A Guide to Writing and Assessing Learning Outcomes

National Board of Accreditation (NBA) is responsible for the accreditation of higher education institutions in India. NBA is also a full member of the Washington Accord. NBA accredits programmes and not the institutions.

If an institution is planning to apply for NBA accreditation for a department, then in Criterion 3.1 of Self-Assessment Report (SAR) of NBA document, you are explicitly asked to mention the CO - PO mapping for a minimum of 8 core courses.

So before applying for NBA accreditation, the concerned department should make sure that their COs are well defined and serves the purpose of Outcome Based Education (OBE). Institutions adopting OBE try to bring changes to the curriculum by dynamically adopting to the requirements of the different stakeholders like Students, Parents, Industry Personnel and Recruiters.

Higher Education Institutions are classified into two categories by NBA

Tier - 1 Institutions consists of all IITs, NITs, Central Universities, State Universities and Autonomous Institutions. Tier - 1 institutions can also claim the benefits as per the Washington Accord.

Tier - 2 Institutions consists of affiliated colleges of Universities.

Blooms Taxonomy

Bloom's taxonomy is considered as the global language for education. Bloom's Taxonomy is frequently used by teachers in writing the course outcomes as it provides a readymade structure and list of action verbs.

The stages ascend in complexity and what they demand of students. First students need to simply remember information provided to them — but reciting something doesn't demonstrate having learned it, only memorization. With understanding comes the ability to explain the ideas and concepts to others. The students are then challenged to apply the information and use it in new ways, helping to gain a deeper understanding of previously covered material and demonstrating it moving forward.

Questioning information is a vital part of learning, and both analysis and evaluation do just this. Analysing asks a student to examine the information in a new way, and evaluation demands the student appraise the material in a way that lets them defend or argue against it as they determine. The final step in the revised taxonomy is creating, which entails a developing new product or point of view. How does this learned information impact your world? How can it be used to impact not just your education but the way you interact with your surroundings?

By utilizing Bloom's Taxonomy, students are not going to forget the information as soon as the class ends — rather, they retain and apply the information as they continue to grow as a student and in their careers, staying one step ahead of the competition.

Here is the revised Bloom's document with action verbs, which we frequently refer to while writing COs for our courses.

Definitions	I. Remember	II. Understand	III. Apply	IV. Analyze	V. Evaluate	VI. Create
Bloom's Definition	EXHIBIT MEMORY OF PREVIOUSLY LEARNED MATERIAL BY RECALLING FACTS, TERMS, BASIC CONCEPTS, AND ANSWERS.	DEMONSTRATE UNDERSTANDING OF FACTS AND IDEAS BY ORGANIZING, COMPARING, TRANSLATING, INTERPRETING, GIVING DESCRIPTIONS, AND STATING MAIN IDEAS.	SOLVE PROBLEMS TO NEW SITUATIONS BY APPLYING ACQUIRED KNOWLEDGE, FACTS, TECHNIQUES AND RULES IN A DIFFERENT WAY.	EXAMINE AND BREAK INFORMATION INTO PARTS BY IDENTIFYING MOTIVES OR CAUSES. MAKE INFERENCES AND FIND EVIDENCE TO SUPPORT GENERALIZATIONS.	PRESENT AND DEFEND OPINIONS BY MAKING JUDGMENTS ABOUT INFORMATION, VALIDITY OF IDEAS, OR QUALITY OF WORK BASED ON A SET OF CRITERIA.	COMPILE INFORMATION TOGETHER IN A DIFFERENT WAY BY COMBINING ELEMENTS IN A NEW PATTERN OR PROPOSING ALTERNATIVE SOLUTION.
Verbs	Choose Define Find How Label List Match Name Omit Recall Relate Select Show Spell Tell What When Where Which Who Why	Classify Compare Contrast Demonstrate Explain Extend Illustrate Infer Interpret Outline Relate Rephrase Show Summarize Translate	Apply Build Choose Construct Develop Experiment with Identify Interview Make use of Model Organize Plan Select Solve Utilize	Analyze Assume Categorize Classify Compare Conclusion Contrast Discover Dissect Distinguish Divide Examine Function Inference Inspect List Motive Relationships Simplify Survey Take part in Test for Theme	Agree Appraise Assess Award Choose Compare Conclude Criteria Criticize Decide Deduct Defend Determine Disprove Estimate Evaluate Explain Importance Influence Interpret Judge Justify Mark Measure Opinion Perceive Prioritize Prove Rate Recommend Rule on Select Support Value	Adapt Build Change Choose Combine Compile Compose Construct Create Delete Design Develop Discuss Elaborate Estimate Formulate Happen Imagine Improve Invent Make up Maximize Minimize Modify Original Originate Plan Predict Propose Solution Solve Suppose Test Theory

What is Outcome Based Education (OBE)?

Institutions adopting OBE try to bring changes to the curriculum by dynamically adapting to the requirements of the different stakeholders like Students, Parents, Industry Personnel and Recruiters. OBE is all about feedback and outcomes.

Four levels of outcomes from OBE are:

1. Program Educational Objectives (PEOs)
2. Program Outcomes (POs)
3. Program Specific Outcomes (PSOs)
4. Course Outcomes (COs)

Why OBE?

1. International recognition and global employment opportunities.
2. More employable and innovative graduates with professional and soft skills, social responsibility and ethics.
3. Better visibility and reputation of the technical institution among stakeholders.
4. Improving the commitment and involvement of all the stakeholders.
5. Enabling graduates to excel in their profession and accomplish greater heights in their careers.
6. Preparing graduates for the leadership positions and challenging them and making them aware of the opportunities in the technology development.

