IARE

INSTITUTE OF
AERONAUTICAL ENGINEERING

Outcome Based Education (OBE) Manual

IARE : BT23

Department of Information Technology

Contents

OVERVIEW

Outcome Based Education (OBE) is an educational model that forms the base of a quality education system. There is no single specified style of teaching or assessment in OBE. All educational activities carried out in OBE should help the students to achieve the set goals. The faculty may adapt the role of instructor, trainer, facilitator, and/or mentor, based on the outcomes targeted.

OBE enhances the traditional methods and focuses on what the Institute provides to students. It shows the success by making or demonstrating outcomes using statements ”able to do” in favour of students. OBE provides clear standards for observable and measurable outcomes.

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

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.

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. 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

Clarity: The focus on outcome creates a clear expectation of what needs to be accomplished by the end of the course.
Flexibility: With a clear sense of what needs to be accomplished, instructors will be able to structure their lessons around the students' needs.
Comparison: OBE can be compared across the individual, class, batch, program and institute levels.
Involvement: Students are expected to do their own learning. Increased student's involvement allows them to feel responsible for their own learning, and they should learn more through this individual learning.

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

India, OBE and Accreditation:

From 13 June 2014, India has become the permanent signatory member of the Washington Accord. Implementation of OBE in higher technical education also started in India. The National Assessment and Accreditation Council (NAAC) and National Board of Accreditation (NBA) are the autonomous bodies for promoting global quality standards for technical education in India. NBA has started accrediting only the programs running with OBE from 2013.

The National Board of Accreditation mandates establishing a culture of outcome-based education in institutions that offer Engineering, Pharmacy, Management program. Reports of outcome analysis help to find gaps and carryout continuous improvements in the education system of an Institute, which is very essential.

1 Vision, Mission, Quality Policy, Philosophy & Core Values

Vision

The Department envisions to become a Center of Excellence in Information Technology with a strong teaching and research environment that produces competent graduates and to inculcate traits to make them not only good professionals but also kind, committed and socially oriented human beings.

Mission

To promote a teaching and learning process that includes latest advancements in information technology, that provides strong practical base for the graduates to make them excellent human capital for sustainable competitive edge and social relevance by inculcating the philosophy of continuous learning and innovation in the core areas.

Quality Policy

Our policy is to nurture and build diligent and dedicated community of engineers providing a professional and unprejudiced environment, thus justifying the purpose of teaching and satisfying the stake holders.

A team of well qualified and experienced professionals ensure quality education with its practical application in all areas of the Institute.

Philosophy

The essence of learning lies in pursuing the truth that liberates one from the darkness of ignorance and Institute of Aeronautical Engineering firmly believes that education is for liberation.

Contained therein is the notion that engineering education includes all fields of science that plays a pivotal role in the development of world-wide community contributing to the progress of civilization. This institute, adhering to the above understanding, is committed to the development of science and technology in congruence with the natural environs. It lays great emphasis on intensive research and education that blends professional skills and high moral standards with a sense of individuality and humanity. We thus promote ties with local communities and encourage transnational interactions in order to be socially accountable. This accelerates the process of transfiguring the students into complete human beings making the learning process relevant to life, instilling in them a sense of courtesy and responsibility.

Core Values

Excellence: All activities are conducted according to the highest international standards.

Integrity: Adheres to the principles of honesty, trustworthiness, reliability, transparency and accountability.

Inclusiveness: To show respect for ethics, cultural and religious diversity and freedom of thought.

Social Responsibility: Promotes community engagement, environmental sustainability, and global citizenship. It also promotes awareness of, and support for, the needs and challenges of the local and global communities.

Innovation: Supports creative activities that approach challenges and issues from multiple perspectives in order to find solutions and advance knowledge.

2 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 accomplishmentafter 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 asit will be read by prospective students who wants to join the programme. Three to five PEOs are recommended.

Program Educational Objective – I: Success in Information Technology:
To prepare the graduates for a successful career to meet the diversified needs of industry, academia and research.

Program Educational Objective – II: Industrial awareness and research:
Apply knowledge of societal impacts of information technologies in the course of their career related activities ethically and appropriately.

Program Educational Objective – III: Successful employment and professional ethics:

To equip graduates with a solid foundation in discrete mathematical and engineering fundamentals required to develop problem solving ability in complex engineering design.

Program Educational Objective – IV: Being a leader in professional and societal environment:
To inculcate in graduates the qualities of leadership in technology innovation and entrepreneurship with effective communication skills, teamwork, ethics and to create ability for life-long learning needed in a successful professional career.

2.1 Mapping of program educational objectives to program outcomes and program specific outcomes:

The following Figure 1 shows the correlation between the PEOs and the POs

PEO-I	PEO-II	PEO-III	PEO-IV
PO: 1, 2, 4, 5, 11	**PO:** 1, 2, 3, 4, 5, 7, 10	**PO:** 2, 3, 4,5, 6, 11	**PO:** 3,5,6, 8, 9, 10, 11,12

