IARE
INSTITUTE OF AERONAUTICAL ENGINEERING

Outcome Based Education (OBE) Manual
IARE - R18

Department of Aeronautical Engineering

M.TECH in AEROSPACE ENGINEERING

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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

1.1 Vision and Mission of Institute

Vision

To bring forth professionally competent and socially progressive, capable of working across cultures meeting the global standards ethically.

Mission

To provide students with an extensive and exceptional education that prepares them to excel in their profession, guided by dynamic intellectual community and be able to face the technically complex world with creative leadership qualities.
Further, be instrumental in emanating new knowledge through innovative research that emboldens entrepreneurship and economic development for the benefit of wide spread community.

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.

1.2 Vision and Mission of the department

Vision

To build a strong community of dedicated graduates with expertise in the field of aeronautical science and engineering suitable for industrial needs having a sense of responsibility, ethics and ready to participate in aerospace activities of national and global interest.

Mission

To actively participate in the technological, economic and social development of the nation through academic and professional contributions to aerospace and aviation areas, fostering academic excellence and scholarly learning among students of aeronautical engineering.

M1: To provide an extensive and exceptional education that equips students with the knowledge, skills, and professionalism required to excel in their careers and contribute effectively to the aerospace industry.

M2: To nurture creative leadership qualities and develop the ability to address complex technical challenges with innovation, critical thinking, and ethical responsibility

M3: To promote research and innovation aimed at generating new knowledge, advancing aerospace technologies, and fostering a culture of lifelong learning

M4: To encourage entrepreneurship and economic development, empowering graduates to create sustainable solutions and contribute to the advancement of the wider community and the nation.

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 accomplishment after 4 to 5 years of graduation. PEOs can be written from different perspectives like Career, Technical Competency and Behaviour. While writing the PEOs do not use the technical terms as it will be read by prospective students who wants to join the programme. Three to five PEOs are recommended.

Program Educational Objective – I:

Obtain employment in industry, government institutions, small businesses, or organizations successfully using the skills they acquired in aerospace engineering and related fields.

Program Educational Objective – II:

Pursue Doctoral degree and to conduct research at various Universities /Institutions.

Program Educational Objective – III:

.Apply their in-depth knowledge in Computational Mechanics / Fluid Dynamics to evaluate, analyze and synthesize existing and novel designsof aerospace components and systems.

Program Educational Objective – IV:

Contribute to the advancement of aerospace engineering, science or related fields through new discoveries, solving problems, program management or by educating/mentoring others.

With a view to challenge ourselves and to nurture diverse capabilities for professional and intellectual growth for our students it is important for the department to define departmental objectives in generalized and broad format. Adherence to these objectives is proposed to be demonstrated through actions or achievements.

The department of Aeronautical Engineering periodically reviews these objectives and as part of this review process, encourages comments from all interested parties including current students, alumni, prospective students, faculty, teaching assistants and members of related professional organizations, and colleagues from other educational institutions.

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, 3, 4, 5, 6	**PO:**1, 2, 3, 4, 5, 6	**PO:** 1, 2, 3, 4, 5, 6	**PO:** 1, 2, 3, 4, 5, 6

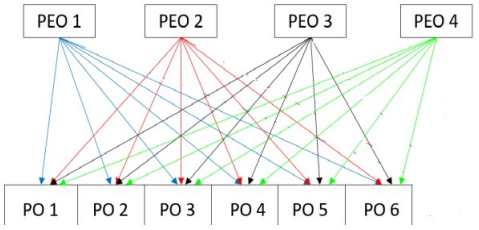


FIGURE 1: Correlation between the PEOs and the POs

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.

M. Tech (ASE) - PROGRAM OUTCOMES (PO's)	
A Post Graduate in Aerospace engineering Program will demonstrate:	
PO1	Independently carry out research /investigation and development work to solve practical problems.
PO2	Write and present a substantial technical report/document.
PO3	Demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
PO4	Identify, formulate, analyze and design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools.
PO5	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

4 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) Lifelong learning and Research**	**(2) Success in Professional career**	**(3) Communication skills and Leadership**	**(4) Design/ Development of Solutions**
PO1	Independently carry out research /investigation and development work to solve practical problems.	3	3	3	2
PO2	Write and present a substantial technical report/document.	3	3	2	2

PO3	Demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program	3	3	2	2
PO4	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.	3	3	2	2
PO5	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.	3	3	2	2
PO6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.	2	3	3	3

Relationship between Program Outcomes and Program Educational Objectives
Key: 3 = High; 2 = Medium; 1= Low

- The assessment process of POs 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.