Benefits of OBE for Faculty Members

Faculty members are referred to as Change of Agents in OBE.

1. Teaching will become a far more creative and innovative career.
2. Faculty members will no longer feel the pressure of having to be the “source of all knowledge”.
3. Faculty members shape the thinking and vision of students towards a course.

Program Educational Objectives (PEOs)

Program Educational Objectives (PEOs) should be defined by the Head of the Department in consultation with the faculty members. PEOs are a promise by the department to the aspiring students about what they will achieve once they join the programme. PEO assessment is not made compulsory by NBA as it is quite difficult to measure in Indian context. NBA assessors usually do not ask for PEO assessment. PEOs are about professional and career accomplishment after 4 to 5 years of graduation. PEOs can be written from different perspectives like Career, Technical Competency and Behaviour. While writing the PEOs do not use the technical terms as it will be read by prospective students who wants to join the programme. Three to five PEOs are recommended.

Program Outcomes (POs)

A Program Learning Outcome is **broad** in scope and be able to do at the end of the programme. POs are to be in line with the graduate attributes as specified in the Washington Accord. POs are to be specific, measurable and achievable.

NBA has defined 12 POs and you need not define those POs by yourself and it is common for all the institutions in India.

In the syllabus book given to students, there should be clear mention of course objectives and course outcomes along with CO-PO course articulation matrix for all the courses.

Program Specific Outcomes (PSOs)

Program Specific Outcomes (PSOs) are statements that describe what the graduates of a specific engineering program should be able to do. A list of PSOs written for the department of Computer Science and Engineering is given below.

PSO 1: Understand, design and analyse computer programs in the areas related to Algorithms, System Software, Web design, Bigdata, Artificial Intelligence, Machine Learning and Networking.

PSO 2: Focus on improving software reliability, network security and information retrieval systems.

PSO 3: Make use of modern computer tools for creating innovative career paths, to be an entrepreneur and desire for higher studies.

Course Outcomes (COs)

A **Course Outcome** is a formal statement of what students are expected to learn in a course. When creating Course Outcomes remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning. Course learning outcome statements refer to specific knowledge, practical skills, areas of professional development, attitudes, higher-order thinking skills, etc. that faculty members expect students to develop, learn, or master during a course.

A well-formulated set of Course Outcomes will describe what a faculty member hopes to successfully accomplish in offering their particular course(s) to prospective students, or what specific skills, competencies, and knowledge the faculty member believes that students will have attained once the course is completed. The learning outcomes need to be concise descriptions of what learning is expected to take place by course completion.

Developing Course Outcomes

When creating course outcomes consider the following guidelines as you develop them either individually or as part of a multi-section group:

- Limit the course outcomes to 8-12 statements for the entire course [more detailed outcomes can be developed for individual units, assignments, chapters, etc. if the instructor(s) wish (es)].
- Focus on overarching knowledge and/or skills rather than small or trivial details.

- Focus on knowledge and skills that are central to the course topic and/or discipline.
- Create statements that have a student focus rather than an instructor centric approach (basic e.g., "upon completion of this course students will be able to list the names of the 28 states and 8 union territories" versus "one objective of this course is to teach the names of the 28 states and 8 union territories").
- **Focus on the learning that *results* from the course rather than describing activities or lessons that are in the course.**
- Incorporate and/or reflect the institutional and departmental missions.
- Include various ways for students to show success (outlining, describing, modelling, depicting, etc.) rather than using a single statement such as "at the end of the course, students will know _____ "as the stem for each expected outcome statement.

When developing learning outcomes, here are the core questions to ask yourself:

- *What do we want students in the course to learn?*
- *What do we want the students to be able to do?*
- *Are the outcomes observable, measurable and are they able to be performed by the students?*

Course outcome statements on the course level describe:

1. What faculty members want students to *know* at the end of the course *AND*
2. What faculty members want students *to be able to do* at the end of the course?

Course outcomes have three major characteristics

1. They specify an action by the students/learners that is ***observable***
2. They specify an action by the students/learners that is ***measurable***
3. They specify an action that is done by the ***students/learners*** rather than the faculty members

Effectively developed expected learning outcome statements should possess all three of these characteristics. When this is done, the expected learning outcomes for a course are designed so that they can be assessed. When stating expected learning outcomes, it is important to use ***verbs*** that describe exactly what the student(s) / learner(s) will be able to *do* upon completion of the course.

Relationship of Course Outcome to Program Outcome

The Course Outcomes need to link to the Program Outcomes. Use the following learning outcomes formula:

STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE

For example, you can use the following template to help you write an appropriate course level learning outcome.

"Upon completion of this course students will be able to *(knowledge, concept, rule or skill you expect them to acquire)* by *(how will they apply the knowledge or skill/how will you assess the learning).*"

Characteristics of Effective Course Outcomes

Well written course outcomes:

- Describe what you want your students to learn in your course.
- Are aligned with program goals and objectives.
- Tell how you will know an instructional goal has been achieved.
- Use action words that specify definite, observable behaviours.
- Are assessable through one or more indicators (papers, quizzes, projects, presentations, journals, portfolios, etc.)
- Are realistic and achievable.
- Use simple language

Examples of Effective Course Outcomes

After successful completion of the course, Students will be able to:

- Critically review the methodology of a research study published in a scholarly sociology journal.
- Design a Web site using HTML and JavaScript.
- Describe and present the contributions of women to American history.
- Recognize the works of major Renaissance artists.
- Facilitate a group to achieve agreed-upon goals.
- Determine and apply the appropriate statistical procedures to analyze the results of simple experiments.
- Develop an individual learning plan for a child with a learning disability.
- Produce a strategic plan for a small manufacturing business.
- Analyse a character's motivation and portray that character before an audience.
- Differentiate among five major approaches to literary analysis
- List the major ethical issues one must consider when planning a human-subjects study.
- Locate and critically evaluate information on current political issues on the Web.
- List and describe the functions of the major components of the human nervous system.
- Correctly classify rock samples found in...
- Conduct a systems analysis of a group interaction.
- Demonstrate active listening skills when interviewing clients.

