



Outcome Based Education (OBE) Manual IARE - MT25



Department of Aeronautical Engineering
M.TECH in AEROSPACE ENGINEERING

Contents

| | |
|---------------------------------------------------------------------------------------------------------------|----------|
| Contents | 3 |
| 1 Vision, Mission, Quality Policy, Philosophy & Core Values | 1 |
| 1.1 Vision and Mission of Institute | 1 |
| 1.2 Vision and Mission of the department | 2 |
| 2 Program Educational Objectives (PEOs) | 2 |
| 2.1 Mapping of program educational objectives to program outcomes and program specific outcomes: | 3 |
| 3 Program Outcomes (POs) | 3 |
| 4 Relation between the Program Educational Objectives and the POs | 4 |
| 5 Blooms Taxonomy | 6 |
| 5.1 Incorporating Critical Thinking Skills into Course Outcome Statements . | 6 |
| 5.2 Definitions of the different levels of thinking skills in Bloom’s taxonomy: | 7 |
| 5.3 List of Action Words Related to Critical Thinking Skills | 7 |
| 6 Guidelines for writing Course Outcome Statements: | 11 |
| 6.1 Course Outcomes (COs) | 11 |
| 6.2 Developing Course Outcomes | 11 |
| 6.3 Relationship of Course Outcome to Program Outcome | 12 |
| 6.4 Characteristics of Effective Course Outcomes | 12 |
| 6.5 Examples of Effective Course Outcomes | 13 |
| 6.6 CO-PO Course Articulation Matrix (CAM) Mapping | 15 |
| 6.7 Tips for Assigning the values while mapping COs to POs. | 17 |
| 6.8 Method for Articulation | 17 |
| 7 Key Competencies for Assessing Program Outcomes: | 18 |
| 8 Program Outcomes Attained through course modules: | 21 |
| 9 Methods for measuring Learning Outcomes and Value Addition: | 21 |
| 9.1 Continuous Internal Assessment (CIA) | 22 |
| 9.2 Alternate Assessment Tools (AAT) | 22 |
| 9.3 Semester End Examination (SEE) | 22 |
| 9.4 Laboratory and Project Works | 23 |
| 9.5 Course Exit Surveys | 23 |
| 9.6 Programme Exit Survey | 23 |
| 9.7 Alumni Survey | 23 |
| 9.8 Employer Survey | 23 |
| 9.9 Course Expert Committee | 24 |
| 9.10 Programme Assessment and Quality Improvement Committee (PAQIC) . | 24 |

| | | |
|------|----------------------------------------------------------------|----|
| 9.11 | Department Advisory Board (DAB) | 24 |
| 9.12 | Faculty Meetings | 24 |
| 9.13 | Professional Societies | 24 |
| 10 | CO - Assessment processes and tools: | 25 |
| 10.1 | Direct Assessment: | 25 |
| 10.2 | Indirect Assessment: | 26 |
| 11 | PO - Assessment tools and Processes | 27 |
| 11.1 | PO Direct Attainment is calculated using the following rubric: | 27 |
| 12 | Course Description: | 28 |

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 designs of 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 |

