INSTITUTE OF CHEMICAL TECHNOLOGY
Ordinances, Regulations and Syllabi relating to the
Degree of Master of Technology in Bioprocess Technology
(M. Tech. Bioprocess Technology)
2018-2019

1. Introduction

The Institute is revamping its academic structure especially for the masters courses by way of introducing the compulsory industrial training for a period of six months (to be taken in the third semester of the program). 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 earlier 21. All the courses will continue to be credit based and the evaluation will be grade based.

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

SR. NO.	PROGRAM 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 solution to the problems.
6	The graduates will be able to study the impact of 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 & 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 & 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 gives 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 Practicals (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 x 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, home work, 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, student 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.

(c) 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 some times 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

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

(c) 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 hasn't 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.

(d) Grades **FF** and **I** are place-holders 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.

(e) 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.

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

(g) **'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 g(iii) above shall be done by Disciplinary Action Committee (DAC)).

(h) 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:

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

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 grades 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 withstanding 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	10	15	25	50
BST 2102	Core II: Unit Operations in Bioprocessing	3	2	1	0	10	15	25	50
BST 2103	Core III: Industrial Biocatalysis	3	2	1	0	10	15	25	50
	Elective I	3	2	1	0	10	15	25	50
	Elective II	3	2	1	0	10	15	25	50
BSP2101	Bioprocess Engineering Laboratory	3			6	25	-	25	50
BSP2102	Seminar and Critical Review	3	---	---	6	-	-	30 (Report) 20 (Presentation)	50
BSP2103	Research Project-I	6	---	---	12	-	-	60 (Report) 40 (Presentation)	100
	TOTAL:	27	10	5	24				450
SEMESTER II									
BST2104	Core IV: Bioprocess and Biosystem Engineering	3	2	1	0	10	15	25	50
BST2105	Core V:Bioreactor Design and Industrial Bioprocess Automation	3	2	1	0	10	15	25	50
BST2106	Core VI: Adsorptive, Chromatographic and Membrane separations	3	2	1	0	10	15	25	50
	Elective III	3	2	1	0	10	15	25	50
	Elective IV	3	2	1	0	10	15	25	50
BSP2104	Biosciences and Bioprocess Technology Laboratory	3			6	25		25	50
BSP2105	Research Project-II	9	---	---	18	-	-	90 (Report) 60 (Presentation)	150
	TOTAL:	27	10	5	24	-	-	-	450
SEMESTERS III									
BSP2106	Industrial Training (15 weeks to maximum of 6 months)	30	-	-	40			270 (Report) 180 (Presentation)	450
SEMESTER IV									
BSP2107	Research Project-III	30	-	-	40	-	-	270 (Report) 180 (Presentation)	450

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

SEMESTER - I

	Course Code: BST 2101 (Core subject)	Course Title: BST 2101 Bioreaction Engineering (Marks 50)	Credits = 3		
			L	T	P
	Semester: I	Total contact hours: 30	2	1	0

List of Prerequisite Courses

	Basic thermodynamics and chemical kinetics, Simple design methods, graphical procedures, and comparison of capabilities of the major reactor types.	

List of Courses where this course will be prerequisite

	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Technology	

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

Students will understand the mechanistic of biochemical reactions, kinetics, thermodynamics, phase equilibria and intermolecular forces, material and energy balance etc. They will be able to explain its applications in biotechnology (fermentation, biocatalysis, biotransformations etc.), biopharmaceutical, biochemical, agroprocessing, natural product, nutraceutical, edible oil, flavor and fragrance, food processing and pharmaceuticals etc. industries according to the biochemical reaction involved.

Module	Course Contents (Topics and subtopics)	Reqd. hours
1	Material and Energy Balance Computations	5
2	Basic Biochemistry, Basic Microbiology and Basic Molecular Biology, Principles of biochemical reactions and kinetics	5
3	Thermodynamics of bioreactions and biotransformations	5
4	Unstructured and simple structured models, Mechanistic models and morphologically structured models	5
5	Phase equilibria in multicomponent systems Partioning in biorelevant systems Calculation of phase equilibria in colloidal systems: UNIFAC, COSMO-RS (exercises in computer pool) Calculation of partitioning coefficients in biological membranes: COSMO-RS (exercises in computer pool)	5
6	Application of equations of state (vapour pressure, phase equilibria, etc.) (exercises in computer pool) Intermolecular forces, interaction Potenitials Introduction in statistical thermodynamics	5

List of Text Books/ Reference Books

1.Chemical Reaction Engineering: Levenspiel O
2.Chemical Engineering Kinetics: Smith J.
3.Elements of Chemical Reaction Engineering: H.Scott, Fogler.
4.Basic Biotechnology, edited by Colin Ratledge and Bjorn Kristiansen, Cambridge University Press 2003.
5.Biochemical Engineering Fundamentals, Bailey, and Ollis, McGraw Hill Book Co.1986.
6.Bioreacation Engineering, K. Schergeri, Vols 1 & 2, John Wiley. 1985.
7.Bioprocess computations in Biotechnology, T.K. Ghosh, Ellis Horwood Publications, 1988.
8.Advanced Biochemical Engg., ' Henry R. Bugay Georgs Belforj, John Wiley & Sons.'
9. Lehninger, Biochemistry, 4th edition, 2005
10. M.J. Pelczar, E.C.S. Chase and N.R. Kreigh, "Microbiology", 4th Edition, Tata