- Apply social psychological principles to suggest solutions to contemporary social problems.

A more detailed model for stating learning objectives requires that objectives have three parts: a condition, an observable behaviour, and a standard. The table below provides three examples.

S No	Condition	Observable Behaviour	Standard
1	Given a list of drugs.	the student will be able to classify each item as amphetamine or barbiturate.	with at least 70% accuracy.
2	Immediately following a fifteen-minute discussion on a topic.	the student will be able to summarize in writing the major issues being discussed.	mentioning at least three of the five major topics.
3	Given an algebraic equation with one unknown.	the student will be able to correctly solve a simple linear equation.	within a period of five minutes.

The following examples describe a Course Outcome that is not measurable as written, an explanation for why the Course Outcome is not considered measurable, and a suggested edit that improves the Course Outcome.

Original Course Outcome	Evaluation of language used in this Course Outcome	Improved Course Outcome
Explore in depth the literature on an aspect of teaching strategies.	*Exploration is not a measurable activity but the quality of the product of exploration would be measurable with a suitable rubric.*	Upon completion of this course the students will be able to: write a paper based on an in-depth exploration of the literature on an aspect of teaching strategies.

Examples that are TOO general and VERY HARD to measure…

- …will appreciate the benefits of learning a foreign language.
- …will be able to access resources at the Institute library.
- …will develop problem-solving skills.
- …will have more confidence in their knowledge of the subject matter.

Examples that are still general and HARD to measure…

- …will value knowing a second language as a communication tool.
- …will develop and apply effective problem-solving skills that will enable one to adequately navigate through the proper resources within the institute library.
- …will demonstrate the ability to resolve problems that occur in the field.
- …will demonstrate critical thinking skills, such as problem solving as it relates to social issues.

Examples that are SPECIFIC and relatively EASY to measure…

- …will be able to read and demonstrate good comprehension of text in areas of the student's interest or professional field.
- …will demonstrate the ability to apply basic research methods in psychology, including research design, data analysis, and interpretation.
- …will be able to identify environmental problems, evaluate problem-solving strategies, and develop science-based solutions.
- …will demonstrate the ability to evaluate, integrate, and apply appropriate information from various sources to create cohesive, persuasive arguments, and to propose design concepts.

An Introspection - Examine Your Own Course Outcomes

1. If you have written statements of broad course goals, take a look at them. If you do not have a written list of course goals, reflect on your course and list the ***four to six most important*** student outcomes you want your course to produce.
2. Look over your list and check the one most important student outcome. If you could only achieve one outcome, which one would it be?
3. Look for your outcome on the list of key competencies or outcomes society is asking us to produce. Is it there? If not, is the reason a compelling one?
4. Check each of your other "most important" outcomes against the list of outcomes. How many are on the list of key competencies?
5. Take stock. What can you learn from this exercise about what you are trying to accomplish as a teacher? How clear and how important are your statements of outcomes for your use and for your students'? Are they very specifically worded to avoid misunderstanding? Are they supporting important needs on the part of the students?

Write Your Course Outcomes!

One of the first steps you take in identifying the expected learning outcomes for your course is identifying the purpose of teaching the course. By clarifying and specifying the purpose of the course, you will be able to discover the main topics or themes related to students' learning. Once discovered, these themes will help you to outline the expected learning outcomes for the course. Ask yourself:

- What role does this course play within the program?
- How is the course unique or different from other courses?
- Why should/do students take this course? What essential knowledge or skills should they gain from this experience?
- What knowledge or skills from this course will students need to have mastered to perform well in future classes or jobs?
- Why is this course important for students to take?

CO-PO Course Articulation Matrix Mapping

Course Articulation Matrix shows the educational relationship (Level of Learning achieved) between Course Outcomes and Program Outcomes for a Course. This matrix strongly indicates whether the students are able to achieve the course learning objectives. The matrix can be used for any course and is a good way to evaluate a course syllabus.

The Table 1 gives information about the action verbs used in the POs and the nature of POs, stating whether the POs are technical or non-technical. You need to understand the intention of each POs and the Bloom's level to which each of these action verbs in the POs correlates to. Once you have understood the POs then you can write the COs for a course and see to what extent each of those COs correlate with the POs.