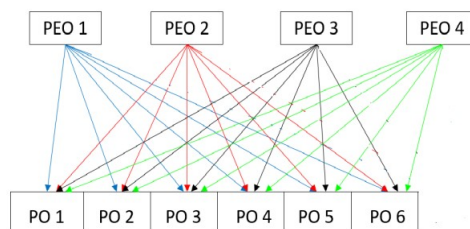


FIGURE 1: Correlation between the PEOs and the POs

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 multi-disciplinary 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 multi-disciplinary 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 |
| <ul style="list-style-type: none"> • Knowledge of terminologies • Knowledge of specific details and elements | <ul style="list-style-type: none"> • Knowledge of classifications and categories • Knowledge of principles and generalizations • Knowledge of theories, models and structures | <ul style="list-style-type: none"> • Knowledge of subject specific skills and algorithms • Knowledge of subject specific techniques and methods • Knowledge of criteria for determining when to use appropriate procedures | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • Choose • Define • Find • How • Label • List • Match • Extend | <ul style="list-style-type: none"> • Classify • Compare • Contrast • Demonstrate • Explain • Illustrate • Infer • Interpret | <ul style="list-style-type: none"> • Apply • Build • Choose • Construct • Develop • Interview • Make use of • Model | <ul style="list-style-type: none"> • Analyze • Assume • Categorize • Classify • Compare • Discover • Dissect • Distinguish | <ul style="list-style-type: none"> • Agree • Appraise • Assess • Award • Choose • Criticize • Decide • Deduct • Importance | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why | <ul style="list-style-type: none"> • Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with | <ul style="list-style-type: none"> • Organize • Plan • Select • Solve • Utilize • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize • Identify | <ul style="list-style-type: none"> • Divide • Examine • Function • Inference • Inspect • List Motive • Simplify • Survey • Take part in • Test for Theme • Conclusion • Contrast | <ul style="list-style-type: none"> • Defend • Determine • Disprove • Estimate • Evaluate • Influence • Interpret • Judge • Justify Mark • Measure • Opinion • Perceive • Prioritize • Prove • Criteria • Criticize • Compare • Conclude | <ul style="list-style-type: none"> • 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 $\leq C \leq 5\%$ - No correlation.

1 – 5 < C $\leq 40\%$ - Low / Slight.

2 – 40% < C < 60% - Moderate

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

7 Key Competencies for Assessing Program Outcomes:

| PO | NBA statement / Vital features | No. of vital features |
|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| PO1 | <p>Independently carry out research /investigation and development work to solve practical problems.</p> <ol style="list-style-type: none"> 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 | <p>Write and present a substantial technical report/document.</p> <ol style="list-style-type: none"> 1. Clarity (writing/ presentation) 2. Grammar/ punctuation (writing) 3. Speaking/ Presenting 4. Subject knowledge while preparing report 5. Being work on research related areas | 05 |
| PO3 | <p>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.</p> <ol style="list-style-type: none"> 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 |

| PO | NBA statement / Vital features | No. of vital features |
|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| PO4 | <p>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.</p> <ol style="list-style-type: none"> 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 |
| PO5 | <p>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.</p> <ol style="list-style-type: none"> 1. Project management professional certification 2. Being work on advanced degree 3. Personal continuing education efforts 4. Ongoing learning- stays up with industry trends / new technology 5. Continued personal development 6. Scope statement 7. Deliverables 8. Budget 9. Human resources and procurement plan | 9 |

| PO | NBA statement / Vital features | No. of vital features |
|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| PO6 | <p>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.</p> <ol style="list-style-type: none"> 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 Aerospace Engineering Curriculum (MT25) 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 | | | | | | | |
| BAEE01 | Advanced Vehicle Aerodynamics | ✓ | ✓ | | | ✓ | |
| BAEE02 | Jet and Rocket Propulsion | ✓ | ✓ | ✓ | | ✓ | |
| BAEE05 | Professional Core Elective - I (Applied Computational Fluid Dynamics) | ✓ | ✓ | | ✓ | | |
| BAEE07 | Professional Core Elective - II (Unmanned Aerial Vehicles) | ✓ | ✓ | ✓ | | ✓ | |
| BHSE01 | Research Methodology and IPR | ✓ | ✓ | ✓ | | ✓ | |
| BAEE11 | Advanced Aerodynamics Laboratory | ✓ | ✓ | | ✓ | | |
| BAEE12 | Computational Aerospace Engineering Laboratory | ✓ | ✓ | | ✓ | | |
| M.Tech - II Semester | | | | | | | |
| BAEE13 | Flight Dynamics and Control | ✓ | ✓ | | | | ✓ |
| BAEE14 | Aerospace Structural Mechanics | ✓ | ✓ | | ✓ | | ✓ |
| BAEE16 | Professional Core Elective – III (Ground Vehicle Aerodynamics) | ✓ | ✓ | ✓ | | | |
| BAEE22 | Professional Core Elective – IV (Advanced Finite Element Methods)” | ✓ | ✓ | | | | |
| BAEE23 | Flight Simulation and Controls Laboratory | ✓ | ✓ | ✓ | ✓ | ✓ | |
| BAEE24 | Advanced Structural Analysis Laboratory | ✓ | | ✓ | | | ✓ |
| BAEE25 | Mini Project with Seminar | ✓ | ✓ | | | ✓ | |
| M.Tech - III Semester | | | | | | | |
| BAEE27 | Professional Core Elective – V (Flight Simulation) | ✓ | ✓ | | | | ✓ |
| BPSE30 | Open Elective Course (Waste to Energy) | ✓ | ✓ | ✓ | | | |
| BAEE34 | Dissertation Work Review - II | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| M.Tech - IV Semester | | | | | | | |
| BAEE35 | Dissertation Work Review - III | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| BAEE36 | Dissertation Viva Voce | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

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 exit 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 as a 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 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 motivates 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 | <ul style="list-style-type: none"> • 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.