5 Blooms Taxonomy

Bloom's taxonomy is considered as the global language for education. Bloom's Taxonomy is frequently used by teachers in writing the course outcomes as it provides a readymade structure and list of action verbs. The stages ascend in complexity and what they demand of students. First students need to simply remember information provided to them — but reciting something doesn't demonstrate having learned it, only memorization. With understanding comes the ability to explain the ideas and concepts to others. The students are then challenged to apply the information and use it in new ways, helping to gain a deeper understanding of previously covered material and demonstrating it moving forward. Questioning information is a vital part of learning, and both analysis and evaluation do just this. Analysing asks a student to examine the information in a new way, and evaluation demands the student appraise the material in a way that lets them defend or argue against it as they determine. The final step in the revised taxonomy is creating, which entails a developing new product or point of view. How does this learned information impact your world? How can it be used to impact not just your education but the way you interact with your surroundings? By utilizing Bloom's Taxonomy, students are not going to forget the information as soon as the class ends - rather, they retain and apply the information as they continue to grow as a student and in their careers, staying one step ahead of the competition.

5.1 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 2: Revised version of Bloom's taxonomy

5.2 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.

5.3 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

6 Guidelines for writing Course Outcome Statements:

Well-written course outcomes involve the following parts:

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

6.1 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.

6.2 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 5-6 statements for the entire course [more detailed outcomes can be developed for individual units, assignments, chapters, etc. if the instructor(s) wish (es)].
- Focus on overarching knowledge and/or skills rather than small or trivial details
- Focus on knowledge and skills that are central to the course topic and/or discipline.
- Create statements that have a student focus rather than an instructor centric approach (basic e.g., “upon completion of this course students will be able to list the names of the 28 states and 8 union territories” versus “one objective of this course is to teach the names of the 28 states and 8 union territories”).
- Focus on the learning that results from the course rather than describing activities or lessons that are in the course.
- Incorporate and/or reflect the institutional and departmental missions.

- Include various ways for students to show success (outlining, describing, modelling, depicting, etc.) rather than using a single statement such as "at the end of the course, students will know _____ "as the stem for each expected outcome statement.

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

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

Course outcome statements on the course level describe:

- 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.

6.3 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)."

6.4 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

6.5 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.

S No	Condition	Observable Behaviour	Standard
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?

6.6 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 7: Process for mapping the values for CO-PO Matrix

Type	**POs**	**Action Verb(s) in POs**	**Bloom's level(s) for POs**	**Bloom's level(s) for COs**
Technical	PO1	Apply	L3	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
	PO2	Identify	L2	
		Formulate	L6	
		Review	L2	
	PO3	Design	L6	
		Develop	L3, L6	
	PO4	Analyse	L4	
		Interpret	L2, L3	
		Design	L6	
	PO5	Create	L6	
		Develop	L3	
		Apply	L3	
	PO6	Develop	L3	
		Solve	L6	

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).

6.7 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.

6.8 Method for Articulation

1. Identify the key competencies of POs 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 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 and your course syllabus for writing the justification.
3. Make a table with number of key competencies for CO – PO 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 mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, Course Articulation Matrix (CO - PO Mapping) is prepared with COs and POs and COs 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

7 Key Competencies for Assessing Program Outcomes:

PO	NBA statement / Vital features	No. of vital features
PO1	**Independently carry out research /investigation and development work to solve practical problems.** 1. Independence and Self driven 2. Scope definition and deliverables 3. Work breakdown structures and schedules 4. Budget 5. Quality 6. Resource identification and implementation 7. Demonstrate the solution to the stakeholders	07
PO2	**Write and present a substantial technical report/document.** 1. Demonstrate and communicate effectively in writing report and document/ present orally. 2. Clarity (writing/ presentation) 3. Grammar/ punctuation (writing) 4. Speaking/ Presenting 5. Subject knowledge while preparing report 6. Being work on research related areas	06

PO	NBA statement / Vital features	No. of vital features
PO3	**Demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.** 1. Knowledge, understanding and demonstrations of aerospace applications in real time scenario. 2. Problem formulation and abstraction 3. Use creativity to establish innovative solutions 4. Experimental design 5. Manage the design process and evaluate outcomes using modern tools 6. Solution development or experimentation / Implementation 7. Interpretation of results and Validation	07
PO4	**Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools.** 1. Understand the need of users with the importance of considerations such as CFD and Solidworks 2. Scientific principles and methodology 3. Problem formulation and abstraction 4. Use creativity to establish innovative solutions 5. Experimental design 6. Manage the design process and evaluate outcomes 7. Computer software / simulation packages / diagnostic equipment / technical library resources / literature search tools 8. Solution development or experimentation / Implementation 9. Interpretation of results and Validation 10. Awareness of Quality issues	10