Table 1: Process for mapping the values for CO-PO Matrix

<table>
<tr><th>Type</th><th>POs</th><th>Action Verb(s) in POs</th><th>Bloom's level(s) for POs</th><th>Bloom's level(s) for COs</th></tr>
<tr><td rowspan="13">Technical</td><td>PO 1</td><td>Apply</td><td>L3</td><td rowspan="13">• Bloom's L1 to L4 for Theory Courses.
• Bloom's L1 to L5 for Laboratory Courses.
• Bloom's L1 to L6 for Mini Project and Main Project.</td></tr>
<tr><td rowspan="3">PO 2</td><td>Identify</td><td>L2</td></tr>
<tr><td>Formulate</td><td>L6</td></tr>
<tr><td>Review</td><td>L2</td></tr>
<tr><td rowspan="2">PO 3</td><td>Design</td><td>L6</td></tr>
<tr><td>Develop</td><td>L3, L6</td></tr>
<tr><td rowspan="3">PO 4</td><td>Analyse</td><td>L4</td></tr>
<tr><td>Interpret</td><td>L2, L3</td></tr>
<tr><td>Design</td><td>L6</td></tr>
<tr><td rowspan="3">PO 5</td><td>Create</td><td>L6</td></tr>
<tr><td>Select</td><td>L1, L2, L6</td></tr>
<tr><td>Apply</td><td>L3</td></tr>
<tr><td rowspan="7">Non-Technical</td><td>PO 6</td><td colspan="3" rowspan="7">THUMB RULE
• If Bloom's L1 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 1.
• If Bloom's L2 to L3 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 2.
• If Bloom's L4 to L6 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 3.</td></tr>
<tr><td>PO 7</td></tr>
<tr><td>PO 8</td></tr>
<tr><td>PO 9</td></tr>
<tr><td>PO 10</td></tr>
<tr><td>PO 11</td></tr>
<tr><td>PO 12</td></tr>
</table>

And at the end, the POs can be calculated using various descriptors that you may define. The mapping of CO towards a PO is evaluated using descriptors such as High, Medium, Low etc…

Observations:

1. The first five POs are purely of technical in nature, while the other POs are non-technical.

2. For the theory courses, while writing the COs, you need to restrict yourself between Blooms Level 1 to Level 4. Again, if it is a programming course, restrict yourself between Blooms Level 1 to Level 3 but for the other courses, you can go up to Blooms Level 4.
3. For the laboratory courses, while composing COs, you need to restrict yourself between Blooms Level 1 to Level 5.
4. Only for Mini-project and Main project, you may extend up to Blooms Level 6 while composing COs.
5. For a given course, the course in-charge has to involve all the other Professors who teach that course and ask them to come up with the CO-PO mapping. The course in-charge has to take the average value of all of these CO-PO mappings and finalize the values or the course in-charge can go with what the majority of the faculty members prefer for. Ensure that none of the Professors who are handling the particular course discuss with each other while marking the CO-PO values.
6. If you want to match your COs with non-technical POs, then correlate the action verbs used in the course COs with the thumb rule given in the table and map the values. (Applies only for mapping COs to non-technical POs).

Tips for Assigning the values while mapping COs to POs.

1. Select action verbs for a CO from different Bloom's levels based on the importance of the particular CO for the given course.
2. Stick on to single action verbs while composing COs but you may go for multiple action verbs if the need arises.
3. You need to justify for marking of the values in CO-PO articulation matrix. Use a combination of words found in the COs, POs and your course syllabus for writing the justification. Restrict yourself to one or two lines.
4. Values to CO-PO (technical POs in particular) matrix can be assigned by
    a. Judging the importance of the particular CO in relation to the POs. If the CO matches strongly with a particular PO criterion then assign 3, if it matches moderately then assign 2 or if the match is low then assign 1 else mark with " - " symbol.
    b. If an action verb used in a CO is repeated at multiple Bloom's levels, then you need to judge which Bloom's level is the best fit for that action verb.

Method for Articulation

1. Identify the key competencies of POs/PSOs to each CO and make a corresponding mapping table with assigning √ mark at the corresponding cell. One observation to be noted is that the first five POs are purely of technical in nature, while the other POs are non-technical.
2. Justify each CO - PO/PSO mapping with a justification statement and recognize the number of vital features mentioned in the justification statement that are matching with the given Key Attributes for Assessing Program Outcomes. Use a combination of words found in the COs, POs//PSOs and your course syllabus for writing the justification.

3. Make a table with number of key competencies for CO – PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Make a table with percentage of key competencies for CO – PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, Course Articulation Matrix (CO - PO / PSO Mapping) is prepared with COs and POs and COs and PSOs on the scale of 0 to 3, 0 being no correlation (marked with " - "), 1 being the low/slight correlation, 2 being medium/moderate correlation and 3 being substantial/high correlation based on the following strategy

0 – $\mathbf{0} \leq \boldsymbol{C} \leq 5\%$ – No correlation.
1 – $5 < \boldsymbol{C} \leq 40\%$ – Low / Slight.
2 – $40\ \% < \boldsymbol{C} < 60\%$ – Moderate
3 – $60\% \leq \boldsymbol{C} < 100\%$ – Substantial / High

Key Attributes for Assessing Program Outcomes:

PO No.	NBA Statement / Vital Features	No. of Vital Features
PO 1	Apply the knowledge of mathematics, science, Engineering fundamentals, and an Engineering specialization to the solution of complex Engineering problems (**Engineering Knowledge)**. Knowledge, understanding and application of 1. Scientific principles and methodology 2. Mathematical principles 3. Own and / or other engineering disciplines to integrate / support study of their own engineering discipline.	**3**
PO 2.	Identify, formulate, review research literature, and analyse complex Engineering problems reaching substantiated conclusions using first principles of mathematics natural sciences, and Engineering sciences (**Problem Analysis).** 1. Problem or opportunity identification 2. Problem statement and system definition 3. Problem formulation and abstraction 4. Information and data collection 5. Model translation 6. Validation 7. Experimental design 8. Solution development or experimentation / Implementation 9. Interpretation of results 10. Documentation	**10**
PO 3.	Design solutions for complex Engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and Environmental considerations (**Design/Development of Solutions).** 1. Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues; 2. Understand customer and user needs and the importance of considerations such as aesthetics; 3. Identify and manage cost drivers; 4. Use creativity to establish innovative solutions; 5. Ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal; 6. Manage the design process and evaluate outcomes.	**10**