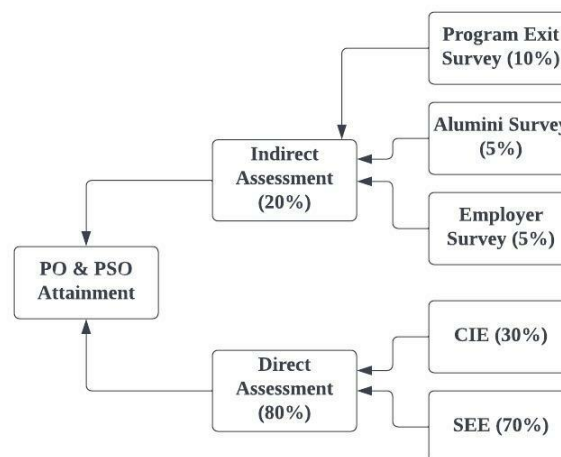


FIGURE 3: Evaluation process of POs attainment

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 - 500 043, Hyderabad, Telangana

COURSE OUTLINE DESCRIPTION

| SECTION 1: General Information about the Course | |
|--------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Course Title | GROUND VEHICLE AERODYNAMICS |
| Course Code | BAEE17 |
| Course Start | Second Semester |
| Course Type | Elective |
| Regulation | IARE - MT 25 |
| Prerequisite Courses | Aerodynamics (AAED08) |
| Department | Aeronautical Engineering |
| Number of Credits | 3 Credit hours |
| Academic Year | 2025-26 |
| Method(s) of Instruction | Theory |
| Course Administrator | Dr. Yagya Dutta Dwivedi , Professor of Aeronautical Engineering IARE10650 yagyadutta.dwivedi@iare.ac.in |
| Course Coordinator's Name | Dr. Juluru Sandeep , Assistant Professor of Aeronautical Engineering IARE11184 j.sandeep@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= |
| Course Description | This subject deals with automotive Aerodynamics are the study of air flows around and through the vehicle body. More generally, it can be labelled "Fluid Dynamics" because air is really just a very thin type of fluid. Above slow speeds, the air flow around and through a vehicle begins to have a more pronounced effect on the acceleration, top speed, fuel efficiency and handling. Influence of flow characteristics and improvement of flow past vehicle bodies to reduction of fuel consumption, more favorable comfort characteristics (mud deposition on body, noise, ventilating and cooling of passenger compartment) and improvement of driving characteristics (stability, handling, traffic safety) |
| Course Objectives | The students will try to learn: a. The basics of vehicle aerodynamics, history of developments and apply the concepts of fluid mechanics to automobiles. b. The drag on ground vehicles and analyze the effects of various configurations of cars on drag. c. The stability and handling qualities based of ground vehicles due to side wind loads and dirt accumulation. d. The concepts to race car design and understand various experimental techniques applied in automotive aerodynamics. |
| Text and Reference Books | TEXTBOOKS: 1. Wolf-Heinrich Hucho, "Aerodynamics of Road Vehicles", SAE International, 1998. 2. Joseph Katz, "Race Car Aerodynamics Designing for Speed", Bentley |

| | |
|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <p>Publishers, 2nd edition, 1996.</p> <p>Reference Books</p> <ol style="list-style-type: none"> 1. Alan Pope, "Wind Tunnel Testing", John Wiley & Sons, 2nd edition, 1974. |
| Learning Resources | <p>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.</p> |
| Supplemental Materials | <p>Readings, Videos, and Links</p> <ol style="list-style-type: none"> 1. https://www.buildyourownracecar.com/race-car-aerodynamics-basics-and-design/ 2. https://www.ara.bme.hu/oktatas/letolt/Vehicleaerodyn/Vehicleaerodyn.pdf 3. https://auto.howstuffworks.com/fuel-efficiency/fuel-economy/aerodynamics.html 4. https://www.slideshare.net/friendsrtg/vehicle-body-engineering-aerodynamics |
| Learning and Teaching Strategies | <p>Online material will provide the foundation of the learning resources, requiring the students to log in and engage regularly throughout the sixteen weeks of the course.</p> <p>There will be a mix of suggested readings, discussions and video content containing embedded digital content and undertake the assessment tasks.</p> |