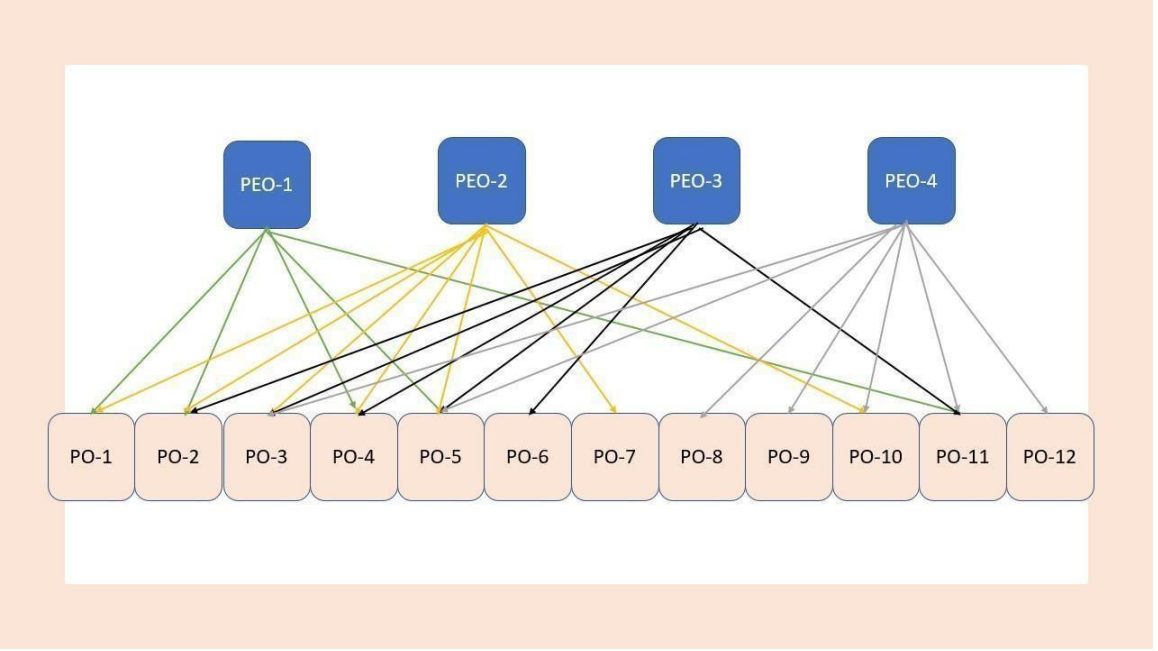


FIGURE 1: Correlation between the PEOs and the POs

The following Figure 2 shows the correlation between the PEOs and the PSOs

PEO-I	PEO-II	PEO-III	PEO-IV
PSO: 1	**PSO:** 1	**PSO:** 2	**PSO:** 3

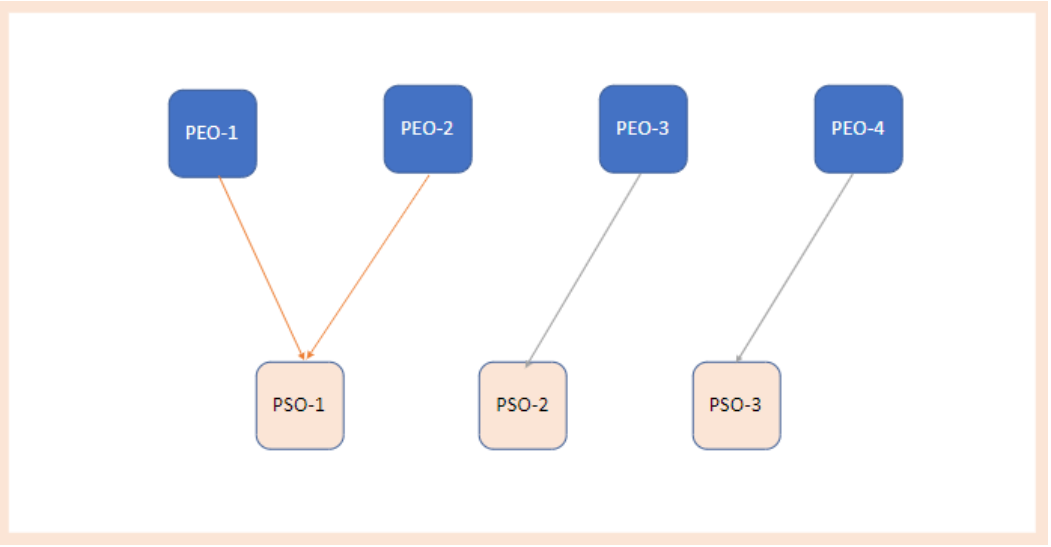


FIGURE 2: Correlation between the PEOs and the PSOs

3 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.

B. Tech (IT) - PROGRAM OUTCOMES (PO's)	
A graduate of the Information Technology Program will demonstrate:	
PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences
PO3	**Design/development of solutions:** 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.
PO4	**Conduct investigations of complex problems:** 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.

PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society:** 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.
PO7	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication:** 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.
PO11	**Project management and finance:** 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.
PO12	**Life-long learning:** 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.

4 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 Information Technology is given below.

B. Tech (IT) - PROGRAM SPECIFIC OUTCOMES (PSO's)	
A graduate of the Information Technology Program will demonstrate:	
PSO1	Design next-generation computer systems, networking devices, search engines, soft computing and intelligent systems, web browsers, and knowledge discovery tools
PSO2	Focus on mobile and web applications development and learn the emerging technologies and frameworks in demand with employers and contemporary challenges.
PSO3	Practical experience in shipping real world software, using industry standard tools and collaboration techniques will equip to secure and succeed in first job upon graduation in IT industry

5 Relation between the Program Educational Objectives and the POs

Broad relationship between the program objectives and the program outcomes is given in the following Table below:

PEO's→ ↓ PO's		(1) Excellence in Career	(2) Profession Effec-tiveness	(3) l Problem Solving	(4) Exercising Leadership
PO1	Apply the knowledge of mathematics, science, engi-neering fundamentals, and an engineering specializa-tion to the solution of com-plex engineering problems.			3	

PO2	Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.			3	
PO3	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.		3		2
PO4	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.	3			3
PO5	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.		2	2	

PO6	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.		3		2
PO7	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.		3		3
PO8	Apply ethical principles and commit to professional ethics and responsibil- ities and norms of the engineering practice.		3		
PO9	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings	3		3	
PO10	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.		3		

PO11	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.	2		2	
PO12	Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader ina team, to manage projects and in multidisciplinary environments.				2

Relationship between Program Outcomes and Program Educational Objectives

Key: 3 = High; 2 = Medium; 1= Low

6 Relation between the Program Specific Outcomes and the Program Educational Objectives:

PEO's→ ↓ PSO's		(1) Excellence in Career	(2) Profession Effec-tiveness	(3) l Problem Solving	(4) Exercising Leadership
PSO1	Design next-generation computer systems, networking devices, search engines, soft computing and intelligent systems, web browsers, and knowledge discovery tools.		3		2
PSO2	Focus on mobile and web applications development and learn the emerging technologies and frameworks in demand with employers and contemporary challenges	3		3	2
PSO3	Practical experience in shipping real world software, using industry standard tools and collaboration techniques will equip to secure and succeed in first job upon graduation in IT industry.	2	3	2	

Relationship between Program Specific Outcomes and Program Educational Objectives

Key: 3 = High; 2 = Medium; 1= Low

Note:

- The assessment process of POs and PSOs can be direct or indirect.

- The direct assessment will be done through interim assessment by conducting continuous internal exam and semester end exams.
- The indirect assessment on the other hand could be done through student's programme exit questionnaire, alumni survey and employment survey.

7 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 defendor 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 yourworld? 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.

7.1 Incorporating Critical Thinking Skills into Course Outcome Statements

Many faculty members choose to incorporate words that reflect critical or higher-order thinking into their learning outcome statements. Bloom (1956) developed a taxonomy outlining the different types of thinking skills people use in the learning process. Bloom argued that people use different levels of thinking skills to process different types of information and situations. Some of these are basic cognitive skills (such as memorization) while others are complex skills (such as creating new ways to apply information). These skills are often referred to as critical thinking skills or higher-order thinking skills.

Bloom proposed the following taxonomy of thinking skills. All levels of Bloom's taxonomy of thinking skills can be incorporated into expected learning outcome statements. Recently, Anderson and Krathwohl (2001) adapted Bloom's model to include language that is oriented towards the language used in expected learning outcome statements. A summary of Anderson and Krathwohl's revised version of Bloom's taxonomy of critical thinking is provided in Figure 3.

FIGURE 3: Revised version of Bloom's taxonomy

7.2 Definitions of the different levels of thinking skills in Bloom's taxonomy:

1. **Remember** –recalling relevant terminology, specific facts, or different procedures related to information and/or course topics. At this level, a student can remember something, but may not really understand it.

2. **Understand** –the ability to grasp the meaning of information (facts, definitions, concepts, etc.) that has been presented.

3. **Apply** –being able to use previously learned information in different situations or in problem solving.

4. **Analyze** –the ability to break information down into its component parts. Analysis also refers to the process of examining information in order to make conclusions regarding cause and effect, interpreting motives, making inferences, or finding evidence to support statements/arguments.

5. **Evaluate** –being able to judge the value of information and/or sources of information based on personal values or opinions.

6. **Create** –the ability to creatively or uniquely apply prior knowledge and/or skills to produce new and original thoughts, ideas, processes, etc. At this level, students are involved in creating their own thoughts and ideas.

7.3 List of Action Words Related to Critical Thinking Skills

Here is a list of action words that can be used when creating the expected student learning outcomes related to critical thinking skills in a course. These terms are organized according to the different levels of higher-order thinking skills contained in Anderson and Krathwohl's (2001) revised version of Bloom's taxonomy.

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

The cognitive process dimensions- categories:

Lower Order of Thinking (LOT)			**Higher Order of Thinking (HOT)**		
Remember	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Interpreting Illustrating Classifying Summarizing Inferring (concluding) comparing explaining	Recognizing (identifying) Recalling (retrieving)	Executing Implementing	Differentiating Organizing Attributing	Checking (coordinating, detecting, testing, monitoring) Critiquing (judging)	Planning Generating Producing (constructing)

The Knowledge Dimension			
Concrete Knowledge→Abstract knowledge			
Factual	**Conceptual**	**Procedural**	**Metacognitive**
• Knowledge of terminologies • Knowledge of specific details and elements	• Knowledge of classifications and categories • Knowledge of principles and generalizations • Knowledge of theories, models and structures	• Knowledge of subject specific skills and algorithms • Knowledge of subject specific techniques and methods • Knowledge of criteria for determining when to use appropriate procedures	• Strategic Knowledge • Knowledge about cognitive task, including appropriate contextual and conditional Knowledge • Self- Knowledge

Action Verbs for Course Outcomes

Lower Order of Thinking (LOT)				Higher Order of Thinking (HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**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 • Extend	• Classify • Compare • Contrast • Demonstrate • Explain • Illustrate • Infer • Interpret	• Apply • Build • Choose • Construct • Develop • Interview • Make use of • Model	• Analyze • Assume • Categorize • Classify • Compare • Discover • Dissect • Distinguish	• Agree • Appraise • Assess • Award • Choose • Criticize • Decide • Deduct • Importance	• Adapt • Build • Solve • Choose • Combine • Invent • Compile • Compose • Construct

Action Verbs for Course Outcomes

Lower Order of Thinking (LOT)				Higher Order of Thinking (HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Verbs	• Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	• Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with	• Organize • Plan • Select • Solve • Utilize • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize • Identify	• Divide • Examine • Function • Inference • Inspect • List Motive • Simplify • Survey • Take part in • Test for Theme • Conclusion • Contrast	• Defend • Determine • Disprove • Estimate • Evaluate • Influence • Interpret • Judge • Justify Mark • Measure • Opinion • Perceive • Prioritize • Prove • Criteria • Criticize • Compare • Conclude	• Create • Design • Develop • Estimate • Formulate • Happen • Imagine • Improve • Make up • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution

8 Guidelines for writing Course Outcome Statements:

Well-written courseoutcomes involve the following parts:

1. Action verb
2. Subject content
3. Level of achievement as per BTL
4. Modes of performing task (if applicable)

8.1 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.