	7. Knowledge and understanding of commercial and economic context of engineering processes; 8. Knowledge of management techniques which may be used to achieve engineering objectives within that context; 9. Understanding of the requirement for engineering activities to promote sustainable development; 10. Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk (including environmental risk) issues;	
PO 4.	Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions (**Conduct Investigations of Complex Problems).** 1. Knowledge of characteristics of particular materials, equipment, processes, or products; 2. Workshop and laboratory skills; 3. Understanding of contexts in which engineering knowledge can be applied (example, operations and management, technology development, etc.); 4. Understanding use of technical literature and other information sources Awareness of nature of intellectual property and contractual issues; 5. Understanding of appropriate codes of practice and industry standards; 6. Awareness of quality issues; 7. Ability to work with technical uncertainty. 8. Understanding of engineering principles and the ability to apply them to analyse key engineering processes; 9. Ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modeling techniques; 10. Ability to apply quantitative methods and computer software relevant to their engineering discipline, in order to solve engineering problems; 11. Understanding of and ability to apply a systems approach to engineering problems.	**11**
PO 5.	Create, select, and apply appropriate techniques, resources, and modern Engineering and IT tools including prediction and modelling to complex Engineering activities with an understanding of the limitations (**Modern Tool Usage).** 1. Computer software / simulation packages / diagnostic equipment / technical library resources / literature search tools.	**1**
PO 6.	Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice (**The Engineer and Society).** 1. Knowledge and understanding of commercial and economic context of engineering processes; 2. Knowledge of management techniques which may be used to achieve engineering objectives within that context; 3. Understanding of the requirement for engineering activities to promote sustainable development; 4. Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk (including environmental risk) issues; 5. Understanding of the need for a high level of professional and ethical conduct in engineering.	**5**
PO 7.	Understand the impact of the professional Engineering solutions in societal and Environmental contexts, and demonstrate the knowledge of, and need for sustainable development (**Environment and Sustainability).** Impact of the professional Engineering solutions (Not technical) 1. Socio economic, 2. Political and 3. Environmental	**3**
PO 8.	Apply ethical principles and commit to professional ethics and responsibilities and norms of the Engineering practice (**Ethics).**	**3**

	1. Comprises four components: ability to make informed ethical choices, knowledge of professional codes of ethics, evaluates the ethical dimensions of professional practice, and demonstrates ethical behavior. 2. Stood up for what they believed in 3. High degree of trust and integrity	
PO 9.	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings (**Individual and Teamwork).** 1. Independence 2. Maturity – requiring only the achievement of goals to drive their performance 3. Self-direction (take a vaguely defined problem and systematically work to resolution) 4. Teams are used during the classroom periods, in the hands-on labs, and in the design projects. 5. Some teams change for eight-week industry oriented Mini-Project, and for the seventeen - week design project. 6. Instruction on effective teamwork and project management is provided along with an appropriate textbook for reference. 7. Teamwork is important not only for helping the students know their classmates but also in completing assignments. 8. Students also are responsible for evaluating each other's performance, which is then reflected in the final grade. 9. Subjective evidence from senior students shows that the friendships and teamwork extends into the Junior years, and for some of those students, the friendships continue into the workplace after graduation. 10. Ability to work with all levels of people in an organization 11. Ability to get along with others 12. Demonstrated ability to work well with a team	**12**
PO 10	Communicate effectively on complex Engineering activities with the Engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions (**Communication).** "Students should demonstrate the ability to communicate effectively in writing / Orally." 1. Clarity (Writing) 2. Grammar/Punctuation (Writing) 3. References (Writing) 4. Speaking Style (Oral) 5. Subject Matter (Oral)	**5**
PO11	Demonstrate knowledge and understanding of the Engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary Environments (**Project Management and Finance).** 1. Scope Statement 2. Critical Success Factors 3. Deliverables 4. Work Breakdown Structure 5. Schedule 6. Budget 7. Quality 8. Human Resources Plan 9. Stakeholder List 10. Communication 11. Risk Register 12. Procurement Plan	**12**
PO12	Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change (**Life - Long Learning).** 1. Project management professional certification / MBA 2. Begin work on advanced degree	**8**

	3. Keeping current in CSE and advanced engineering concepts 4. Personal continuing education efforts 5. Ongoing learning – stays up with industry trends/ new technology 6. Continued personal development 7. Have learned at least 2-3 new significant skills 8. Have taken up to 80 hours (2 weeks) training per year	

FLUID MECHANICS AND MACHINES

COURSE OBJECTIVES:

Students will try to learn:

1. The fundamental knowledge of fluids, their properties and behaviour under various conditions of closed conduit and external flow systems.
2. The development of various static and dynamic fluid flow governing equations from the fundamental conservation laws of motion studied under basic physics and classical mechanics.
3. The comprehensive and rigorous treatment of concepts and principles related to fluid mechanics, which are used in the applications of hydraulics and hydraulic machines etc.
4. A wealth of real world engineering problems and examples towards gaining the experience for how fluid mechanics is applied in engineering practice.
5. The effective use of fluid mechanics in subsequent fields of study such as thermal engineering, heat transfer, refrigeration and air conditioning for the practice of heat power engineering.