	McGrawhill, India. 11. P.A. Ketchum, "Microbiology", John Wiley and Sons, New York, 1984. Freifelder D., "Molecular Biology", Jones and Bartlett Publishers Inc., 1987
Course Outcomes	
1	Able to understand the basics of basic knowledge on enzymatic and microbial kinetics
2	Able to understand the application of thermodynamics in bioprocesses
3	Understand the mechanistic involved in biochemistry, microbiology and molecular biology
4	Understand phase equilibria and intermolecular forces
5	To find out the applications of thermodynamics and intermolecular forces in bioprocessing e.g. protein stability, conformations, affinity interactions etc.

	Course Code: BST 2102 (Core subject)	**Course Title: BST 2102** Unit operations in Bioprocessing **(Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**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, Bioanalyticals				
Description of relevance of this course in the M. Tech. (Bioprocess Technology) Programme					
Students will understand the unit operations, specifically downstream processing operations like cell harvesting, cell lysis, primary product recovery and purification, polishing etc. They will be able to explain its applications of different unit operation in bioprocessing for purification of biomolecules and their scale up in industries according to the separation methods involved.					

Module	**Course Contents (Topics and subtopics)**	**Reqd. hours**
1	Downstream Processing in Biotechnology, Selection of unit operation with due consideration of physical, chemical and biochemical aspect of biomolecules, basic review of bioprocess designing.	5
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
3	Enrichment operations: Membrane – based separations (micro and ultrafiltration, precipitation methods, extractive separation, aqueous two-phase extraction, supercritical extraction, insitu product removal, integrated bioprocessing.	6
4	Product resolution / fractionation: Introduction to adsorptive chromatographic separations processes, electrophoretic separations, hybrid separation technologies (electrochromatography).	5

5	Product finishing: precipitation/crystallization, mixing, dialysis, distillation and drying. Ultracentrifugation as a separation technique for fractionation of cells and proteins.	5
6	Introduction to Process Analytical Technology (PAT) and Quality by Design (QbD). Scale down, monitoring and Validation of bioprocesses	4
List of Text Books/ 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).	
Course Outcomes		
1	Able to understand the basic physicochemical properties of various biomolecules	
2	Able to understand the basics of various unit operations in bioprocessing of biomolecules	
3	Able to understand the process integration of with various unit operations	
4	Able to understand the process optimization with modern strategies	
5	To find out the applications of various unit operations in bioprocessing specifically downstream processing of proteins, enzymes, antibiotics, vitamins, amino acids, nucleic acids, agro-products, biochemicals, glycerides, beverages, food and nutrition, natural products, biofuels, organic acids etc.	

	Course Code: BST 2103 (Core subject)	**Course Title: BST 2103** Industrial Biocatalysis-I **(Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**2**	**1**	**0**
List of Prerequisite Courses					
	Bioreaction Engineering				
List of Courses where this course will be prerequisite					
	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Engineering operations				
Description of relevance of this course in the M. Tech. (Bioprocess Technology) Programme					
Students will understand the state of art and future prospects of industrial biocatalysis. They will be able to explain its applications for synthesis of bio-based materials, and compounds as intermediates for bioproducts and biofuels. The role of recombinant technology, synthetic biology, protein engineering, pathway engineering, metabolic engineering, systems biology, fermentation biology, algal biotechnology etc. in the development of biocatalysis based industries will be covered in this course.					

