotransformations		4		
11	Quantitative analysis of industrial biotransformations		2		
List of Text Books/Reference Books					
1	Industrial Biotransformations. A. Liese, K. Seelbach and C. Wandrey (eds.). Wiley-VCH Verlag.				
2	Biocatalysis in the Pharmaceutical and Biotechnology Industries. R. N. Patel (ed.). CRC Press.				
3	Practical Biotransformations. G. Grogan. Wiley.				
4	Enzyme Biocatalysis. A. Illanes (ed.). Springer.				
Course Outcomes (students will be able to…..)					
1	Understand how biotransformations are carried out		K2		
2	Appreciate the versatile reactions that microbes and enzymes can mediate		K4		

3	Apply the principles and techniques of biotransformations to industrially relevant processes	K3

	Course Code: BST2109 (Elective)	**Course Title: Fermentation and Cell Culture Engineering**	**Credits =**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 60**	**3**	**1**	**0**
List of Prerequisite Courses					
	1. Biological Science				
	2. Life Sciences				
	3. Microbiology				
	4. Biochemistry				
List of Courses where this course will be prerequisite					
	1. PhD in Bioprocess Technology				
	2. PhD in Biotechnology				
	3. PhD in Pharmaceutical Biotechnology				
	4. PhD in Food Biotechnology				

Description of relevance of this course in the M.Tech (bioprocess Technology) Program

Fermentation technology a multi-disciplinary expertise associated with industrial microbiology, chemistry, biochemistry and molecular biology. The focus of Fermentation and Cell Culture Engineering is to provide individuals with the knowledge and skill necessary for bio-manufacturing using microbial, animal or plant cell culture systems i.e. native biological systems or that have been engineered, or that are used outside their natural context, to produce a product at a scale. This course will provide an introduction to the bio-based industry such as biopharmaceutical actives, Bio based chemicals (including but not limited to small organic molecules, proteins, lipids, vitamins, solvents etc). The course is beneficial to examine the application of biological and engineering principles to problems involving microbial, mammalian, and biological/biochemical systems. It will also develop students' knowledge and understanding of microbial and cell culture industrial processing, analytical abilities and problem solving methodologies in this area.

	Course Contents (Topics and subtopics)	**Reqd. hours**
1	Historical perspective of Fermentation, Synthesis methods from chemical (petrochemicals and natural products) and biotechnology routes (fermentation and cell culture technology). Introduction to High value-Low volume and Low value-High volume chemicals	4
2	Strain construction and strain improvement, Nutritional requirements of Microorganisms in fermentation process Microbial Growth, product and substrate kinetics Statistical methods for nutrient optimization for Biochemical production	6
3	Aerobic and anaerobic fermentation, surface, submerged and solid state fermentation technology,	4

	high cell density and high performance bioreactors	
4	Fermentation design (for example based on agitation and aeration), cost consideration Design considerations for aseptic fermentation, Modern Experimental techniques: Batch, fed batch, continuous, Efficiency of fermentation process	6
5	Scale-up criteria Automation, optimization and control of fermentation processes Instrumentation and control systems	4
6	Cell culture engineering and technology, Plant and mammalian cell culture for production of Bioproducts	6
List of Text Books/ Reference Books		
	1. Principles of Fermentation Technology by Peter F. Stanbury, Allan Whitaker and Stephen J hall	
	2. Biochemical Engineering Fundamentals by James E. Bailey and David F. Ollis	
Course Outcomes (students will be able to…..)		
1	Describe in qualitative terms the operation of a variety of bioprocess operations.	K2
2	Able to understand microbial fermentation, growth and product kinetics	K2
3	Able to understand batch, fed batch and continuous processes.	K2
4	Describe the upstream and downstream production of mAbs	K2
5	Describe the methods and technologies used for animal and plant cell cultivation for bio-based chemical production	K2