COURSE OUTCOMES:

After successful completion of the course, Students will be able to:

CO No	Course Outcomes	Knowledge Level (Bloom's Taxonomy)
CO 1	**Identify** the basic properties, various types and patterns of fluid flow configurations that encounter in practice.	Remember
CO 2	**Recognize** the importance and application of dimensions, units and dimensional homogeneity in engineering calculations with specific emphasis to fluid mechanics.	Remember
CO 3	**Explain** various effects of viscosity, static pressure and surface tension such as Newton's law of viscosity, pressure difference and capillary rise etc.,	Understand
CO 4	**Calculate** the viscous forces in various engineering applications as fluids deform due to the no-slip condition.	Apply
CO 5	**Apply** the basic laws of conservation for various phenomena of fluid flow systems by understanding appropriate parametric assumptions and limitations.	Apply

CO 6	**Determine** several properties and parameters of fluid flow problems based on fluid flow governing equations related to different practical scenarios.	Apply
CO 7	**Outline** the regimes and separation of boundary layer during external fluid flow systems.	Analyse
CO 8	**Compare** the total and hydraulic gradient lines for distinct cases of losses during a closed conduit fluid flow systems.	Analyse
CO 9	**Explain** the theories, phenomena and working principles of hydraulic machines.	Understand
CO 10	**Illustrate** all the variations of the velocity triangles pertaining to the analyses of hydraulic machines.	Analyse
CO 11	**Evaluate** the specific and unit indicators for performance of hydraulic machines such as speed, discharge and power numbers etc.,	Evaluate
CO 12	**Judge** the working condition of fluid machines and equipments using various theoretical and experimental procedures of the laboratory.	Evaluate
CO 13	**Choose** the designing procedure of hydraulic machines for real world applications along with enhanced performance and minimized losses.	Apply

PROGRAM SPECIFIC OUTCOMES (PSO's):

PSO 1: Formulate and evaluate engineering concepts of design, thermal and production **to provide solutions for technology aspects in digital manufacturing.**

PSO 2: Focus on ideation and research towards product development using **additive manufacturing, CNC simulation and high-speed machining**.

PSO 3: Make use of **computational and experimental tools** for creating innovative career paths, to be an entrepreneur and desire for higher studies.

Identification of key competencies of POs to each CO:

Course Outcomes (COs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO 1	√														
CO 2	√														
CO 3	√														
CO 4	√	√													
CO 5	√	√													√
CO 6	√	√													√
CO 7	√	√		√											
CO 8	√	√		√											√
CO 9	√	√													√
CO 10	√	√		√											√
CO 11	√	√	√	√											√
CO 12	√	√	√	√											√
CO 13	√	√	√	√											√

JUSTIFICATIONS FOR CO – PO MAPPING:

Course Outcomes (COs)	POs / PSOs	Justification for mapping (Students will be able to)	No. of key competencies
CO 1	**PO 1**	Identify (knowledge) the basic properties, various types, patterns of fluid flow configurations and to a considerable extent appreciate (understanding) their importance and applicability (apply) in *solving (complex) fluid flow engineering problems* by applying the principles of **mathematics, science**.	**2**
CO 2	**PO 1**	Recognize (knowledge) the importance and application (apply) of dimensions, units and dimensional homogeneity in *solving (complex) engineering problems* with specific emphasis to fluid mechanics by applying the principles of **mathematics and engineering fundamentals**.	**2**
CO 3	**PO 1**	Explain (understanding) various effects of viscosity, static pressure and surface tension such as Newton's law of viscosity, pressure difference (apply) and capillary rise etc., in *solving (complex) fluid flow engineering problems* by applying the principles of **mathematics, science and engineering fundamentals**.	**3**
CO 4	**PO 1**	Calculate (Apply) the viscous forces in *solving (complex) fluid flow engineering problems* as fluids deform due to the no-slip condition by applying the principles of **mathematics, science and engineering fundamentals**.	**3**
	PO 2	Understand the given **problem statement** and **formulate** *(complex) fluid engineering problems* related to viscous forces from the provided **information and data** in reaching substantiated conclusions by the **interpretation of results**	**4**
CO 5	**PO 1**	Apply the basic conservation laws of **science** for various phenomena of fluid systems and use **mathematical principles** for *deriving (complex) fluid flow engineering equations* by understanding the appropriate parametric assumptions and limitations based on **engineering fundamentals** of fluid mechanics.	**3**
	PO 2	Understand the given **problem statement** and **formulate** *(complex) fluid flow engineering phenomena and system* for deriving various governing equations of fluid mechanics from the provided **information** and substantiate with the **interpretation of** variations in the **results.**	**4**
	PSO 3	Make use of **computational and experimental tools** for creating innovative career paths, to be an entrepreneur and desire for higher studies in the field of fluid mechanics.	**2**
CO 6	**PO 1**	Determine several **scientific/physical/flow properties and parameters** of *(complex) fluid flow engineering problems* by applying **fluid flow governing equations** related to different **core and interdisciplinary engineering** practical scenarios	**3**
	PO 2	Understand the given **problem statement** and **formulate** *(complex) fluid flow engineering problems* related to various governing laws of fluid mechanics from the provided	**4**