PO	NBA statement / Vital features	No. of vital features
PO5	**Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.** 1. Project management professional certification 2. Being work on advanced degree 3. Personal continuing education efforts 4. Ongoing learning- stayes up with industry trends / new technology 5. Continued personal development 6. Scope statement 7. Deliverables 8. Budget 9. Human resources and procurement plan	9
PO6	**Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.** 1. Teams are used during the classroom periods, in the hands-on labs, and in the design projects 2. Team also is responsible for evaluating each other's performance, which is then reflected in the final grade. 3. Knowledge of management techniques which may be used to achieve engineering objectives within that context; 4. Plan tasks and resources, manage risk and produce deliverables 5. Meeting deadlines and producing solutions 6. Work with all levels of people in team 7. Get along with others 8. Demonstrated ability to work well within a team	8

8 Program Outcomes Attained through course modules:

Courses offered in Aerospacce Engineering Curriculum (IARE-R18) and POs attained through course modules for I, II, III and IV semesters.

Code	Subject	PO					
		1	2	3	4	5	6
M.Tech - I Semester							
BAEB01	”Advanced Mathematics in Aerospace Engineering”	✓	✓			✓	
BAEB02	Space Propulsion	✓	✓	✓		✓	
BAEB05	”Professional Core Elective - I (Advance Computational Aerodynamics)”	✓	✓		✓		
BAEB06	”Professional Core Elective - II (Unmanned Aerial Vehicles)”	✓	✓	✓		✓	
BAEB09	”Advanced Computational Aerodynamics Laboratory”	✓	✓		✓		
BAEB10	”Computational Aerospace Engineering Laboratory”	✓	✓		✓		
M.Tech - II Semester							
BAEB11	Flight Dynamics and Control	✓	✓				✓
BAEB12	Engineering Analysis of Flight Vehicles	✓	✓		✓		✓
BAEB14	”Professional Core Elective – III (Rocket and Missile)”	✓	✓	✓			
BAEB16	”Professional Core Elective – IV (Atmospheric Re-entry Vehicles)”	✓	✓				
BAE19	”Flight Simulation and Controls Laboratory”	✓	✓	✓	✓	✓	
BAEB20	Computational Structures Laboratory	✓		✓			✓
BAEB21	Mini Project with Seminar	✓	✓			✓	
M.Tech - III Semester							
BCSB31	Research Methodology and IPR	✓	✓		✓		
BAEB24	”Professional Core Elective – V (Airport Planning and Operations)”	✓	✓				✓
BCSB30	Open Elective Courses (Waste to Energy)	✓	✓	✓			
BAEB40	Phase-I Dissertation	✓	✓	✓	✓	✓	✓
M.Tech - IV Semester							
BAEB41	Phase-II Dissertation	✓	✓	✓	✓	✓	✓

9 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.

9.1 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.

9.2 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. The AAT chosen for this course is given in table.

9.3 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.

9.4 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.

9.5 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 DAC meetings.

9.6 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 DAC for implementation purposes.

9.7 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.

9.8 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.

9.9 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.

9.10 Programme Assessment and Quality Improvement Committee (PAQIC)

PAC Monitors the achievements of Program Outcomes (POs) 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.

9.11 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.

9.12 Faculty Meetings

The DAC 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 DAC's suggestions and guidelines. All these proceedings are recorded and kept for the availability of all faculties.

9.13 Professional Societies

The importance of professional societies like IEEE, IETE, ISTE, IE (I) 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.

10 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%

10.1 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

S No	Courses	Components	Frequency	Max. Marks	Evidence
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
4	Comprehensive Examination	Written examination (objective type)	Once in a semester	50	Online assessment
		Oral examination	Once in a Semester	50	Viva

10.2 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 12: 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 assess the 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.

11 PO - Assessment tools and Processes

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

1. Direct method
2. Indirect method

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

TABLE 13: Attainment of PO

	Assessment	Tools	Weight
POs 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.

11.1 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 attainment through course outcome attainment.