8.2 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 askyourself:

- 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:

- What faculty members want students to know at the end of the course AND
- What faculty members want students to be able to do at the end of the course?

Course outcomes have three major characteristics

- They specify an action by the students/learners that is observable
- They specify an action by the students/learners that is measurable
- 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.

8.3 Relationship of Course Outcome to Program Outcome

The Course Outcomes need to link to the Program Outcomes.

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)."

8.4 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

8.5 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

- 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.
- Look over your list and check the one most important student outcome. If you could only achieve one outcome, which one would it be?
- 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?
- Check each of your other "most important" outcomes against the list of outcomes. How many are on the list of key competencies?
- 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?

8.6 CO-PO Course Articulation Matrix (CAM) 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 CO's correlate with the POs.

TABLE 9: Process for mapping the values for CO-PO Matrix

<table>
<tr><th>Typ</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>PO1</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 project work, experiential learning</td></tr>
<tr><td rowspan="3">PO2</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">PO3</td><td>Design</td><td>L6</td></tr>
<tr><td>Develop</td><td>L3, L6</td></tr>
<tr><td rowspan="3">PO4</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">PO5</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>PO6</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>PO7</td></tr>
<tr><td>PO8</td></tr>
<tr><td>PO9</td></tr>
<tr><td>PO10</td></tr>
<tr><td>PO11</td></tr>
<tr><td>PO12</td></tr>
</table>

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).

8.7 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.

8.8 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

$0 – 0 \leqq C \leqq 5\%$ - No correlation.

$1 - 5 < C \leqq 40\%$ - Low / Slight.

$2 - 40\% < C < 60\%$ - Moderate

$3 - 60\% \leqq C < 100\%$ - Substantial / High

9 Key Competencies for Assessing Program Outcomes:

PO	NBA statement / Vital features	No. of vital features
PO1	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
PO2	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	NBA statement / Vital features	No. of vital features
PO3	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 con- siderations 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 includingproduction, operation, maintenance and disposal 6. Manage the design process and evaluate outcomes 7. Knowledge and understanding of commercial and economic con-text 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 pro-mote sustainable development 10. Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk issues	10

PO	NBA statement / Vital features	No. of vital features
PO4	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 product 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 stan-dards 6. Awareness of quality issues 7. Ability to work with technical uncertainty. 8. Understanding of engineering principles and the ability to applythem to analyse key engineering processes 9. Ability to identify, classify and describe the performance of sys- tems and components through the use of analytical methods and modeling techniques 10. Ability to apply quantitative methods and computer software rel-evant to their engineering discipline, in order to solve engineeringproblems 11. Understanding of and ability to apply a systems approach to en-gineering problems.	11
PO5	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	NBA statement / Vital features	No. of vital features
PO6	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 eth-ical conduct in engineering	5
PO7	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
PO8	Apply ethical principles and commit to professional ethics and responsibilities and norms of the Engineering practice (Ethics). 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	3

PO	NBA statement / Vital features	No. of vital features
PO9	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. Ability to work with all levels of people in an organization 10. Ability to get along with others 11. Demonstrated ability to work well with a team 12. Subjective evidence from senior students shows that the friend- ships and teamwork extend into the Junior years, and for some of those students, the friendships continue into the workplace after graduation.	12
PO10	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

PO	NBA statement / Vital features	No. of vital features
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 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	8

10 Key Competencies for Assessing Program Specific Outcomes:

PSO	NBA statement / Vital features	No. of vital features
PSO1	Design next-generation computer systems, networking devices, search engines, soft computing and intelligent systems, web browsers, and knowledge discovery tools. 1. Ability to develop next generation computer systems. 2. Acquire knowledge in designing of search engines. 3. Understanding how all the elements of the network link together (routers,switches, servers, desktops, laptops, and printers). 4. Acquire knowledge of soft computing techniques for solving complex computational problems. 5. Acquire knowledge of data mining techniques. 6. Design and develop user interfaces for the android platform	6
PSO2	Focus on mobile and web applications development and learn the emerging technologies and frameworks in demand with employers and contemporary challenges. 1. Ability to develop website models. 2. Explore historical, current, and emerging techniques and technologies for lifelong learning and professional development	2

PSO	NBA statement / Vital features	No. of vital features
PSO3	Practical experience in shipping real world software, using industry standard tools and collaboration techniques will equip to secure and succeed in first job upon graduation in IT industry. 1. Acquire practical experience in languages and software tools for developing real world software. 2. Ability to provide security for the developed software.	2

11 Program Outcomes and Program Specific outcomes Attained through course modules:

Courses offered in Information Technology Curriculum (IARE-BT23) and POs/PSOsattained through course modules for I, II, III, IV, V, VI, VII and VIII semesters.

Code	Subject	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
ACAD14	Human Computer Interaction (UI&UX)	✓	✓	✓		✓						✓		✓		✓
ACCD04	Information Security Management	✓	✓	✓	✓							✓		✓		✓
ACSD01	Object Oriented Programming	✓	✓	✓		✓					✓		✓	✓		✓
ACSD02	Object Oriented Programming with Java Laboratory	✓	✓	✓		✓	✓		✓					✓	✓	✓
ACSD03	Essentials of Innovation	✓	✓	✓	✓	✓				✓	✓		✓	✓	✓	✓

ACSD04	Mobile Applications Development	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓	✓
ACSD05	Essentials of Problem Solving	✓	✓	✓		✓					✓		✓	✓	✓	✓
ACSD06	Programming for Problem Solving Laboratory	✓	✓	✓		✓	✓		✓					✓	✓	
ACSD08	Data Structures	✓	✓	✓	✓	✓					✓		✓	✓	✓	✓
ACSD09	Operating Systems	✓	✓	✓	✓						✓		✓	✓	✓	✓
ACSD10	Operating Systems Laboratory	✓	✓	✓											✓	✓
ACSD11	Data Structures Laboratory	✓	✓	✓	✓	✓					✓		✓	✓	✓	✓
ACSD12	Prototype and Design Building	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓
ACSD13	Design and Analysis of Algorithms	✓	✓	✓							✓	✓		✓		✓
ACSD14	Web Systems Engineering	✓	✓	✓	✓	✓						✓		✓	✓	✓
ACSD15	Object Oriented Software Engineering	✓	✓	✓		✓						✓		✓		✓
ACSD16	Design and Analysis of Algorithms Laboratory		✓	✓		✓				✓		✓				✓
ACSD17	Web Systems Engineering Laboratory	✓	✓	✓	✓	✓						✓		✓	✓	✓
ACSD19	Data Mining and Machine Learning	✓	✓	✓	✓	✓	✓					✓		✓	✓	✓
ACSD20	Cloud Application Development	✓	✓	✓	✓	✓	✓					✓		✓	✓	✓
ACSD21	Artificial Intelligence	✓	✓	✓	✓							✓		✓	✓	✓
ACSD24	Advanced Computer Architecture	✓	✓		✓	✓						✓		✓		✓
AECD04	Computer System Architecture	✓	✓	✓	✓						✓		✓	✓	✓	✓
AEED01	Elements of Electrical and Electronics Engineering	✓	✓											✓		