		information and data in reaching substantiated conclusions by the **interpretation of results.**	
	PSO 3	Make use of **computational and experimental tools** for creating innovative career paths, to be an entrepreneur and desire for higher studies in the field of fluid mechanics.	**2**
CO 7	**PO 1**	Relate (knowledge, understand and apply) the regimes and separation of boundary layer during external fluid flow *(complex) engineering problems* by applying the principles of **mathematics, science and fluid engineering fundamentals**.	**3**
	PO 2	Understand the given **problem statement** and **formulate** boundary layer phenomena of external fluid flow *(complex) engineering problems* from the provided **information and data** in reaching substantiated conclusions by the **interpretation of results.**	**4**
	PO 4	**Recognize (knowledge) the characteristics** of boundary layer regimes and **processes,** understand the corresponding **context of the engineering knowledge**, **technical uncertainty** of the boundary layer causing the separation, **analyse key regimes** of the boundary layer by applying the displacement measures incorporating the **systems approach**.	**5**
CO 8	**PO 1**	Model the total and hydraulic gradient lines for distinct cases of losses in *solving (complex) closed conduit fluid flow engineering problems* by **applying** the principles of **mathematics, science and** governing equations **engineering fundamentals** of fluid flow systems.	**3**
	PO 2	Understand the given **problem statement** and **formulate** closed conduit fluid flow *(complex) engineering problems* from the provided **information and data** in reaching substantiated conclusions by the **interpretation of results.**	**4**
	PO 4	**Recognize (knowledge) the characteristics** of various losses in several types of pipe arrangements and **processes,** understand the corresponding **context of the engineering knowledge**, **technical uncertainty** of the losses causing the variations in the corresponding energy at various locations of the pipes, **analyse key heads** of the total and hydraulic gradient lines by applying the laws of friction by incorporating the **systems approach**.	**5**
	PSO 3	Make use of **computational and experimental tools** for creating innovative career paths, to be an entrepreneur and desire for higher studies in the field of fluid mechanics.	**2**
CO 9	**PO 1**	Explain (understanding) the theories, phenomena and working principles (knowledge) of hydraulic machines and their applicability (apply) in *solving (complex) engineering problems* related to hydraulic machines by applying the principles of fluid flow **engineering fundamentals** and their **integration and support with other engineering disciplines**, **mathematics, science**.	**3**
	PO 2	Understand the given **problem statement** and **formulate** the design *(complex) engineering problems* of hydraulic machines	**4**

		from the provided **information and data** in reaching substantiated conclusions by the **interpretation of results.**	
	PSO 3	Make use of **computational and experimental tools** for creating innovative career paths, to be an entrepreneur and desire for higher studies in the field of fluid mechanics.	**2**
CO 10	**PO 1**	Illustrate all the variations of the velocity triangles by understanding the knowledge in *solving (complex) engineering problems* related to analyses of hydraulic machines by applying the principles of fluid flow **engineering fundamentals** and their **integration and support with other engineering disciplines**, trigonometry (**mathematics), and scientific methodologies**.	**3**
	PO 2	Understand the given **problem statement** and **formulate** the design *(complex) engineering problems* of hydraulic machines, **translate the information** into the illustration of velocity triangles from the provided **information and data, develop solutions** based on the outlet tip of the vanes**, validate** the illustrated velocity triangles in reaching substantiated conclusions by the **interpretation of results.**	**7**
	PO 4	**Recognize (knowledge) the characteristics** of various kinds of velocity triangles and **processes,** understand the corresponding **context of the engineering knowledge related** to the outlet velocity triangle, **technical uncertainty** of the vane angles and properties of fluid jet causing the variations in the corresponding velocity triangles, **analyse key parameters,** angles, flow and whirl components of the velocity triangles by applying the impact of jet principles by incorporating the **systems approach**.	**5**
	PSO 3	Make use of **computational and experimental tools** for creating innovative career paths, to be an entrepreneur and desire for higher studies in the field of fluid mechanics.	**2**
CO 11	**PO 1**	Evaluate the specific and unit indicators for *solving (complex) engineering problems* related to performance of hydraulic machines by applying the principles of fluid flow **engineering fundamentals** and their **integration and support with other engineering disciplines**, **mathematics, and scientific methodologies**.	**3**
	PO 2	Understand the given **problem statement** and **formulate** the performance *(complex) engineering problems* of hydraulic machines, **translate the information** into the model and prototype systems from the provided **information and data, develop solutions** based on the performance indicators**, validate** the hydraulic machines in reaching substantiated conclusions by the **interpretation of results.**	**7**
	PO 3	**Understand the customer needs** of installing hydraulic machines, **identify the cost limitations** for the selection of parameters, **use creativity** in applying the methods of model analyses **for innovative solutions**, **evaluate the outcomes** of the model analysis for the performance of hydraulic machines, **and understand the economic context** of the model analysis.	**5**