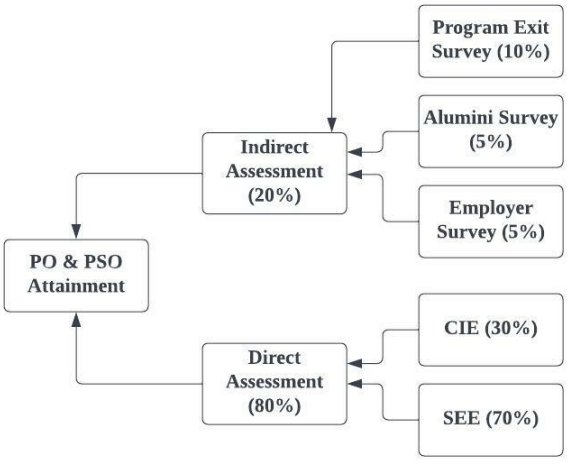


FIGURE 3: Evaluation process of POs attainment

12 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
- How Program Outcomes are assessed
- Mapping of each CO with PO(s)
- Justification for CO – PO mapping- direct
- Total count of key competencies for CO – PO
- Percentage of key competencies for CO – PO
- Course articulation matrix (PO mapping)
- Assessment methodology-direct
- Assessment methodology-indirect
- Syllabus
- List of Text Books / References / Websites
- Course Plan

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043
COURSE DESCRIPTION

Branch	**AEROSPACE ENGINEERING**				
Course Title	**ADVANCED COMPUTATIONAL AERODYNAMICS**				
Course Code	BAEB05				
Program	M.Tech				
Semester	I	AE			
Course Type	Elective				
Regulation	R-18				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	-	3	-	-
Course Coordinator	Dr. Bodavula Aslesha, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAE004	IV	Low speed Aerodynamics
B.Tech	AHS011	II	Mathematical Transform Techniques
B.Tech	AAE008	V	High Speed Aerodynamics
B.Tech	AAE013	VI	Computational Aerodynamics

II COURSE OVERVIEW:

This course deals with the theory of fluid flow (subsonic and supersonic) and those behind the commercial fluid dynamic software available today. It starts with the mathematical basics such as the spatial resolution methods for numerical solutions of partial differential equations (Boundary Value Problems and Initial Boundary Value Problems) and time dependent methods. Followed by boundary conditions for the formation of boundary layers in different conditions. Later comes the analytical method for solving supersonic flow i.e., Method of Characteristics. Lastly, the quintessential method for solving flow around an airfoil (Panel Methods) is addressed.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Advanced Computational Aerodynamics	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). **Semester End Examination (SEE):** The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into FIVE modules and each module carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each module. Each question carries 14 marks. There could be a maximum of three sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept
30 %	To test the analytical skill of the concept
20 %	To test the application skill of the concept

Continuous Internal Assessment (CIA):
For each theory course the CIA shall be conducted by the faculty/teacher handling the course as given in Table 4. CIA is conducted for a total of 30 marks, with 25 marks for Continuous Internal Examination (CIE) and 05 marks for technical seminar and term Paper.

Table 2: Assessment pattern for Theory Courses

Component	Theory		Total Marks
Type of Assessment	CIE Exam	Technical Seminar and Term paper	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 9^{th} and 17^{th} week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration, consisting of 5 one mark compulsory questions in part-A and 4 questions in part-B. The student has to answer any 4 questions out of five questions, each carrying 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Technical Seminar and Term Paper:
Two seminar presentations are conducted during I year I semester and II semester. For seminar, a student under the supervision of a concerned faculty member, shall identify a topic in each course and prepare the term paper with overview of topic. The evaluation of Technical seminar and term paper is for maximum of 5 marks. Marks are awarded by taking average of marks scored in two Seminar Evaluations.

VI COURSE OBJECTIVES:

The students will try to learn:

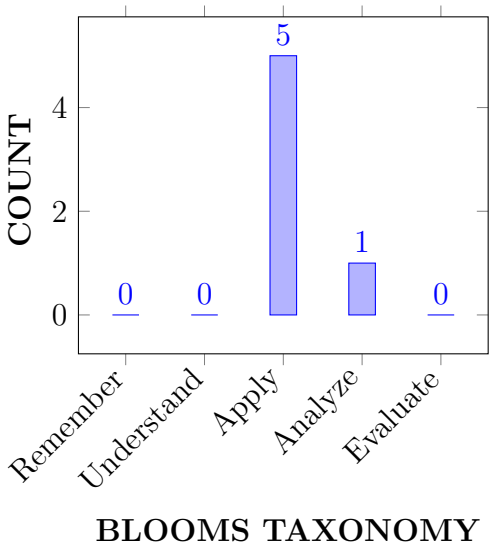
I	The fundamental principles of numerical methods and panel methods for solving the compressible flow problems.
II	The initial methods applied in the process of CFD tools development, their advantages and disadvantages over modern developed methods.
III	The different methods evolved in analyzing the numerical stability of solutions of supersonic nozzle flows.
IV	The techniques in time marching steps to sustain the accurate solution for flow-field problems