AEED03	Electrical and Electronics Engineering Laboratory	✓	✓			✓					✓					
AHSD01	Professional Communication										✓					
AHSD02	Matrices and Calculus	✓	✓													
AHSD03	Engineering Chemistry	✓	✓					✓								
AHSD04	Professional Communication Laboratory									✓	✓					
AHSD05	Engineering Chemistry Laboratory	✓	✓					✓								
AHSD07	Applied Physics	✓	✓		✓									✓		
AHSD08	Differential Equations and Vector Calculus	✓	✓													
AHSD09	Applied Physics Laboratory	✓	✓		✓											
AHSD11	Probability and Statistics	✓	✓													
AITD01	Mathematics for Computing	✓	✓	✓										✓		
AITD02	Programming with Objects Laboratory	✓	✓	✓	✓	✓		✓	✓				✓	✓	✓	
AITD03	Database Management Systems	✓	✓	✓	✓	✓						✓		✓	✓	✓
AITD04	Computer Networks	✓	✓	✓	✓	✓	✓					✓		✓	✓	✓
AITD05	Database Management Systems Laboratory	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓
AMED02	Manufacturing Practice	✓		✓		✓		✓				✓				✓
AMED03	Engineering Graphics							✓	✓	✓	✓	✓	✓			

12 Methods for measuring Learning Outcomes and Value Addition:

There are many different ways to assess student learning. In this section, we present the different types of assessment approaches available and the different frame works to interpret the results.

i) Continuous Internal Assessment (CIA)
ii) Alternate Assessment Tools (AAT)
iii) Semester end examination (SEE)
iv) Laboratory and project work

v) Course exit survey
vi) Program exit survey
vii) Alumni survey
viii) Employer survey
ix) Course expert committee
x) Program Assessment and Quality Improvement Committee (PAQIC)
xi) Department Advisory Board (DAB)
xii) Faculty meetings
xiii) Professional societies

The above assessment indicators are detailed below.

12.1 Continuous Internal Assessment (CIA)

Two Continuous Internal Examinations (CIEs) are conducted for all courses by the department. All students must participate in this evaluation process. These evaluations are critically reviewed by HOD and senior faculty and the essence is communicated to the faculty concerned to analyze, improve and practice so as to improve the performance of the student.

12.2 Alternate Assessment Tools (AAT)

This AAT enables faculty to design own assessment patterns during the CIA. The AAT converts the classroom into an effective learning center. The AAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video, MOOCs etc.

12.3 Semester End Examination (SEE)

The semester end examination is conducted for all the courses in the department. Before the Semester end examinations course reviews are conducted, feedback taken from students and remedial measures will be taken up such that the student gets benefited before going for end exams. The positive and negative comments made by the students about the course are recorded and submitted to the departmental academic council (DAC) and to the principal for taking necessary actions to better the course for subsequent semesters.

12.4 Laboratory and Project Works

The laboratory work is continuously monitored and assessed to suit the present demands of the industry. Students are advised and guided to do project works giving solutions to research / industrial problems to the extent possible by the capabilities and limitations of the student. The results of the assessment of the individual projects and laboratory work can easily be conflated in order to provide the students with periodic reviews of their overall progress and to produce terminal marks and grading.

12.5 Course Exit Surveys

Students are encouraged to fill-out a brief survey on the fulfillment of course objectives. The data is reviewed by the concerned course faculty and the results are kept open for the entire faculty. Based on this, alterations or changes to the course objectives are undertaken by thorough discussions in faculty and DAB meetings.

12.6 Programme Exit Survey

The programme exist questionnaire form is to be filled by all the students leaving the institution. The questionnaire is designed in such a way to gather information from the students regarding the program educational objectives, solicit about program experiences, carrier choices, as well as any suggestions and comments for the improvement of the program. The opinions expressed in exit interview forms are reviewed by the DAB for implementation purposes.

12.7 Alumni Survey

The survey asks former students of the department about the status of their employment and further education, perceptions of institutional emphasis, estimated gains in knowledge and skills, involvement a sunder graduate student, and continuing involvement with Institute of Aeronautical Engineering. This survey is administered every three years. The data obtained will be analyzed and used in continuous improvement.

12.8 Employer Survey

The main purpose of this employer questionnaire is to know employer's views about the skills they require of employees compared to the skills actually possessed by them. The purpose e is also to identify gaps in technical and vocational skills, need for required training practices to fill these gaps and criteria for hiring new employees. These employer surveys are reviewed by the College Academic Council (CAC) to affect the present curriculum to suit the requirement so the employer.

12.9 Course Expert Committee

The course expert team is responsible in exercising the central domain of expertise in developing and renewing the curriculum and assessing its quality and effectiveness to the highest of professional standards. Inform the Academic Committee the 'day-to-day' matters as are relevant to the offered courses. This committee will consider the student and staff feedback on the efficient and effective development of the relevant courses. The committee also review the course full stack content developed by the respective course coordinator.

12.10 Programme Assessment and Quality Improvement Committee (PAQIC)

PAQIC Monitors the achievements of Program Outcomes (POs), Program Specific Outcomes (PSOs) and Program Educational Objectives (PEOs). It will evaluate the program effectiveness and proposes the necessary changes. It also prepares the periodic reports on program activities, progress, status or other special reports for management. It also motives the faculty and students towards attending workshops, developing projects, working models, paper publications and engaging in

research activities.

12.11 Department Advisory Board (DAB)

Departmental Advisory Board plays an important role in the development of the department. Department level Advisory Board will be established for providing guidance and direction for qualitative growth of the department. The Board interacts and maintains liaison with key stakeholders. DAB will Monitor the progress of the program and develop or recommend the new or revised goals and objectives for the program. Also, the DAB will review and analyze the gaps between curriculum and Industry requirement and gives necessary feedback or advices to be taken to improve the curriculum.

12.12 Faculty Meetings

The DAB meets bi-annually for every academic year to review the strategic planning and modification of PEOs. Faculty meetings are conducted at least once in fortnight for ensuring the implementation of DAB's suggestions and guidelines. All these proceedings are recorded and kept for the availability of all faculties.

12.13 Professional Societies

The importance of professional societies like IEEE, ACM, ISTE, CSI etc., are explained to the students and they are encouraged to become members of the above to carry out their continuous search for knowledge. Student and faculty chapters of the above societies are constituted for a better technical and entrepreneurial environment. These professional societies promote excellence in instruction, research, public service and practice.

13 CO - Assessment processes and tools:

Course outcomes are evaluated based on two approaches namely direct and indirect assessment methods. The direct assessment methods are based on the Continuous Internal Assessment (CIA) and Semester End Examination (SEE) whereas the indirect assessment methods are based on the course end survey and program exit survey provided by the students, Alumni and Employer. The weightage in CO attainment of Direct and Indirect assessments are illustrated in Table.

Assessment Method	Assessment Tool	Weightage in CO attainment
Direct Assessment	Continuous Internal Assessment (CIE & AAT)	80%
	Semester End Examination	
Indirect Assessment	Course End Survey	20%

13.1 Direct Assessment:

Direct assessment methods are based on the student's knowledge and performance in the various assessments and examinations. These assessment methods provide evidence that a student has

command over a specific course, content, or skill, or that the students work demonstrates a specific quality such as creativity, analysis, or synthesis.

The various direct assessment tools used to assess the impact of delivery of course content is listed in Table.

- Continuous internal examination, semester end examinations, AAT (includes assignment, 5 minutes videos, seminars etc.) are used for CO calculation.
- The attainment values are calculated for individual courses and are formulated and summed for assessing the POs.
- Performance in AAT is indicative of the student's communication skills.