Module	Course Contents (Topics and subtopics)	Reqd. hours
1	Biocatalysts, aspects of biocatalytic process design and development, steps from laboratory to industrial scale, applications, global market and societal challenges	2
2	Biocatalysis using natural enzymes, microorganisms (bacteria, yeast, fungi), eukaryotic cells (insect, CHO, algae, plant cell cultures), plants, and recombinant enzymes engineered for specific applications, Catalytic activity of biomolecules – enzymes and ribozymes; Enzyme applications: Hydrolase enzymes – lipases, esterases, proteases etc. with specific examples and mechanism, Lyases – e.g. Aspartase, tyrosine-phenol lyase; Isomerases – e.g. glucose isomerise; Transferases –e.g. aminotransferases, PLP as cofactor; Ligases; Oxidoreductases – dehydrogenases, oxidases, oxygenases, peroxidases.	4
3	Enzyme structure-function relationships, Thermodynamics of protein folding and substrate binding, , Enzyme kinetics and modes of inhibition; Regulation mechanisms; Mechanism of enzyme action; Multienzyme systems; Selection and screening of biocatalysts for activity, stability and substrate or product selectivity; Extremozymes – biocatalysts at extremes of temperature, pressure and pH.	6
4	Biocatalysis versus chemical catalysis; Understanding when to use a biocatalyst for a chemical problem; Advantages/disadvantages of biocatalysts compared to traditional chemical reactions and heterogeneous/ homogeneous catalysis; Mild reaction conditions, excellent stereo- chemo- and regio- selectivity versus substrate specificity, product inhibition, lack of catalysts robustness, cofactor recycling; Isolated enzyme systems and whole cell systems. Free and immobilized enzymes for biocatalysis. Water versus organic solvent; Reactor and process technology: types, mass balances and their modes of operation; Biocatalyst recycling and recovery; Enzyme immobilization.	6
5	Enzymes in organic synthesis, Enzymes in novel media, Green chemistry, Oxidation catalysis, Catalysis in water, Homogeneous catalysis, Heterogeneous catalysis, Asymmetric catalysis	6
6	Modern branches of biotechnology as the workhorse for biocatalysts design improvement, Synthetic biology and biocatalyst engineering, Enzyme discovery and metagenomics, enzyme engineering strategies Chassis selection and host cell engineering, Practical enzyme characterisation, Industrial availability in enzyme production, Scale-up challenges, Process economics and sustainability	6
List of Text Books/ Reference Books		
1	Nelson, D. L. And M.M. Cox (2005), Lehninger, Principles Of Biochemistry. 4th Edition, W. H. Freeman And Company.	
2	Conn, E.E., P. K. Stumpf, G. Bruening and R. Y. Doi. (1987) Outlines Of Biochemistry, 5th Edition, 1987. John Wiley & Sons. New York.	
3	Grunwald P, Biocatalysis- Biochemical Fundamentals And Applications (2017) ISBN-13: 978-1783269082	
4	K. Buchholz, V. Kasche and U. T. Bornscheuer (2005) Biocatalysts and Enzyme technology Wiley VCH Verlag GmbH and Co.	
5	Gaikar V G, ( )Biotransformations And Bioprocesses (Biotechnology and Bioprocessing Series) ISBN-13: 978-0824757137	
6	Grunwald P, (2014) Industrial Biocatalysis, Edited by Peter Grunwald, Pan Stanford ISBN 9789814463881	
7	Copeland R A, (2000) Enzymes: A Practical Introduction to Structure, Mechanism and Data Analysis, Second Edition, Wiley VCH, ISBN: 978-0-471-35929-6	
Course Outcomes		
1	Able to understand the fundamentals of Biocatalysis, principles of designing biocatalysts	

2	Basic biochemistry of enzymes and their mechanisms, types of reactions catalysed
3	Understand the challenges and solutions associated with conducting biocatalysis and different modes of carrying out these reactions
4	Understand the methods, tools and strategies for modifying biocatalysts
5	Applications for biocatalysis in different areas

	Course Code:	**Course Title: (Elective I) (Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**2**	**1**	**0**
Elective-I (from the list appended) Candidate will have to choose one of the elective subjects offered for that semester from the elective subjects. A consolidated list of all the elective subjects is given at the end.					

	Course Code:	**Course Title: (Elective II) (Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**2**	**1**	**0**
Elective-II (from the list appended) Candidate will have to choose one of the elective subjects offered for that semester from the elective subjects. A consolidated list of all the elective subjects is given at the end.					

	Course Code: **BSP 2101**	**Course Title: BSP 2101** Bioprocess Engineering Laboratory **(Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**-**	**-**	**6**
List of Prerequisite Courses					
	Bioreaction Engineering, unit operations in bioprocessing				
List of Courses where this course will be prerequisite					
	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Engineering operations				
Description of relevance of this course in the M. Tech. (Bioprocess Technology) Programme					
Students will understand and explain the application of various chemical and biochemical engineering concepts in bioprocessing of bioproducts (both small and large biomolecules).					
Module	**Course Contents (Topics and subtopics)**		**Reqd. hours**		

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.	

Course Outcomes

1	To be able to perform experiments to ascertain the governing bioprocesses and biochemical engineering principles
2	To design experimental configurations/loops for demonstrating the basic governing fundamentals
3	To perform calculations and predict the trends in design variables as a function of operating/geometric parameters
4	To effectively operate the analytical facilities

	Course Code: **BSP 2102**	**Course Title: BSP 2102** Seminar and Critical Review **(Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours:**	**-**	**-**	**6**

The Seminar work is concerned with a detailed and critical review of an area of interest to Bioprocess Technology (Upstream and Downstream processing, Product characterization, Molecular biology etc). Typically, the report should contain and will be evaluated based on the following points:

(a) Introduction: 2 pages maximum,

(b) Exhaustive review of literature (including figures): 10 – 12 pages: 50% Weightage

(c) 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.

2. Two typed copies of the report on thesis size bond paper (297 mm x 210 mm) are to be submitted to Coordinator on **time to be decided by the coordinator.** The detailed timetable for the presentation would be communicated.

3. The report should be prepared using the Times Roman font (size 12) using 1 1/2 spacing leaving 1-inch margin on all sides 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. Figures and tables should be shown as a part of the running text. Each figure should be drawn inside a rectangular box of 12 cm width and 10 cm height. The

figures must be sufficiently clear and hand drawn figures will be acceptable. Particular care must be taken if a figure is photocopied from source. Each figure must have a sequence number and caption below. Each table must have a sequence number and title at the top.

4. 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.

5. The report must be precise. All important aspects of the topic should be considered and reported. **The total number of pages, including tables, figures, and references should not exceed 30.** Chapters or subsections need not be started on new pages, while getting the report typed.