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Apply** the flux approach, flux vector splitting, upwind reconstruction-evolution methods for solving the compressible flow problems using Euler's equations.	Apply
CO 2	**Make use of** the explicit, implicit, time split methods and approximate factorization schemes for obtaining the stabilized numerical solution of subsonic and supersonic nozzle flows	Apply
CO 3	**Develop** the boundary layer transformation equations for steady external flows on airfoil, wings and aircraft using finite difference method.	Apply
CO 4	**Analyze** the structured, unstructured grids and dummy cells using physical boundary conditions for attaining the accurate results of fluid flow problems.	Analyze
CO5	**Identify** the characteristic lines and compatibility equations for designing the supersonic nozzle having shock free and isentropic flow	Apply
CO6	**Utlize** the effects of compressibility and viscosity on thin airfoil for establishing the numerical solution in aerodynamic problems	Apply

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools.
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	-	✓	-	-	-
CO 2	✓	-	✓	-	-	-
CO 3	✓	-	✓	-	-	-
CO 4	✓	-	✓	-	-	-
CO 5	✓	-	✓	-	-	-
CO 6	✓	-	✓	-	-	-

X COURSE ARTICULATION MATRIX (CO – PO MAPPING):

CO'S and PO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	1	-	-	-
CO 2	3	-	1	-	-	-
CO 3	3	-	1	-	-	-
CO 4	3	-	3	-	-	-
CO 5	3	-	1	-	-	-
CO 6	3	-	1	-	-	-
TOTAL	18	-	8	-	-	-
AVERAGE	3	-	1.3	-	-	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

UNIT I	**NUMERICAL SOLUTIONS**
	Euler equations: Flux approach, Lax-Wendroff method, basic principles of upwind schemes, flux vector splitting, Steger Warming flux vector splitting, Van Leer flux vector splitting, Upwind reconstruction, evolution, Goduno's first order upwind method, Roe's first order upwind method.
UNIT II	**TIME DEPENDENT METHODS**
	Stability of solution, explicit methods, FTFS, FTCS, FTBS, Leapfrog method, Lax method. Implicit methods: Euler's FTCS, Crank Nicolson method, description of Lax- Wendroff scheme, McCormack two step predictor-corrector method, description of time split methods, approximate factorization schemes.
UNIT III	**Boundary conditions**

	Boundary Layer Equations: Setting up the boundary layer equations, flat plate boundary layer solution, boundary layer transformations, explicit and implicit discretization, solution of the implicit difference equations, integration of the continuity equation, boundary layer edge and wall shear stress, Keller-box scheme Concept of dummy cells, solid wall inviscid flow, viscous flow, farfield concept of characteristic variables, modifications for lifting bodies inlet outlet boundary, injection boundary, symmetry plane, coordinate cut, periodic boundaries, interface between grid blocks, flow gradients at boundaries of unstructured grids.
UNIT IV	**METHOD OF CHARACTERISTICS**
	Philosophy of method of characteristics, determination of characteristic lines, two dimensional irrotational flow, determination of compatibility equations, unit processes, supersonic nozzle design by the method of characteristics, supersonic wind tunnel nozzle, minimum length nozzles, domain of dependence and range of influence.
UNIT V	**PANEL METHODS**
	Basic formulation, boundary conditions, physical considerations, reduction of a problem to a set of linear algebraic equations, aerodynamic loads, preliminary considerations prior to establishing numerical solution, steps toward constructing a numerical solution, solution of thin airfoil with lumped vortex filament, accounting for effects of compressibility and viscosity.

TEXTBOOKS

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WEB REFERENCES:

1. https://www.afs.enea.it/project/neptunius/docs/fluent/html/ug/main_pre.htm

COURSE WEB PAGE:

1.