	PO 4	**Recognize (knowledge) the characteristics** of various kinds of performance indicators and **processes** of hydraulic machines**,** understand the corresponding **context of the engineering knowledge related** to the performance indicators and measures, **technical uncertainty** of the unit and specific quantities causing the variations in the performance of hydraulic machines, **analyse key indicators** of performance by applying the model analysis by incorporating the **systems approach**.	**5**
	PSO 3	Make use of **computational and experimental tools** for creating innovative career paths, to be an entrepreneur and desire for higher studies in the field of fluid mechanics.	**2**
CO 12	**PO 1**	Judge the working condition of fluid machines and equipments by *solving (complex) engineering problems* related to hydraulic machines by applying the principles of fluid flow **engineering fundamentals** and their **integration and support with other engineering disciplines**, **mathematics, and scientific methodologies**.	**3**
	PO 2	Understand the given **problem statement** and **formulate** the *(complex) engineering problems* of hydraulic machines, **translate the information** into the model and prototype systems from the provided **information and data, develop solutions** based on the functionality of the machines and equipments**, validate** the hydraulic machines in reaching substantiated conclusions by the **interpretation of results.**	**7**
	PO 3	**Understand the user needs** of hydraulic machines for working, **identify the cost limitations** for the selection of parameters, **use creativity** in applying the methods of model analyses **for innovative solutions**, **evaluate the outcomes** of the model analysis for the performance of hydraulic machines, **and understand the economic context** of the model analysis.	**5**
	PO 4	**Recognize (knowledge) the characteristics** of various kinds of performance indicators and **processes** of hydraulic machines**,** understand the corresponding **context of the engineering knowledge related** to the performance indicators and measures, **technical uncertainty** of the unit and specific quantities causing the variations in the performance of hydraulic machines, **analyse key indicators** of performance by applying the model analysis by incorporating the **systems approach**.	**5**
	PSO 3	Make use of **computational and experimental tools** for creating innovative career paths, to be an entrepreneur and desire for higher studies in the field of fluid mechanics.	**2**
CO 13	**PO 1**	**Choose** the designing procedure of hydraulic machines for *solving (complex) engineering problems* related to real world applications along with enhanced performance and minimized losses by applying the principles of fluid flow **engineering fundamentals** and their **integration and support with other engineering disciplines**, **mathematics, and scientific methodologies**.	**3**

	PO 2	Understand the given **problem statement** and **formulate** the *(complex) engineering problems* of hydraulic machines, **translate the information** into the model and prototype systems from the provided **information and data, develop solutions** based on the functionality of the machines and equipments**,** **validate** the hydraulic machines in reaching substantiated conclusions by the **interpretation of results.**	**7**
	PO 3	**Understand the user needs** of hydraulic machines for working, **identify the cost limitations** for the selection of parameters, **use creativity** in applying the methods of model analyses **for innovative solutions**, **evaluate the outcomes** of the model analysis for the performance of hydraulic machines, **and understand the economic context** of the model analysis.	**5**
	PO 4	**Recognize (knowledge) the characteristics** of various kinds of performance indicators and **processes** of hydraulic machines**,** understand the corresponding **context of the engineering knowledge related** to the performance indicators and measures, **technical uncertainty** of the unit and specific quantities causing the variations in the performance of hydraulic machines, **analyse key indicators** of performance by applying the model analysis by incorporating the **systems approach**.	**5**
	PSO 3	Make use of **computational and experimental tools** for creating innovative career paths, to be an entrepreneur and desire for higher studies in the field of fluid mechanics.	**2**

NUMBER OF KEY COMPETENCIES FOR CO – PO MAPPING:

Course Outcomes (COs)	Program Outcomes (POs) / Number of Vital Features												Program Specific Outcomes (PSOs) / Number of Vital Features		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
	3	10	10	11	1	5	3	3	12	5	12	12	1	2	2
CO 1	2														
CO 2	2														
CO 3	3														
CO 4	3	4													
CO 5	3	4													2
CO 6	3	4													2
CO 7	3	4		5											
CO 8	3	4		5											2
CO 9	3	4													2
CO 10	3	7		5											2
CO 11	3	7	5	5											2
CO 12	3	7	5	5											2
CO 13	3	7	5	5											2

PERCENTAGE OF KEY COMPETENCIES FOR CO – PO MAPPING:

Course Outcomes (COs)	Program Outcomes (POs) / Number of Vital Features												Program Specific Outcomes (PSOs) / Number of Vital Features		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
	3	10	10	11	1	5	3	3	12	5	12	12	1	3	2
CO 1	66.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO 2	66.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO 3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO 4	100.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO 5	100.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
CO 6	100.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
CO 7	100.0	40.0	0.0	45.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO 8	100.0	40.0	0.0	45.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
CO 9	100.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
CO 10	100.0	70.0	0.0	45.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
CO 11	100.0	70.0	50.0	45.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
CO 12	100.0	70.0	50.0	45.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
CO 13	100.0	70.0	50.0	45.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

COURSE ARTICULATION MATRIX (CO - PO / PSO MAPPING):

COs and POs and COs and PSOs on the scale of 0 to 3, **0** being **no correlation**, **1** being the **low correlation**, **2** being **medium correlation** and **3** being **high correlation**.

0 – **0** ≤ C ≤ 5% – No correlation; **2** – 40 % < C < 60% – Moderate.

1 – 5 < C ≤ 40% – Low / Slight; **3** – 60% ≤ C < 100% – Substantial / High

Course Outcomes (COs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO 1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO 2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO 3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO 4	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-
CO 5	3	1	-	-	-	-	-	-	-	-	-	-	-	-	3
CO 6	3	1	-	-	-	-	-	-	-	-	-	-	-	-	3
CO 7	3	1	-	2	-	-	-	-	-	-	-	-	-	-	-
CO 8	3	1	-	2	-	-	-	-	-	-	-	-	-	-	3
CO 9	3	1	-	-	-	-	-	-	-	-	-	-	-	-	3
CO 10	3	3	-	2	-	-	-	-	-	-	-	-	-	-	3
CO 11	3	3	2	2	-	-	-	-	-	-	-	-	-	-	3
CO 12	3	3	2	2	-	-	-	-	-	-	-	-	-	-	3
CO 13	3	3	2	2	-	-	-	-	-	-	-	-	-	-	3
TOTAL	39	18	6	12											24
AVERAGE	**3.0**	**1.8**	**2.0**	**2.0**											**3.0**

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