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, Guided independent study hours: 10, Homework / Programming assignment hours: 9, 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 | | | |
| TLA 6 | Scheduled revision sessions | | | |
| TLA 7 | Guided independent study: Directed viewing of video materials / PPTs | | | 10 |
| TLA 8 | Independent private study | | | |
| TLA 9 | Laboratory Exercises | | | |
| TLA 10 | Homework assignments / Programming assignments | | | 9 |
| 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 |
| 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 | Apply the knowledge of fluid mechanics, and aerodynamics for designing a frontal portion of a vehicle. | Apply |
| CO2 | Analyze the lateral stability problems of vehicle to improve the vehicle dynamics under different conditions. | Analyze |
| CO3 | Apply the knowledge of mechanisms, and measurement techniques for the stability of ground vehicle. | Apply |
| CO4 | Apply the knowledge of flow behavior over different components of race vehicle for designing a race car. | Apply |
| CO5 | Apply the knowledge of wind tunnel test for optimizing the ground vehicle design. | Apply |
| CO6 | Apply the knowledge of measuring equipment and transducers to investigate the roadside performance of vehicle. | Apply |

SECTION 3B: Cognitive Levels

| Blooms Taxonomy Level | Cognitive Level in Percentage (%) |
|-----------------------|-----------------------------------|
| Remember | 0 |
| Understand | 0 |
| Apply | 80 |
| Analyse | 20 |
| Evaluate | 0 |
| Create | 0 |

SECTION 4: Content and Context of Applied Computational Fluid Dynamics

| | |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CO1 | Apply the knowledge of fluid mechanics, and aerodynamics for designing a frontal portion of a vehicle. |
| | <p>Understanding Aerodynamic Design Principles for Vehicle Frontal Geometry</p> <ol style="list-style-type: none"> External Flow Fundamentals: The aerodynamic behavior around the vehicle front is governed by continuity, momentum, and energy equations, with emphasis on boundary layer development and flow separation control. Drag Mechanisms: The frontal profile significantly influences pressure drag and skin friction drag, which determine the overall aerodynamic efficiency of the vehicle. Flow Control and Shape Optimization: Streamlining, curvature design, and stagnation point management help reduce wake formation and minimize aerodynamic losses. Computational Analysis: CFD-based simulations enable prediction of pressure distribution, velocity contours, and drag coefficient for optimized frontal design. <p>With this, students will be able to design aerodynamically efficient vehicle frontal geometries to minimize drag and improve fuel economy.</p> |
| CO2 | Analyze the lateral stability problems of vehicle to improve the vehicle dynamics under different conditions. |
| | <p>Understanding Lateral Stability and Vehicle Dynamic Behavior</p> <ol style="list-style-type: none"> Yaw Motion and Load Transfer: Lateral vehicle motion is governed by yaw dynamics and load transfer mechanisms that affect tire grip during turning maneuvers. Understeer and Oversteer Characteristics: Stability behavior is determined by cornering stiffness, slip angle variations, and steering response. |