6. 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.

7. The list of references should be arranged in alphabetical order of the names of authors. In the text, the reference should be cited with author's name and year. (author – date style) For example:

(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. The references must be given in the following standard format.

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

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

(e) 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).

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

8. Consistency of units should be maintained in the written report. SI systems should be used. [For SI system – Ref: Ind. Chem. Engr., 24, 32, 3 (1983)]. Units used in the literature (if not SI) should be correctly converted.

9. The time allotted for the oral presentation of seminar is 20 minutes: additional 10 minutes are provided for questions and answers.

10. INCOMPLETE AND CARELESSLY WRITTEN REPORT IS LIABLE TO BE REJECTED.

11. The last date for submission will NOT be extended on any grounds whatsoever.

12. There must not be any acknowledgment about the guidance by the faculty in the Seminar.

13. 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.

14. Word-to-word copying from the published article is not permitted. Flowery language is not to be used.

The submitted report will be evaluated by the research guide and an external examiner

	from the Department/Industry based on the presentation made by the candidate. A suitable combination of the marks for report and presentation will be considered for the final evaluation.	
Course Outcomes		
1	Survey literature related to the given topic	
2	Analyze the reported outcomes and classify the work under key categories	
3	Write a technically correct report as per the suggested guidelines and present the seminar work	

	Course Code: BSP 2103	**Course Title: BSP 2103** Research Project -I **(Marks 100)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours:**	**-**	**-**	**12**
	Details: The Research project I is concerned with detailed literature review of the assigned research area in consultation with the research supervisor, developing an experimental/analytical/simulation protocol and initiate the actual research work. Based on the outcomes of the candidate is expected to submit a report as per similar guidelines provided for BSP2102 above which will be evaluated by the research guide and an external examiner from the Department/Industry based on the presentation made by the candidate. A suitable combination of the marks for report and presentation will be considered for the final evaluation.				
Course Outcomes					
1	Analyze existing literature for research topic and develop detailed plan of experiments/ simulations				
2	Systematically perform experiments/modeling activity to accomplish the set objectives				
3	Critically analyse the results and write a technically correct report as per the suggested guidelines and present the work				

SEMESTER II

	Course Code: BST 2104 (Core subject)	Course Title: BST 2104 Bioprocess and Biosystem Engineering (Marks 50)	Credits = 3		
			L	T	P
	Semester: II	Total contact hours: 30	2	1	0

List of Prerequisite Courses

	Biochemical reactions, enzyme catalysis, nucleic acid, proteins, and metabolites	

List of Courses where this course will be prerequisite

	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Technology	

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

Students will understand the mechanistic of cellular systems, pathway engineering for native and none-native products, bioinformatics and modeling of bioreactors. They will be able to explain its applications in biotechnology (fermentation, biocatalysis, biotransformations etc.), biopharmaceutical, biochemical, agroprocessing, natural product, nutraceutical, edible oil, flavor and fragrance, food processing and pharmaceuticals etc. industries according to the biochemical reaction involved.

Module	Course Contents (Topics and subtopics)	Reqd. hours
1	Thermodynamics of Biosystems	6
2	Principles of Cellular Metabolism and Principles of Metabolic flux analysis, Elementary Mode Modeling, Cybernetic principles of optimal growth modeling,	6
3	Biochemical pathway engineering, Rational manipulation of biosystems through metabolic and genetic engineering techniques to provide new biocatalysts/bioproducts/value added products.	6
4	New approaches for design of cellular systems: Integration of recombinant technology and process design, as well as bioinformatics and process systems engineering	6
5	Basic principles of System and Synthetic biology and modeling of bioreactors	6

List of Text Books/ Reference Books

	1.Ahindra Nag, Biosystems Engineering, 1 edition, McGraw-Hill, Inc, 2009 2. Biosystem Engineering Journal, Elsevier

Course Outcomes

1	Able to understand the basics of basic knowledge on genetic and metabolic engineering for improvement of biosystem/s
2	Able to understand the application of thermodynamics in molecular aspects in designing of new systems for upstream processing
3	Understand the mechanistic involved in biochemistry, microbiology and molecular biology
4	Understand phase equilibria and intermolecular forces
5	To find out the applications of thermodynamics and intermolecular forces in bioprocessing e.g. protein stability, conformations, affinity interactions etc.

	Course Code: BST 2105 (Core subject)	Course Title: BST 2105 Bioreactor Design and Industrial Bioprocess Automation (Marks 50)	Credits = 3		
			L	T	P
	Semester: II	Total contact hours: 30	2	1	0
List of Prerequisite Courses					
	Basic knowledge of biological processes, cellular metabolism, enzyme and microbial kinetics, and basic mathematics				
List of Courses where this course will be prerequisite					
	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Technology				

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

Students will understand various bioreactors, their design and operation for production of biotech products. They will also learn bioreactor modeling, process optimization as well as continuous Biomanufacturing for biopharmaceuticals, biochemicals, agroprocessing, natural product, nutraceutical, edible oil, flavor and fragrance, food processing and pharmaceuticals etc. industries according to the biochemical reaction involved.