S No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core / Elective	Continuous Internal Examination	Twice in a semester	25	Answer script
		Alternative Assessment Tools (AAT)	Twice in a semester	5	Video / Quiz / assignment
		Semester End Examination	Once in a semester	70	Answer script
2	Laboratory	Conduction of experiment	Once in a week	4	Work sheets
		Observation	Once in a week	4	Work sheets
		Result	Once in a week	4	Work sheets
		Record	Once in a week	4	Work sheets
		Viva	Once in a week	4	Work sheets
		Internal laboratory assessment	Once in a semester	10	Answer script
		Semester End Examination	Once in a semester	70	Answer script
3	Project Work	Presentation	Twice in a semester	30	Presentation
		Semester End Examination	Once in a semester	70	Thesis report

13.2 Indirect Assessment:

Course End Survey - In this survey, questionnaires are prepared based on the level of understanding of the course and the questions are mapped to Course Outcomes. The tools and processes used in indirect assessment are shown in Table.

TABLE 15: Tools used in Indirect assessment

Tools	Process	Frequency
Course end survey	• Taken for every course at the end of the semester • Gives an overall view that helps to assessthe extent of coverage/ compliance of COs • Helps the faculty to improve upon the various teaching methodologies	Once in a semester

Direct Tools: (Measurable in terms of marks and w.r.t. CO) Assessment done by faculty at department level

Indirect Tools: (Non measurable (surveys) in terms of marks and w.r.t. CO) Assessment done at institute level.

14 PO/PSO - Assessment tools and Processes

The institute has the following methods for assessing attainment of POs/PSOs.

1. Direct method
2. Indirect method

The attainment levels of course outcomes help in computing the PO/PSO based upon the mapping done.

TABLE 16: Attainment of PO/PSOs

	Assessment	Tools	Weight
POs/PSOs Attainment	Direct Assessment	CO attainment of courses	80%
	Indirect Assessment	Student exit survey	20%
		Alumni survey	
		Employer survey	

The CO values of both theory and laboratory courses with appropriate weightage as per CO-PO mapping, as per Program Articulation Matrix are considered for calculation of direct attainment of PO/PSOs.

14.1 PO Direct Attainment is calculated using the following rubric:

PO Direct Attainment = (Strength of CO-PO)*CO attainment / Sum of CO-PO strength.

The below figure represents the evaluation process of POs/PSOs attainment through course outcome attainment.

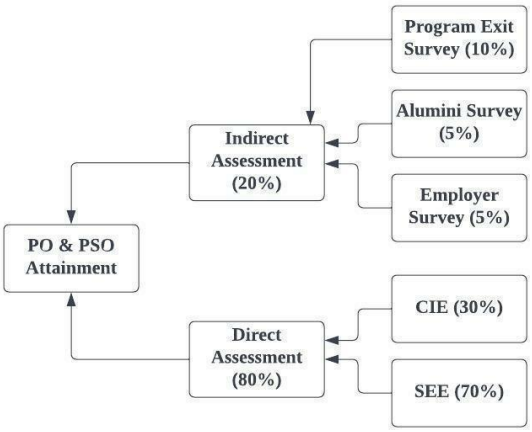


FIGURE 4: Evaluation process of POs/PSOs attainment

15 Course Description:

The "Course Description" provides general information regarding the topics and content addressed in the course. A sample course description is given in Annexure – A for the reference.

The "Course Description" contains the following contents:

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Content delivery / Instructional methodologies
- Evaluation Methodology
- Course Objectives
- Course Outcomes
- Program Outcomes
- Program Specific Outcomes
- How Program Outcomes are assessed
- How Program Specific Outcomes are assessed
- Mapping of each CO with PO(s), PSO(s)
- Justification for CO – PO / PSO mapping- direct
- Total count of key competencies for CO – PO/ PSO mapping
- Percentage of key competencies for CO – PO/ PSO
- Course articulation matrix (PO / PSO mapping)
- Assessment methodology-direct
- Assessment methodology-indirect
- Syllabus
- List of Text Books / References / Websites

15.2 Course Description:

COURSE OUTLINE DESCRIPTION

SECTION 1: General Information about the Course	
Course Title	**Computer System Architecture**
Course Code	AECD04
Course Start	Third Semester
Course Type	Core
Regulation	IARE – BT23
Prerequisite Courses	-
Department	Information Technology
Number of Credits	3 Credit hours
Academic Year	2025 - 26
Method(s) of Instruction	Theory
Course Coordinator's Name	**Dr. A Karthik,** Assistant Professor IARE10693 **a.karthik@iare.ac.in**
Prior Learning Assessment and Recognition (PLAR)	Students interested in PLAR pathways for open learning can register one semester prior to the start of semester. Students will receive the necessary contact information one semester in advance.
Open Learning Faculty Member Information	Open Learning Faculty (OLF) is available to assist students. Students will receive the necessary contact information at the start of the course.
Course Webpage	https://akanksha.iare.ac.in/index?route=course/details&course_id=528
Course Description	This course introduces the principles of basic computer organization, CPU organization, and the basic architecture concepts. The course emphasizes performance and cost analysis, instruction set design, register transfer languages, arithmetic, logic and shift micro-operations, pipelining, memory technology, memory hierarchy, virtual memory management, and I/O organization of computer, parallel processing and inter process communication and synchronization
Course Objectives	**The students will try to learn:** a. The concepts of register transfer logic and arithmetic operations, instruction format, and instruction cycle. b. The basic components of computer systems, functionality, and interactions with the Components c. Memory hierarchy, memory management and I/O management. d. Pipelining and Multiprocessor techniques for the improvement of efficiency
Text and Reference Books	**Text Books** 1. M. Morris Mano, "Computer Systems Architecture", Pearson, 3 rd Edition, 2015 2. Patterson, Hennessy, "Computer Organization and Design: The Hardware/Software Interface", Morgan Kaufmann, 5 th Edition, 2013. **Reference Books** 1. John. P. Hayes, "Computer System Architecture", McGraw-Hill, 3 rd Edition, 1998 2. Carl Hamacher, Zvonko G Vranesic, Safwat G Zaky, "Computer Organization", McGraw-Hill, 5 th Edition, 2002. 3. William Stallings, "Computer Organization and Architecture", Pearson Edition, 8 th Edition, 2010
Learning Resources	**Course full stack** is made available in IARE learning management portal – Akansha, which includes lecture notes, tutorial question bank, definition and terminology, tech-talk topics, assignments, Model question papers (2 sets),

	complex engineering problem solving statements, power point presentations (PPTs) and ELRV lecture recordings at: • https://akanksha.iare.ac.in/index?route=course/details&course_id=528 • https://www.youtube.com/playlist?list=PLzkMouYverALiWDrSZQIpcl0lSzD4zhvz
Supplemental Materials	Readings, Videos, and Links 1. https://www.geeksforgeeks.org/computer-organization-and-architecture-tutorials/ 2. http://www.cs.iit.edu/~virgil/cs470/Book/
Learning and Teaching Strategies	Online material will provide the foundation of the learning resources, requiring the students to login and engage regularly throughout the sixteen weeks of the course.. There will be a mix of suggested readings, discussions and video content containing embedded digital content and undertake the assessment tasks.

SECTION 2: Teaching Learning Scheme

At least 48 lecture hours of scheduled teaching and learning activities (TLA) will be delivered in person, with the remaining hours for scheduled and self-scheduled teaching and learning activities delivered either in person or online.