	Course Code: BST2122	Course Title: Introduction to Bioinformatics (Marks 100)	Credits = 4		
			L	T	P
	Semester: I	Total contact hours: 60	2	1	1
List of Prerequisite Courses					
	A candidate is expected to have basic knowledge of the following topics; *Chemistry*: structure, conformation, configuration, stereoisomers, reactivity, reaction coordinates, transition state, electrophilic and nucleophilic attacks *Biochemistry*: amino acids, peptide bond, hydrogen bond, hydrophobic/polar properties of residues, nucleotides, nucleosides *Molecular Biology*: basic knowledge of the structure of DNA and RNA, the central dogma of life				
List of Courses where this course will be prerequisite					
	1.				
Description of relevance of this course in the M.Tech. BPT Program					
	The course is designed to introduce students to the basic theoretical knowledge of various computational analytical techniques employed in bioinformatics, as well as provide hands-on training to the forerunner methods used in understanding, processing, and analyzing bioinformatics data related to genomics, proteomics, and in silico pharmaceutics. It also aims to develop skills needed to collect, understand, analyze, and manage data generated through high throughput technology.				
Module	**Course Contents (Topics and Subtopics)**				**Reqd.hrs**
1	**Concepts in Genomics** Structure of DNA, the structure of RNA, concepts of gene and genetic information, and the process of transcription.				4
2	**Concepts in Proteomics** Amino acids, peptides, the process of translation, structural concepts in proteins (primary, secondary, and tertiary), concepts of protein folding				4
3	**Databases and File Formats** Databases: NCBI, EXPASY, EBI, PDB, PubMed, DDBJ, EMBL, PIR, SWISSPROT, TrEMBL, NDB, CCSD, TIGR, SANGER, Composite databases File formats: Genbank, DDBJ, FASTA, PDB, SwissProt, etc.				2

4	**Sequence Alignment and Related Analyses** Local alignment, global alignment, pairwise sequence alignment, multiple sequence alignment, algorithms of sequence alignments, quantitative trait locus Practical classes (Computer Lab): 1. Introduction to Nucleotide Databases and Protein Databases 2. Data Retrieval and Interoperability 3. Sequence comparison and alignment: BLAST, PSIBLAST, ClustalW	3
5	**Structural Bioinformatics** Molecular modeling, homology modeling, three-dimensional structures, Ramachandran plot, moieties and motifs, Hidden Markov Model (HMM), Chou-Fasman method, Garnier-Osguthorpe-Robson method (GOR), measuring the accuracy of prediction, Monte Carlo, potential energy surface of a molecule, force fields and their generic forms. Practical classes (Computer Lab): 1. Structure visualization: PyMol, Schrödinger, Gaussian, or similar software packages 2. Geometry Optimization: Gaussian, Jaguar, or similar software packages 3. Ramachandran plot: Generation and analysis 4. Protein structure prediction: MODELLER, BHAGEERATH-H, SWISS-MODEL	6
6	**Concepts of Molecular Docking** Energy minimization, ligand preparation, conformational searches, active sites, receptor-ligand docking, protein-protein docking, algorithms of docking (genetic algorithm, fast shape matching, simulated annealing, incremental construction, evolutionary programming, distance geometry) Practical classes (Computer Lab): 1. Docking: Autodock, Schrödinger, HEX, or similar software packages	2
7	**Molecular Dynamics** Introduction to computer-based molecular dynamics simulations, types of molecular dynamics simulations (quantum-level, Born-Oppenheimer approximation, macromolecular), simulation models (coarse-grained model, bead rod, bead spring), Ensembles (microcanonical, canonical, grand canonical, isobaric-isothermal) Practical classes (Computer Lab): 1. Molecular Dynamics Simulations: Born-Oppenheimer MD, Desmond Simulations, or similar modules	2
8	**Computer-Aided Drug Discovery (CADD)**	3