Module	Course Contents (Topics and subtopics)	Reqd. hours
1	Background of bioreactors, Modeling and Design of bioreactors: batch, fed-batch, and continuous flow types (Airlift bioreactors, Airlift pressure cycle bioreactors, Loop bioreactor, Stirred tank bioreactors, Fluidized bed bioreactor, Packed-bed reactors, Trickle bed bioreactor, Bubble column fermenter, Multiphase bioreactors, Disposable bioreactors and Wave bioreactor).	6
2	Design of Stirrers and impellers. Design, development and scale up of bioreactors and photobioreactors for production of antibiotics, enzymes, vaccines, therapeutic products and biofuels. Reactors with non ideal mixing. Immobilized enzyme/cell reactors.	6
3	Mass and Heat Transfer, Shear effects in cell cultures, Pontryagin maximum principle for the determination of optimal flow rate to fed batch reactors, optimization for the production of primary and secondary biological products. Bioremediation and Waste treatment, Microbial reactors with and without cell recycle. Bioreactor operations for industrial-important biological products and for biological treatment of wastewater. Design of activated sludge and fixed-film systems. Solid state, Surface, submerged and anaerobic fermentation, Sterilization and asepsis.	6
4	Principles and Strategies for Control of Bioreactors (feedback, feedforward, adaptive and statistical control, fuzzy logic control), of bioreactors and ancillary equipment.	6
5	Industrial bioprocess and their process automation (batch, semiautomatic and automatic processes). Continuous Biomanufacturing processes	6

List of Text Books/ Reference Books

1. Najafpour, G. D., "Biochemical Engineering and biotechnology", Elsevier, 2007.
2. Doran, P.M., "Bioprocess Engineering Principles", Academic Press, 2005.
3. Walker, J.M. and Rapley, R., "Molecular Biology and Biotechnology", 4th Edition, Royal Society of Chemistry, 2000.
4. Blanch, H. W. and Clark, D. S., "Biochemical Engineering", Marcel Dekker, Inc., 1999.

	Dunn, I.J., Heinzle, E., Ingham J. and Prenosil, J.E., "Biological Reaction Engineering: Dynamic Modeling Fundamentals with Simulation Examples", 2nd Edition, Wiley-VCH, 2003.
Course Outcomes	
1	Able to design and analyze batch, continuous flow, and fed batch reactors with specific instrumentation required for the efficient monitoring and control of simple bioreactor, ancillary equipment required for the aseptic feeding, sampling and processing of bioreactor fluids
2	Able to understand the application of design in biological reactors with cell recycle streams
3	Students should be able to apply the reactor optimization principles for the design of bioreactors for industrially important biological products, primary and secondary metabolites
4	Understand usefulness of automatic and continuous biomanufacturing
5	To find out the applications of bioreactor design and continuous processing for various biotech products

	Course Code: BST 2106 (Core subject)	**Course Title: BST 2106 Adsorptive, Chromatographic and Membrane Separations (Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 30**	**2**	**1**	**0**
List of Prerequisite Courses					
	Transport Phenomena, unit operation in bioprocesses, plug flow and fluidized bed reactors, basics of separation and purification				
List of Courses where this course will be prerequisite					
	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Technology				

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

Students will understand various adsorption of biomolecules and preparative chromatographic separations. They will also learn membrane filtration operations for various biomolecules including process optimization and integration for manufacturing for biopharmaceuticals, biochemicals, agroprocessing, natural product, nutraceutical, edible oil, flavor and fragrance, food processing and pharmaceuticals etc. industries according to the biochemical reaction involved.

Module	**Course Contents (Topics and subtopics)**	**Reqd. hours**
1	Introduction, Theory and chemistry of adsorption. Chromatographic Fundamentals: Retention, Band Spreading, Resolution; Dynamics of Chromatography: Basic mass transfer equations, Method of moments, Linear dispersion model, Linear staged models for chromatography; Instrument Requirements for Chromatography: System design, Column packing techniques; Fundamentals of Adsorption: Gibbs adsorption isotherm, Adsorption isotherm models, Local equilibrium theory and solute movement plots;	5
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;	6

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; Mode of contacting solids with liquid: Packed bed , expanded bed, fluidized bed, moving bed (Simulated moving bed, True moving bed, Liquid-solid circulating fluidized bed, Fluidized moving bed);	6
4	Novel Chromatographic Morphologies: Continuous annular systems, Radial flow, centrifugal chromatography, SMB, ISMB, Continuous chromatography (PCC and varicol systems), Perfusion chromatography, Membrane chromatography and Monoliths; Chromatographic Applications in Biotechnology: Applications of various modes of operation, sequencing of chromatographic operations, Multidimensional separations for proteomics.	5
5	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.	5
6	Process optimization using advanced strategies, QbD, DOE, Multivariate data analysis (MVDA), Process integration and intensification for biotech products	3
List of Text Books/ Reference Books		
	1. Anurag Rathore and Ajoy Velyudhan, Scale-up and optimization in preparative chromatography, 2003 2. Sewell P.A. Clarke B, Chromatographic separations. John Wiley & Sons, 1991 3. Lindsay B., High performance Liquid Chromatography, John Wiley & Sons, 4. Lecture Notes on short course on Enantiomeric separations, April 28-29,1995. 5. Handbook of membrane separations: chemical, pharmaceutical, food and biotechnological applications by Anil K. Pabby, Syed Rezvi and Anna Satre, CRC press, 2009 6. Filtration and purification in biopharmaceutical industry, second edition by Miak Jornitz and Theodore Meltzer, Informa Healthcare, Vol. 174	
Course Outcomes		
1	Able to understand high resolution techniques in bioseparation, purification of small and large biomolecules by chromatography, polishing and concentration steps in bioprocessing	
2	Able to understand column packing, designing of separation and its scale-up,	
3	Students should be able to understand of nature of membranes; membrane transport mechanism; design of membrane modules and plant; membrane fouling	
4	The ability to 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	
5	To find out the applications of process chromatography and membrane filtration for processing for various biotech products	