Notional Study Time: 90 Hours (Lecture hours: 48, Tutorial hours: 8, demonstration hours: 2, Guided independent study hours: 07, Homework assignment hours: 10, Course project / Preparation for complex problem solving hours: 15)

TLA Code	Teaching and Learning Activities	Number	Duration (hours)	Total workload
TLA 1	Lectures	48	01	48
TLA 2	Tutorials	08	01	08
TLA 3	Case Study	-	-	-
TLA 4	Problem Solving	-	-	-
TLA 5	Demonstration	02	01	02
TLA 6	Scheduled revision sessions	-	-	-
TLA 7	Guided independent study: Directed viewing of video materials / PPTs	7	7	7
TLA 8	Independent private study	-	-	-
TLA 9	Laboratory Exercises	-	-	-
TLA 10	Homework assignment	10	10	10
TLA 11	Placement / work based learning or Specific practical training	-	-	-
TLA 12	Presentation / Seminar Preparation	-	-	-
TLA 13	Course Project / Preparation for Complex Problem Solving	15	1	15
TLA 14	Technical visit	-	-	-
TLA 15	Field activities	-	-	-
			Total study hours	**90**
			Expected total study hours	**90**

SECTION 3A: Course Outcomes		
After successfully completing this course, the student will be able to:		
Outcome Number	**Course Outcomes**	**Learning Domain**
CO1	**Demonstrate** a thorough understanding of the basic concepts and principles of computer system architecture.	Understand
CO2	**Analyze** different types of instruction sets and addressing modes.	Analyse
CO3	**Evaluate** memory management techniques such as paging, segmentation and virtual memory.	Evaluate
CO4	**Compare** different I/O techniques including programmed I/O, interrupt driven I/O and direct memory access (DMA) .	Understand
CO5	**Explore** the implications of parallel processing and apply concepts of pipelining and parallelism to enhance system performance.	Analyse
CO6	**Summarize** the concepts of pipelining and inter process communication for advanced processor design.	Understand

SECTION 3B: Cognitive Levels	
Blooms Taxonomy Level	**Cognitive Level in Percentage (%)**
Remember	0
Understand	50
Apply	34
Analyse	16
Evaluate	0
Create	0

SECTION 4: Content and Context of Computer System Architecture	
CO1	**Demonstrate a thorough understanding of the basic concepts and principles of computer system architecture.**
	Learners must understand the basic structural organization of a computer system including the role of the control unit, ALU, memory, and input/output systems. Students should be able to identify and explain the working of different instruction formats, addressing modes, and the stages of instruction execution (fetch, decode, execute). They are expected to analyze data path and control path of simple processor designs and evaluate performance based on memory hierarchy (cache, main memory, and secondary storage). Learners must demonstrate the ability to differentiate between RISC and CISC architectures, pipeline processing, and parallelism in architecture. Students are encouraged to apply these concepts in analyzing and designing basic computer architecture models using tools or simulation environments to understand real-world implications of theoretical concepts.
CO2	**Analyze different types of instruction sets and addressing modes.**
	Learners must understand various instruction set architectures (ISA) including RISC, CISC, and hybrid designs. They should be able to classify instruction types such as data transfer, arithmetic, logic, control flow, and I/O instructions. Students must identify and explain different addressing modes such as immediate, direct, indirect, register, register indirect, indexed, and relative. They should be capable of interpreting how these addressing modes influence instruction length, execution time, and memory access. Through analysis of different ISAs, learners are encouraged to evaluate how instruction formats and addressing mechanisms affect the overall performance and complexity of the CPU. They should also perform comparative assessments of code efficiency using multiple addressing modes and justify the selection of an ISA for specific

	application domains.
CO3	**Evaluate memory management techniques such as paging, segmentation and virtual memory.**
	Learners must understand the fundamental concepts of memory management, including how memory is allocated, protected, and shared among processes. They should be able to differentiate between contiguous and non-contiguous memory allocation strategies. Students must analyze how paging divides memory into fixed-size blocks and how page tables are maintained. They should evaluate segmentation as a method of dividing memory based on logical divisions and compare its efficiency and flexibility with paging. Virtual memory concepts must be clearly understood, including demand paging, page replacement algorithms (FIFO, LRU, Optimal), and their impact on performance and system throughput. Students should be able to compute effective access times and simulate memory access scenarios.
CO4	**Compare different I/O techniques including programmed I/O, interrupt driven I/O and direct memory access (DMA) .**
	Learners must understand the fundamental role of input/output operations in a computer system and the need for efficient communication between the processor and peripheral devices. They must compare programmed I/O, where the CPU actively waits for the I/O operation to complete, with interrupt-driven I/O, which allows the CPU to perform other tasks while waiting for an I/O interrupt. Students should analyze Direct Memory Access (DMA) as a technique that bypasses CPU intervention during data transfer, thus significantly improving system throughput. They must understand the configuration of DMA controllers, bus arbitration, and priority management.
CO5	**Explore the implications of parallel processing and apply concepts of pipelining and parallelism to enhance system performance.**
	Learners must understand the basic principles of parallel processing, including the motivation behind concurrency, speedup, and scalability. They should explore the types of parallelism: data-level, instruction-level, and task-level. Students are expected to understand the structure and functioning of pipelined processors, covering stages like instruction fetch, decode, execute, memory access, and write-back. They should be able to analyze pipeline hazards (structural, data, and control), and explore techniques such as forwarding, hazard detection, and branch prediction to minimize performance losses. Concepts of multi-core systems, SIMD, and MIMD architectures should be explored to understand real-world implementations of parallelism. Learners should evaluate the impact of these designs on throughput and latency through case studies or simulations.
CO6	**Summarize the concepts of pipelining and inter process communication for advanced processor design.**
	Learners must understand the foundational concepts of pipelining, including linear pipelines, pipeline stages, throughput, and latency. They should be able to explain how pipelining improves instruction execution by overlapping operations and minimizing idle CPU cycles. Students must also study inter-process communication (IPC) mechanisms such as shared memory, message passing, semaphores, and sockets. They should summarize how IPC is essential for synchronization and coordination among processes in multi-core and parallel processing environments. Special emphasis should be placed on how modern advanced processors incorporate pipelining and IPC features to enhance performance, resource sharing, and responsiveness.

SECTION 5: Complex Engineering Problem Solving
Programs, complex problem solving and programming projects Complex Engineering Problem Solving in Computer System Architecture is an essential skill for B. Tech Computer Science students, as it challenges them to apply their theoretical knowledge to real-world problems. It

equips students with a deep understanding of the internal structure and operational principles of modern computer systems. It covers essential topics such as processor design, instruction set architecture (ISA), memory hierarchy, pipelining, parallelism, and input/output mechanisms. Through this course, students learn to analyze the trade-offs in architectural decisions and evaluate how hardware components interact to execute instructions efficiently. Emphasis is placed on solving complex engineering problems by applying theoretical concepts to real-world scenarios. Learners are encouraged to use simulation tools and programming environments to design, model, and optimize architectural systems. This course nurtures critical thinking and problem-solving abilities by challenging students to address issues such as latency reduction, performance enhancement, and resource optimization—key to developing efficient, scalable, and high-performance computing systems.

SECTION 6A: Assessment Methods – Direct

Item	Evaluation Components	Week in / out	Marks
AAT: 1 - 1	Tech-Talk	Week – 2 / 5	05
AAT: 1 - 2	Definition and Terminology	Week – 4 / 7	05
AAT: 2 - 1	Complex Engineering Problem Solving	Week – 9 / 12	05
AAT: 2 - 2	Concept Video	Week – 12 / 15	05
CIE – 1	2 hours - Answer 4 out of 5 questions	Week - 9	10
CIE – 2	2 hours - Answer 4 out of 5 questions	Week - 17	10
SEE	3 hours - Answer 1 from each module	Week - 18	60
		Total Marks	**100**

Department's Late Submission Policy:

1. 1 – 24 hours: 25% of the mark will be deducted
2. > 24 hours: Not accepted

SECTION 6B: Assessment Methods –Indirect

Course End Survey (End Semester OBE Feedback)	✓

SECTION 7: Content Delivery / Instructional Methodologies
Please tick (✓) relevant engineering competency profile covered

✓	 Power Point Presentations	✓	 Chalk and Talk	✓	 MOOC	✓	 AAT

SECTION 8: Engineering Competencies (ECs) Focused
Please tick (✓) relevant engineering competency profile covered

EC Number	Attributes	Profiles	(✓)
EC1	Depth of knowledge required (CP)	Ensures that all aspects of an engineering activity are soundly based on fundamental principles - by diagnosing, and taking appropriate action with data, calculations, results, proposals, processes, practices, and documented information that may be ill-founded, illogical, erroneous, unreliable or unrealistic requirements applicable to the engineering discipline	✓
EC2	Depth of analysis required (CP)	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	✓
EC3	Design and development of solutions (CA)	Support sustainable development solutions by ensuring functional requirements, minimize environmental impact and optimize resource utilization throughout the life cycle, while balancing performance and cost effectiveness.	✓
EC4	Range of conflicting requirements (CP)	Competently addresses complex engineering problems which involve uncertainty, ambiguity, imprecise information and wide-ranging or conflicting technical, engineering and other issues.	✓