	Introduction to drug discovery and development, structure-based design, ligand-based design, pharmacophore mapping and modeling, ADMET predictions, applications of chemoinformatics in drug development Practical classes (Computer Lab): 1. Prediction of ADMET: Ligand-based analyses, quantum chemical calculations and their relevance to ADMET, the accuracy of predictions	
9	**Qualitative Structure Activity Relationship (QSAR)** Linear free energy relationships descriptors, correlation coefficient, boot-strap analysis, F-value analysis, CoMFA, and CoMSIA	2
10	**Virtual screening** Molecular information databases, large datasets for virtual screening, ligand-based screening, receptor-based screening, hybrid models for screening, high-throughput screening	1
11	**Future Aspects of Computational Analyses in Natural Sciences** Discussion on machine learning (ML), parallel computing methods and implementation, high-performance computers, artificial intelligence (AI), scientific data processing, and **Introduction to Data Analytics.**	2
List of Textbooks/ Reference Books		
	1. *Introduction to Bioinformatics* by M. Lesk (2002) Oxford University Press.	
	2. *Sequence Analysis in a Nutshell: A Guide to Common Tools and Databases* by S. Markel and D. León (2003) O'Reilly Press.	
	3. *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* by A. D. Baxevanis and B. F. F. Ouellette (2004) Wiley-Interscience.	
	4. *Fundamental Concepts of Bioinformatics by* D. E. Krane and M. L. Raymer (2002) Pearson.	
	5. *Developing Bioinformatics Computer Skills* by C. Gibas and P. Jambeck (2001) O'Reilly Media.	
	6. *Bioinformatics: The Machine Learning Approach* by P. Baldi and S. Brunak (2001) Bradford Books.	
	7. *Bioinformatics Sequence and Genome Analysis* by D. W. Mount (2004) Cold Spring Harbour Laboratory Press.	
	8. *Discovering Genomics, Proteomics and Bioinformatics* by A. M. Campbell and L. J. Heyer (2003) Benjamin Cummings.	
	9. *Introduction to Bioinformatics Algorithms* by N. C. Jones and P. Pevzner (2004) MIT Press.	
	10. *Bioinformatics and Molecular Evolution* by P. G. Higgs and T. K. Attwood (2005) Blackwell Publishing.	
Course Outcomes		

Sr. No		Level
1	Students will have essential as well as working knowledge in the field of bioinformatics.	K2
2	Students will be able to understand and implement in silico drug development process.	K2
3	Students will be able to carry out research and generate important supplementary data to support their research hypotheses with various bioinformatics tools.	K3

	Course Code: BST2108 (Elective)	Course Title: Applied Molecular and Synthetic Biology (Marks 100)	Credits =		
			L	T	P
	Semester: I	Total contact hours: 60	3	1	0
List of Prerequisite Courses					
	Biochemistry, molecular biology and genetics courses				
List of Courses where this course will be prerequisite					
1	BST2104 Bioprocess and Biosystems Engineering				
Description of relevance of this course in the M.Tech. Bioprocess Technology Programme					
The focus of the Applied Molecular and Synthetic Biology course is to provide individuals with the knowledge needed to understand and apply principles of molecular and synthetic biology to design, build and test genetic circuits and machines. This course will provide an introduction to the important principles and techniques that are used in the design and characterization of genetic parts and higher order circuits. It will also develop students' knowledge and understanding of gene cloning, genome engineering and generation of novel constructs for industrial applications.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Gene expression and regulation in *Escherichia coli*		4		
2	Tools for genetic engineering of prokaryotes		6		
3	Tools for genetic engineering of eukaryotes, with a focus on *Saccharomyces cerevisiae*		4		
4	Genome engineering strategies, including genome minimization		6		
5	Synthetic biology principles and the Design-Build-Test-Learn paradigm		4		
6	Genetic parts, BioBricks, 3A Assembly, Synthetic Biology Open Language (SBOL)		6		
List of Text Books/Reference Books					
1	Molecular Biology of the Gene (by James Watson et al.), CSHL Press				
2	Synthetic Biology: Parts, Devices and Applications (edited by Christina Smolke), Wiley				
3	Synthetic Biology: Tools and Applications (edited by Huimin Zhao), Elsevier				
4	Synthetic Biology: A Primer (edited by Paul Freemont and Richard Kitney), Imperial College Press				
Course Outcomes (students will be able to…..)					
1	Design gene expression strategies in model prokaryotic and eukaryotic organisms.		K6		
2	Choose appropriate cloning techniques to express genetic constructs		K6		
3	Modify/edit the genome		K3		
4	Develop fluency in contemporary synthetic biology approaches		K5		
5	Apply synthetic biology approaches to design, construct, and analyse new biological functions and systems not found in nature		K3		