	Course Code:	**Course Title: (Elective III) (Marks 50)**	**Credits = 3**		
			L	**T**	**P**

	Semester: I	**Total contact hours: 30**	**2**	**1**	**0**
Elective-I (from the list appended) Candidate will have to choose one of the elective subjects offered for that semester from the elective subjects. A consolidated list of all the elective subjects is given at the end.					

	Course Code:	**Course Title: (Elective IV) (Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**2**	**1**	**0**
Elective-II (from the list appended) Candidate will have to choose one of the elective subjects offered for that semester from the elective subjects. A consolidated list of all the elective subjects is given at the end.					

	Course Code: **BSP 2104**	**Course Title: BSP 2104** Biosciences and Bioprocess Technology Laboratory **(Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**-**	**-**	**6**
List of Prerequisite Courses					
	Bioreaction Engineering, unit operations in bioprocessing, Microbiology, Biochemistry and Genetics				
List of Courses where this course will be prerequisite					
	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Engineering operations				
Description of relevance of this course in the M. Tech. (Bioprocess Technology) Programme					
Students will understand and explain the application of concepts in basic biology and life sciences as well as biochemical engineering in bioprocessing of bioproducts (both small and large biomolecules), Technical Microbiology, fermentation, biochemistry and molecular biology as well as downstream processing operations.					

Module	**Course Contents (Topics and subtopics)**	**Reqd. hours**
1	Technical Microbiology pertaining to strain isolation for pure culture and its maintenance	
2	Technical Biochemistry and molecular biology pertaining to proteins and enzymes, enzyme activity and kinetics, nucleic acid isolation, protein quantification etc.	
3	Fermentation and Bioreactions: fermentation of primary and secondary metabolite on shake flask and at fermentor level with control parameters	
4	Biocatalysis: enzyme immobilization, enzymatic and whole call biocatalysis	
5	Downstream processing consisting membrane filtration MF/UF/NF/RO, column packing, column qualification, precipitation, solid-liquid extraction, thermodynamic and kinetic chromatographic separations, resolution of biomolecules,	
6	Characterization of biotech and biobased products using various analytical techniques e.g.UV/Vis, HPLC, FTIR, LC-MS/MS, DLS, Electrophoresis etc.	

Course Outcomes	
1	To be able to perform experiments to ascertain the biosciences and life biosciences governing bioprocesses and biochemical engineering principles
2	To design experimental configurations/loops for demonstrating the basic governing fundamentals
3	To perform calculations and predict the trends in design variables as a function of operating/geometric parameters
4	To effectively operate the analytical facilities

	Course Code: BSP 2105	**Course Title: BSP 2105** Research Project -II **(Marks 150)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours:**	**-**	**-**	**18**
	Details: The Research project I is concerned with detailed literature review of the assigned research area in consultation with the research supervisor, developing an experimental/analytical/simulation protocol and initiate the actual research work. Based on the outcomes of the candidate is expected to submit a report as per similar guidelines provided for BSP2102 above which will be evaluated by the research guide and an external examiner from the Department/Industry based on the presentation made by the candidate. A suitable combination of the marks for report and presentation will be considered for the final evaluation.				

Course Outcomes	
1	Systematically perform experiments/modeling activity to accomplish the set objectives
2	Critically analyse the results and present them in coherent manner in the form of graphs, tables etc
3	Write a technically correct report as per the suggested guidelines and present the work