XIV COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
1	Introduction to discretization methods	CO 1	T1 : 18
2	Euler equations: Flux approach	CO 1	T1 : 18.1
3	Lax-Wendroff method	CO 1	T1: 18.1.1
4	Basic principles of upwind schemes	CO 1	T1: 13
5	Flux vector splitting	CO 1	T1:18.2.1
6	Steger Warming flux vector splitting	CO 1	T1:18.2.1
7	Van Leer flux vector splitting	CO 1	T1:18.2.2
8	Upwind reconstruction, evolution	CO 1	T1:18.3
9	Godunov's first order upwind method	CO 1	T1 :18.3.1, 18.3.2
10	Roe's first order upwind method	CO 1	T1 :18.3.1, 18.3.2
11	Stability solution, Explicit methods	CO 2	T2:4.1
12	FTFS, FTCS, FTBS	CO 2	T2:4.1.1
13	Leapfrog methods	CO 2	T2:4.1.5, 4.1.3
14	Lax method	CO 2	T2:4.1.5, 4.1.3
15	Implicit method	CO 2	T2:4.1.4
16	Euler's FTCS	CO 2	T2:4.1.4
17	Crank Nicolson method	CO 2	T2:4.2.4
18	Description of Lax- Wendroff scheme,	CO 2	T2:4.1.6
19	McCormack two step predictor corrector method	CO 2	T2:4.1.8
20	McCormack two step predictor corrector method	CO 2	T2:4.1.8
21	Description of time split methods,	CO 2	T2:4.5.8
22	Approximate factorization schemes	CO 2	T2:4.5
23	Approximate factorization schemes	CO 2	T2:4.5
24	Boundary Layer Equations	CO 3	T2:5.3
25	Setting up the boundary layer equations	CO 3	T2:5.3
26	flat plate boundary layer solution	CO 3	T2:5.3.2
27	Boundary layer transformations	CO 3	T2:5.3.2
28	Explicit discretization	CO 3	R4:4.4
29	Implicit discretization	CO 3	R4:4.4
30	Solution of the implicit difference equations	CO 3	R4:4.4

31	integration of the continuity equation	CO 3	T2:4.2.8
32	boundary layer edge and wall shear stress	CO 3	T2:4.2.8
33	Keller-box scheme	CO 3	T2:4.2.8
34	Concept of dummy cells.	CO 3	T2:4.2.8
35	solid wall inviscid flow, viscous flow	CO 4	R1:8.1, 8.2
36	farfield variables	CO 4	R1:8.1, 8.2
37	concept of characteristic variables	CO 4	R1:8.1, 8.2
38	Modifications for lifting bodies	CO 4	R1:8.3 - 8.6
39	inlet outlet boundary,	CO 4	R1:8.3 - 8.6
40	injection boundary	CO 4	R1:8.3 - 8.6
41	symmetry plane, coordinate cut	CO 4	R1:8.3 - 8.6
42	Periodic boundaries	CO 4	R1:8.7, 8.8
43	Interface between grid blocks	CO 4	R1:8.7, 8.8
44	Flow gradients at boundaries of unstructured grids	CO 4	R1:8.9
45	Philosophy of method of characteristics	CO 5	R2:11.2
46	Determination of characteristic lines, two dimensional irrotational flow	CO 5	R2:11.3
47	two dimensional irrotational flow	CO 5	R2:11.3
48	Determination of compatibility equations, Unit processes	CO 5	R2:11.4, 11.5
49	supersonic nozzle design by the method of characteristics	CO 5	R2:11.7
50	Supersonic wind tunnel nozzle	CO 5	R2:11.7
51	Minimum length nozzles	CO 5	R2:11.8
52	Domain of dependence and range of influence	CO 5	R2:11.6
53	Basic formulation, boundary conditions	CO 6	T4:9.1, 9.2
54	Physical considerations	CO 6	T4:9.3
55	Reduction of a problem to a set of linear algebraic equations	CO 6	T4:9.4
56	Aerodynamic Loads	CO 6	T4: 9.5
57	Preliminary considerations prior to establishing numerical solution	CO 6	T4: 9.6
58	Steps toward constructing a numerical solution	CO 6	T3:9.7
59	Solution of thin airfoil with lumped vortex filament	CO 6	T3:9.8
60	Accounting for effects of compressibility and viscosity	CO 6	T3:9.9
DISCUSSION OF QUESTION BANK			
61	UNIT: I- Numerical Solutions	CO 1	T1
62	UNIT: II- Time Dependent Methods	CO 2	T2, R1
63	UNIT: III- Boundary Conditions	CO3,4	R1

64	UNIT: IV- Method of Characteristics	CO 5	R2
65	UNIT: V- Panel Methods	CO 6	T4

Signature of Course Coordinator **HOD,AE**
Dr.Bodavula Aslesha, Assistant Professor