EC5	Infrequently encountered issues (CP)	Conceptualizes alternative engineering approaches and evaluates potential outcomes against appropriate criteria to justify an optimal solution choice.	-
EC6	Protection of society (CA)	Identifies, quantifies, mitigates and manages technical, health, environmental, safety, economic and other contextual risks associated to seek achievable sustainable outcomes with engineering application in the designated engineering discipline.	-
EC7	Range of resources (CA)	Involve the coordination of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies) in the timely delivery of outcomes	-
EC8	Extent of stakeholder involvement (CP)	Design and develop solution to complex engineering problem considering a very perspective and taking account of stakeholder views with widely varying needs.	-
EC9	Extent of applicable codes, legal and regulatory (CP)	Meet all level, legal, regulatory, relevant standards and codes of practice, protect public health and safety in the course of all engineering activities.	-
EC10	Interdependence (CP)	High level problems including many component parts or sub-problems, partitions problems, processes or systems into manageable elements for the purposes of analysis, modelling or design and then re-combines to form a whole, with the integrity and performance of the overall system as the top consideration.	-
EC11	Continuing professional development (CPD) and lifelong learning (CA)	Undertake CPD activities to maintain and extend competences and enhance the ability to adapt to emerging technologies and the ever-changing nature of work.	✓
EC12	Judgement (CA)	Recognize complexity and assess alternatives in light of competing requirements and incomplete knowledge. Require judgement in decision making in the course of all complex engineering activities.	✓

SECTION 9: Employability Skills

Example: Communication skills / Computational skills / Project based skills

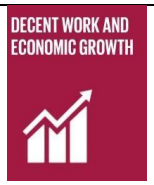
Studying Aerodynamics equips the students with a range of employability skills that are highly valued in industries.

Employability Skills:

- Problem-Solving and Analytical Thinking
- Mathematical and Computational Skills
- Systematic Design and Optimization: Knowledge of scalable and robust system design.
- Knowledge of computer system.
- Teamwork and Collaboration
- Technical Communication:

Project Management:

- Planning and organizing project timelines and tasks.
- Allocating resources efficiently.
- Collaborating and communicating with team members.
- Identifying and mitigating project risks.
- Testing and validating system performance.

SECTION 10: Relevance to Sustainability goals Brief description about the course and its correlation with Sustainability Development Goal (SDGs).		
SDG Goals		**Correlation with SDG**
4		**Quality Education:** This subject will prepare students for modern technological challenges, improving educational tools, and promoting skills essential for global development.
8		**Decent Work and Economic Growth** – Prepares students for careers in technology-driven industries, boosting employability and fostering innovation in the digital economy.
9		**Industry, Innovation, and Infrastructure** – (Industry, Innovation, and Infrastructure) and computer architecture are indirectly linked through the enabling role of technology.
11		**Sustainable Cities and Communities** – Sustainable cities and communities, has strong ties to computer architecture through the concept of "Smart Cities".

SECTION 11A: Mapping between COs and POs / PSOs

Course Outcomes	Program Outcomes (POs)											Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	1	2	3
CO1	✓	✓	✓	-	-	-	-	-	-	-	-	✓	✓	-
CO2	✓	-	-	--	-	-	-	-	-	-	-	✓	✓	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	✓	✓	-	-
CO4	✓	✓	-	✓	-	-	-	-	-	-	✓	✓	-	-
CO5	✓	✓	✓	✓	-	-	-	-	-	-	✓	✓	-	✓
CO6	✓	-	-	-	-	-	-	-	-	-	✓	✓	-	✓

Outcomes		WKS and Indicators of attainment and Justification for mapping (students will be able to)																																				IAs Count
COs	POs	WK 1	WK 2								WK 3			WK 4			WK 5						WK 6			WK 7				WK 8							WK 9						
		a	a	b	c	D	e	f	g	h	a	b	c	a	b	c	a	B	c	d	e	F	a	B	c	a	b	c	d	a	b	c	d	E	f	g	A	b	c	d	e	f	
CO 1	PO 1	•	•	•	•			•	•	•	•		•	•																													10
	PO 2	•	•	•	•			•	•	•		•	•	•																													10
	PO 3																•	•		•	•																							04
	PSO 1	•									•																																02
	PSO 2	•							•	•																																	03
CO 2	PO 1	•	•	•	•	•	•	•				•	•	•																													10
	PSO 1	•	•	•																																							03

	PSO 2	•																																			01
CO 3	PO 1	•	•	•	•	•	•	•			•	•	•																								10
	PO 2	•			•	•	•	•		•		•		•																							10
	PO 3																•	•	•		•																04
	PO 4																											•	•	•	•	•						05
	PO 11																											•	•	•	•	•						05
	PSO 1	•					•																														02
CO 4	PO 1	•	•	•	•	•	•	•			•	•	•																								10
	PO 2	•			•	•	•	•		•		•		•																							09
	PO 4																											•	•		•	•						04
	PSO 1	•																																			01
CO 5	PO 1	•	•	•	•	•	•	•			•	•	•																								10
	PO 2	•	•	•		•	•	•	•			•	•																								09
	PO 3																•		•	•	•																04
	PO 4																											•	•		•	•						04
	PO 11																											•	•	•	•	•						05
	PSO 1	•																																			0
	PSO 3	•																																			01
CO 6	PO 1	•	•	•	•	•	•	•			•	•	•																								10
	PO 11																											•	•	•	•	•						05
	PSO 1	•															•																					02
	PSO 3	•					•																														02

SECTION 11B: Indicators of Attainment with COs to POs and PSOs														
Course Outcomes	Percentage of Indicators of Attainments (IA) with POs and PSOs													
	PO											PSO		
	1	2	3	4	5	6	7	8	9	10	11	1	2	3
CO1	67	67	67	-	-	-	-	-	-	-	-	67	-	100
CO2	67	-	-	-	-	-	-	-	-	-	-	100	-	34
CO3	67	62	67	71	-	-	-	-	-	-	71	67	-	-
CO4	67	62	-	58	-	-	-	-	-	-	-	33	-	-
CO5	67	57	67	57	-	-	-	-	-	-	71	33	-	33
CO6	67	-	-	-	-	-	-	-	-	-	71	67	-	67

SECTION 11C: Course Articulation Matrix of COs to POs														
0 No Contribution (0-5%)			1 Low (≥5 - <40%)			2 Moderate (≥40 - <60%)					3 High (≥60%)		
-														
Course Outcomes	**Program Outcomes (POs)**											**Program Specific Outcomes (PSOs)**		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**	**3**
CO1	3	3	3	-	-	-	-	-	-	-	-	3	-	3
CO2	3	-	-	-	-	-	-	-	-	-	-	3	-	1
CO3	3	3	3	3	-	-	-	-	-	-	3	3	-	-
CO4	3	3		2	-	-	-	-	-	-	-	2	-	-
CO5	3	2	3	2	-	-	-	-	-	-	3	2	-	-
CO6	3	-	-	-	-	-	-	-	-	-	3	3	-	-
Total	18	11	9	7	-	-	-	-	-	-	9	16	-	3
Average	**3**	**2.7**	**3**	**2.3**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**2.7**	**-**	**2.4**

SECTION 11D: Level of Contribution of the COs to POs and PSOs

Number	Programme Outcomes	Proficiency Assessed by	Contribution Level (From 1 to 3)
PO 1	Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in **WK1 to WK4** respectively to develop to the solution of **complex engineering problems**.	CIE / SEE / AAT:1 – 2 Assignments / Open-ended problems	3
PO 2	Identify, formulate, review research literature and analyse **complex engineering problems** reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4).	CIE / SEE / AAT:1 – 2 Hack-a-thon	3
PO 3	Design creative solutions for **complex engineering problems** and design / develop systems / components/ processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)	CIE / SEE / AAT:2 – 1 Complex Engineering Problem Solving	3
PO 4	Conduct investigations of **complex engineering problems** using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8)	CIE / SEE / AAT:2 – 1 Complex Engineering Problem Solving	3
PO 10	Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.	CIE / SEE / AAT:2 – 1 Complex Engineering Problem Solving	3
PSO 1	Design next-generation computer systems, networking devices, search engines, soft computing and intelligent systems, web browsers, and knowledge discovery tools.	AAT: 1 – 1 Tech-Talk	3
PSO 2	Focus on mobile and web applications development and learn the emerging technologies and frameworks in demand with employers and contemporary challenges.	AAT: 1 – 1 Tech-Talk	3
PSO 3	Practical experience in shipping real world software, using industry standard tools and collaboration techniques will equip to secure and succeed in first	AAT: 2 – 1 Complex Engineering Problem Solving	3

	job upon graduation in IT industry.		