FOLLOWING IS THE LIST OF ELECTIVE SUBJECTS

	Course Code: BST 2107 (Elective Subject)	**Course Title: BST 2107** Analytical Techniques in Bioprocessing **(Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**2**	**1**	**0**
List of Prerequisite Courses					
	Basic principles and instrumentation techniques like spectroscopy and liquid chromatography.				
List of Courses where this course will be prerequisite					
	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Engineering operations, Pharmaceutical Biotechnology, Bioanalyticals				
Description of relevance of this course in the M. Tech. (Bioprocess Technology) Programme					
Students will understand various analytical techniques and methods of analysis for biotech, biobased products including proteins, amino acids, vitamins, sugars, nucleic acids, organic acids, polysaccharides, antibiotic, biopharmaceuticals, biologicals, biosimilars etc. They will be able to explain its applications and usefulness of various analytical techniques in quantification and characterization of biotech and biobased products and in process automation in industries according to the processes involved for better control.					
Module	**Course Contents (Topics and subtopics)**		**Reqd. hours**		
1	Qualitative and quantitative analysis of proteins, nucleic acids, polysaccharides and small molecules such as antibiotics, vitamins, natural products etc. Development and application of modern analytical instrumentation.		2		
2	Chromatography: HPLC (including ELSD, CAD and DLS detectors), UPLC, GC, HPTLC, Ion chromatography and 2D techniques etc.		4		
3	Mass spectrometry: Fragmentation patterns for molecular analysis. Derivatisation techniques. Sample introduction features for large molecules. Recent developments in applications to proteomics and metabolomics (SELDI, MALDI, Q-TOF, Triple Quad and Ion trap mass analyzers).		6		
4	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		6		
5	Hybrid techniques: Gas chromatography with Fourier transforms infrared spectroscopic detection (GC-FTIR), gas chromatography with mass spectrometric detection (GC-MS), liquid chromatography with mass spectrometric detection (LC-MS and LC-MS/MS), and inductively coupled plasma with mass spectrometric detection (ICP-MS). Applications to proteomics, metabolomics, Impurity identification and profiling. Electrophoresis: PAGE, SDS-PAGE, Zone electrophoresis, Capillary electrophoresis, 2-D techniques, laser ablation, Qualitative and quantitative analysis using image analyzers. PCR, Q-PCR and RT-PCR techniques.		6		

6	Particle size analysis, SEM, TEM and their application in bioprocessing and bioproduct characterizations Application of IR and NMR spectroscopy, FT-IR, FT-NMR, X-ray diffraction (XRD, XRPD) and differential scanning calorimetry, Microcalorimetry in bioproducts. Synchrotron radiation and their application in bioprocessing Advanced analytical techniques like automated electrophoresis and lab on chip.	6
List of Text Books/ Reference Books		
1	Handbook of analytical separations, vol. 4, by Ian Wilson, 2003	
2	Encyclopedia of spectroscopy and spectrometry, vol. 1-3, 2000	
3	Methods of biochemical Analysis, Vol. 35, Clarence Suelter, 1991	
4	Methods of biochemical Analysis, Vol. 36, Clarence Suelter, 1992	
Course Outcomes (students will be …..)		
1	Able to understand the basics of bioanalytical instrumentation and its applicability in bioprocessing be able to use these techniques carefully during their research work	
2	Quality control for biopharmaceuticals and biochemical	
3	Understand the effect of physicochemical properties of analysis of biotech and biobased products	
4	Understand the raw material, in process and finished product quality control for biotech and biobased products	
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.	

	Course Code: BST 2108 (Elective)	**Course Title: BST 2108 Applied Molecular and Synthetic Biology (Marks 50)**	**Credits = 3**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**2**	**1**	**0**
List of Prerequisite Courses					
	Basic biochemistry, microbiology and genetics				
List of Courses where this course will be prerequisite					
	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Engineering operations, Pharmaceutical Biotechnology, Bioanalyticals				
Description of relevance of this course in the M. Tech. (Bioprocess Technology) Programme					
Students will understand (a) basic genetic toolbox/components to manipulate a cellular system to produce a range of natural and engineered products; (b) Design of efficient and robust toolbox for genetic manipulation of cellular platforms like *E. coli*, *Saccharomyces cerevisiae* and (c) Metabolic engineering of the cellular system to enhance the product titer. They will be able to explain its applications in production					

and designing of Biopharmaceutical and industrial biotechnology products such as recombinant therapeutic proteins and peptides, sugar based molecules like xylitiol, designer biocatalysts etc. .		
Module	**Course Contents (Topics and subtopics)**	**Reqd. hours**
1	**Concept and History of Synthetic Biology**	1
2	Basic expression and regulation in a model organism: *E. coli* 2.1 Gene expression and regulation 2.2 Metabolic pathways and its regulation	4
3	Natural and advanced Genetic Tool Box for Manipulation of Pathways and Gene Expression 3. 1 Extra chromosomal tools: Plasmids, Cosmids 3.2 Genomic tools: Homologous recombination, CRISPR-Cas systems 3.3 Synthetic expression elements : Promoter, ribosome binding sites 3.4 Advance tools for assembly of genetic elements: Gibson assembly 3.5 Genome engineering and synthetic cells	8
4	Synthetic Biology approach for production of Biopharmaceuticals 4.1 Anti malarial Drug : artemisinin production in *Saccharomyces cerevisiae* 4.2 Glycoengineered microbial strain for glycosylated proteins 4.3 Production of recombinant proteins : Single protein production (SPP) system in *Escherichia coli* 4.4 Production of sugar based biotechnological molecules: Xylitol, GOS (galacto-oligosaccharides)	8
5	Synthetic Biology approach for production of Biochemical and Biocatalyst 5.1 Cell free SyPaB (Synthetic Pathway for Biotransformation) 5.2 Cellular platforms for Microbial Engineering	5
6	Critically analyse scientific literature in the area 6.1 The International Genetically Engineered Machine (iGEM) foundation and 6.2 Case study of iGEM competition	4
List of Text Books/Reference Books		
1	Synthetic Biology: Tools and Applications Edited by Huimin Zhao; ISBN: 978-0-12-394430-6	
2	Bioengineering: A conceptual Approach by Mirjana Pavlovic; ISBN 978-3-319-10798-1	
Course Outcomes (students will be …..)		
1	Able to understand the basics of gene expression and pathway regulation	
2	Genetic tool boxes to manipulate the cellular platform for production of Biopharmaceuticals	
3	Production and application of designer biotechnological products	
4	Understand the concept of synthetic cell	
5	Application of synthetic biology for discovery of new set of biotechnological Products	

	Course Code: BST 2109 (Elective)	Course Title: BST 2109 Transport Phenomenon in Bioprocessing (Marks 50)	Credits = 3		
			L	T	P
	Semester: I	Total contact hours: 30	2	1	0
List of Prerequisite Courses					
	Basic mathematics and Algebra				
List of Courses where this course will be prerequisite					
	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Engineering operations, Pharmaceutical Biotechnology, Bioanalyticals				
Description of relevance of this course in the M. Tech. (Bioprocess Technology) Programme					
Students will understand the fluid flow and its types in various biotech processes i.e. fermentation, downstream processing etc. They will be able to explain its applications in bioprocess development and scale up.					

Module	Course Contents (Topics and subtopics)	Reqd. hours
1	Basic laws of one-dimensional diffusive transport: momentum, heat and mass transfer and their analogies; characteristics of transport processes;	4
2	Flow equation, simple shear flow and developing flows, entrance effect, two/three phase flows. Multiphase systems and transport coefficients;	6
3	Convective transport; Transport in turbulent condition	4
4	Non-steady state transport; Transport phenomena in bioprocesses and biosystem: interphase, diffusion in biofilm-floc, determination of transport coefficients, agitation power, and evaluation of oxygen transport rate as a function of operating variables.	6
5	Introduction to microfluidics in bioprocessing unit operations	4
6	Application of transport phenomenon in various bioprocesses, case studies in biochemicals, biopharmaceuticals, bioanalysis	6

List of Text Books/ Reference Books	
1	Biron R. Bird, Warren E. Stewart, and Edwin Lightfoot , "Transport Phenomena"
2	Bennet C.O. and Meyer J.E., "Momentum and mass Transfer"
3	Sission and Pitts "Introduction to Transprot Phenomena"
4	Christie J. Geankoplis, "Transport Processes and Unit Operations", Prentice hall of India, 1997
5	J.C.Slattery, " Momentum, Energy and Mass Transfer in continuum , Kruger Publishing company
Course Outcomes (students will be …..)	
1	Able to understand the basics of transport processes and its applicability in design and development of bioprocesses
2	Able to understand different behaviour of fluid based on biotech system and processes
3	Understand the use of transport phenomenon in scale up of biotech industries
4	To find out the applications in various biotech products i.e. small and large biomolecules etc.

	Course Code: BST 2109 (Elective)	Course Title: BST 2109 Fermentation and Cell Culture Engineering (Marks 50)	Credits = 3		
			L	T	P
	Semester: II	Total contact hours: 30	2	1	0

List of Prerequisite Courses		
	Biological sciences, life sciences, microbiology, biochemistry, bioreaction engineering	

List of Courses where this course will be prerequisite		
	PhD in Bioprocess Technology, Biotechnology, Biochemical Engineering, Chemical Engineering, Chemical Engineering operations, Pharmaceutical Biotechnology, Bioanalyticals	

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

Students will understand the microbial and animal cell culture for production of therapeutic and non-therapeutic products

Module	Course Contents (Topics and subtopics)	Reqd. hours
1	Nature of fermentation processes, Nutritional requirements in fermentation process, Strain Construction and Strain Improvement	6
2	Modern Experimental Techniques: Batch, Fed-Batch, Continuous and extractive Fermentation, High cell-density and High-Performance Bioreactors, Quantitative Physiological Studies	6
3	Aerobic and anaerobic fermentation, surface, submerged and solid state fermentation technology, Statistical methods for fermentation optimization, Instrumentation and Control Systems, Improving the production of recombinant DNA proteins through fermentation development,	6
4	Automation, optimization and Control of fermentation processes, Fermentation design and Cost, Design considerations for aseptic fermentation, Case studies with respect to antibiotic, enzymes and therapeutics.	6
5	Cell culture engineering and technology: Plant and mammalian cell culture for production of bioproducts.	6

List of Text Books/ Reference Books	
1	Wang D. I. C., Cooney C. L., Demain A. L., Dunnil P., Humphrey A. E., Lilly M. D., Fermentation and Enzyme Technology, John Wiles and Sons., 1980.
2	Stanbury P. F. and Whitaker A., Principles of Fermentation Technology, Pergamon Press, 1984.
3	Zubay G., Biochemistry, Macmillan Publishers, 1989.

Course Outcomes

- knowledge of microbial fermentation, growth kinetic and product formation knowledge of

1	Able to understand microbial fermentation, growth kinetic and product formation
2	Able to understand strain improvement, cell culture and its application for production of various bioproducts

3	Understand the use of fermentation and bioreaction for production of therapeutic and non-therapeutic products
4	To find out the applications in various biotech products i.e. small and large biomolecules etc.