SECTION 12: Syllabus	
MODULE I	**REGISTER TRANSFER AND MICROOPERATIONS**
	Register transfer, Bus, and memory transfers, Arithmetic microoperations, Logic microoperations, Shift microoperations, and Arithmetic logic shift unit. Computer arithmetic: Addition and subtraction, floating point arithmetic operations, decimal arithmetic unit.
MODULE II	**ORGANIZATION OF A COMPUTER**
	Instruction codes, Computer registers, Computer instructions, Timing and control, Instruction cycle, Program Input-Output and Interrupt. Instruction formats, Addressing modes, Data Transfer and Manipulation, Program Control, RISC.
MODULE III	**MICROPROGRAMMED CONTROL AND INPUT-OUTPUT ORGANIZATION**
	Micro Programmed Control: Control memory, Address sequencing, Design of control unit, Hardwired control, Micro programmed control. Input-Output Organization: Peripheral devices, Input-Output interface, Modes of transfer, Priority interrupt –Daisy chaining priority, Parallel priority interrupt, Priority encoder; Direct Memory Access, Input-Output Processor – CPU-IOP communication; PCI Express - PCI physical and logical architecture.
MODULE IV	**MEMORY ORGANIZATION**
	Memory organization: Memory hierarchy, main memory, auxiliary memory, associative memory, cache memory, virtual memory; Semiconductor RAMs – Internal organization, Static memories, Dynamic RAMs, Synchronous and Asynchronous DRAMs, Structure of larger memories; Read-only memories, Cache memories – Mapping functions; Nonvolatile Solid-State Memory Technologies, Solid state drives.
MODULE V	**MULTIPROCESSORS**
	Pipeline and Vector Processing: Parallel processing, Pipelining, Instruction pipeline, Vector processing, Array processors. Multiprocessors: Characteristics of multiprocessors, Interconnection structures, Inter-processor arbitration. Multicore Computers: Hardware performance issues, Software performance issues, Multicore organization, Intel Core i7-990X.

Week Number	Topics	Duration (Hours)
1	1.1 Introduction to Register Transfer and Microoperations 1.2 Register transfer 1.3 Bus, and memory transfers 1.4 Arithmetic microoperations	4
2	2.1 Logic microoperations 2.2 Shift microoperations 2.3 Arithmetic logic shift unit 2.4 Computer arithmetic: Addition and subtraction	4
3	3.1 Floating point arithmetic operations 3.2 Decimal arithmetic unit 3.3 Instruction codes 3.4 Computer registers	4
4	4.1 Computer instructions 4.2 Timing and control 4.3 Instruction cycle 4.4 Program Input-Output and Interrupt	4

5	5.1 Instruction formats 5.2 Addressing modes 5.3 Data Transfer and Manipulation 5.4 Program Control, RISC	4
6	6.1 Program Control, RISC 6.2 Micro Programmed Control 6.3 Control memory 6.4 Control memory	4
7	7.1 Address sequencing 7.2 Address sequencing 7.3 Design of control unit 7.4 Design of control unit	4
8	8.1 Hardwired control 8.2 Hardwired control 8.3 Micro programmed control 8.4 Micro programmed control	4
CONTINIUOUS INTERNAL EXAMINATION (CIE- I)		
9	9.1 Input-Output Organization 9.2 Peripheral devices 9.3 Input-Output interface 9.4 Modes of transfer.	4
10	10.1 Modes of transfer 10.2 Priority interrupt –Daisy chaining priority 10.3 Parallel priority interrupt 10.4 Priority encoder	4
11	11.1 Direct Memory Access 11.2 Input-Output Processor – CPU-IOP communication 11.3 PCI Express - PCI physical and logical architecture 11.4 Memory organization, Memory hierarchy	4
12	12.1 Main memory 12.2 Auxiliary memory, Associative memory 12.3 Cache memory 12.4 Virtual memory; Semiconductor RAMs – Internal organization	4
13	13.1 Static memories 13.2 Dynamic RAMs 13.3 Synchronous and Asynchronous DRAMs 13.4 Structure of larger memories	4
14	14.1 Structure of larger memories 14.2 Read-only memories 14.3 Cache memories – Mapping functions 14.4 Nonvolatile Solid-State Memory Technologies, Solid state drives	4
15	15.1 Pipeline and Vector Processing 15.2 Parallel processing, Pipelining, Instruction pipeline 15.3 Vector processing, Array processors 15.4 Multiprocessors: Characteristics of multiprocessors	4
16	16.1 Interconnection structures, Inter-processor arbitration 16.2 Multicore Computers: Hardware performance issues, 16.3 Software performance issues, Multicore organization 16.4 Intel Core i7-990X.	4
	Total	**64**

SECTION 14: Specific Goals for the Course	
The following table shows the knowledge and skills covered by the unit outcomes:	
Knowledge	**Skills**
Learners should understand: • Fundamentals of Computer Architecture • Instruction Set Architecture (ISA) • CPU Organization and Control Unit Design • Memory Hierarchy (Cache, Main, and Virtual Memory) • Data Path and Control Path Design • Pipelining and Performance Optimization • Parallel Processing Architectures • I/O Systems and Communication Techniques • RISC vs. CISC Architecture • Microprogramming and Hardwired Control	**Learners can develop skill in:** • Analytical and Logical Thinking • Computer System Design and Evaluation • Assembly Language Programming • Performance Analysis and Optimization • Hardware Simulation and Modeling • Problem Solving in System-Level Scenarios • Communication and Team Collaboration • Design of Computing Subsystems • Exposure to Industry Practices and Trend • Research in Emerging Computing Architectures

Administrative Information

SECTION 15: History of changes		
Regulations	**Description of change**	**BOS Date**
R 16	From R15 JNTUH, Hyderabad to R16 IARE regulations with change in V module • No change in syllabus	24.07.2016
R 18	Changes from R16 to R18 regulation • Credit weightage is reduced from 4 to 3. • No change in syllabus	16.07.2018
UG 20	Changes from R18 to UG 20 regulation • No change in syllabus	17.11.2020
BT 23	Changes from UG 20 to BT 23 regulation • **Module I:** Register transfer and microoperations are introduced • **Module – V:** Multiprocessors are introduced	21.08.2023

Course Outline Approvals	
Course Coordinator Name: Dr. A Karthik Signature: Date:	**Head of the Department** Name: Dr. M Purushotham Reddy Signature: Date:
Dean of Outcome Based Teaching and Learning Name: Signature: Date:	**Dean of Academics** Name: Signature: Date:

Check List		
Section	**Description**	**Please tick (✓)**
1	General Information about the Course	✓

2	Notional Study Time	✓
3	A. Course Outcomes	✓
	B. Cognitive Levels	✓
4	Content and Context of the Course	✓
5	Complex Engineering Problem Solving	✓
6	A. Assessment Methods – Direct	✓
	B. Assessment Methods – Indirect	✓
7	Content Delivery / Instructional Methodologies	✓
8	Engineering Competencies (ECs) Focused	✓
9	Employability Skills	✓
10	Relevance to Sustainability goals	✓
11	A. Mapping between COs and POs / PSOs	✓
	B. Indicators of Attainment with COs to POs and PSOs	✓
	C. Course Articulation Matrix of COs to POs	✓
	D. Level of Contribution of the COs to POs and PSOs	✓
12	Syllabus	✓
13	Tentative Schedule of Instructions	✓
14	Specific Goals for the Course	✓
15	History of Changes	✓