| | |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <p>3. Dynamic Modeling: Mathematical models based on Newton’s second law are used to predict lateral acceleration, yaw rate, and stability margins.</p> <p>4. Stability Enhancement Techniques: Suspension tuning, tire parameter optimization, and electronic stability systems improve vehicle control under crosswind and high-speed conditions.</p> <p>With this, students will be able to analyze and improve vehicle lateral stability for enhanced safety and dynamic performance.</p> |
| CO3 | Apply the knowledge of mechanisms, and measurement techniques for the stability of ground vehicle. |
| | <p>Understanding Mechanical Systems and Experimental Evaluation of Vehicle Stability</p> <ol style="list-style-type: none"> 1. Steering and Suspension Mechanisms: Ackermann steering geometry, roll center location, and camber variation influence directional stability and handling. 2. Dynamic Stability Parameters: Roll, pitch, and yaw motions are analyzed using mechanical system modeling and free-body diagram approaches. 3. Instrumentation and Sensors: Accelerometers, gyroscopes, load cells, and displacement sensors are used to measure dynamic stability parameters. 4. Data Acquisition and Validation: Experimental measurements are processed through data acquisition systems to validate theoretical stability predictions. <p>With this, students will be able to integrate mechanical design and measurement systems for evaluating and enhancing ground vehicle stability.</p> |
| CO4 | Apply the knowledge of flow behavior over different components of race vehicle for designing a race car. |
| | <p>Understanding Aerodynamic Performance of Race Vehicle Components</p> <ol style="list-style-type: none"> 1. Downforce Generation: Wings and diffusers manipulate airflow to create negative lift (downforce), increasing tire grip during high-speed cornering. 2. Ground Effect Aerodynamics: Underbody flow acceleration and diffuser expansion generate low-pressure zones that enhance stability. 3. Component Interaction: Aerodynamic interference between front wing, rear wing, and sidepods affects overall lift-to-drag ratio. 4. Computational Optimization: CFD simulations evaluate pressure contours, streamline patterns, and aerodynamic coefficients for performance tuning. <p>With this, students will be able to design race vehicles with optimized aerodynamic balance and improved track performance.</p> |
| CO5 | Apply the knowledge of wind tunnel test for optimizing the ground vehicle design. |
| | <p>Understanding Experimental Aerodynamic Testing Using Wind Tunnels</p> <ol style="list-style-type: none"> 1. Similarity Principles: Geometric, kinematic, and dynamic similarity (Reynolds number matching) ensure accurate scaled-model testing. 2. Force and Moment Measurement: Aerodynamic forces and moments are measured using balances and pressure tapping systems. 3. Flow Visualization Techniques: Smoke flow, tufts, and surface pressure mapping help identify separation and wake regions. 4. Data Correlation and Optimization: Experimental results are compared with computational data for validation and design refinement. <p>With this, students will be able to conduct wind tunnel experiments and optimize vehicle designs based on experimental aerodynamic data.</p> |
| CO6 | Apply the knowledge of measuring equipment and transducers to investigate the roadside performance of vehicle. |
| | <p>Understanding Instrumentation and Field Performance Evaluation of Vehicles</p> <ol style="list-style-type: none"> 1. Transducer Principles: Strain gauges, pressure sensors, thermocouples, and LVDTs convert physical parameters into measurable electrical signals. 2. On-Road Testing Procedures: Real-time testing measures parameters such as acceleration, vibration, temperature, and fuel efficiency. 3. Data Acquisition Systems: Signal conditioning and data logging systems process and store dynamic vehicle performance data. 4. Performance Evaluation: Measured roadside data is analyzed to assess NVH characteristics, suspension response, and operational efficiency. <p>With this, students will be able to implement instrumentation systems for real-time vehicle</p> |

| |
|-------------------------------------------|
| performance investigation and validation. |
|-------------------------------------------|

SECTION 5: Complex Engineering Problem Solving

Complex engineering problem solving projects

There is one piece of assessed coursework, involving a mixture of theoretical work and practical work. We encourage to use the laboratory for practical purpose. For the calculation part in the project, they have to develop the programme code in java or python.

Programming part is mandatory for this course. Homework assignments will concentrate on theoretical concepts and techniques. Projects will be full scale to calculate the slopes and deflections of the various structural members discussed in class. All projects are individual assignments. Student are required to complete the tasks during the class period with no assistance.

Ground Vehicle Aerodynamics: The entire course involves applying fluid mechanics principles to reduce drag, control flow separation, and optimize frontal and body geometry for improved fuel efficiency and performance. It also includes analyzing vehicle stability under lateral forces such as crosswinds and cornering, ensuring dynamic safety and handling. Experimental methods like wind tunnel testing and on-road instrumentation are used to validate designs and enhance real-world vehicle performance.

SECTION 6A: Assessment Methods – Direct

| Item | Evaluation Components | Week in / out | Marks |
|--------------------|---------------------------------------|----------------|------------|
| AAT: 1 - 1 | Tech-Talk | Week – 2 / 5 | 05 |
| AAT: 1 - 2 | Assignments | Week – 4 / 7 | 05 |
| AAT: 2 - 1 | Complex Engineering Problem Solving | Week – 9 / 12 | 05 |
| AAT: 2 - 2 | Definitions and Terminology | 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 / Programming skills / Project based skills

Studying Ground Vehicle Aerodynamics equips students with strong analytical, computational, experimental, and industry-oriented skills that are highly valued in automotive, motorsport, and transportation engineering industries..

Employability Skills:

- Ability to apply fluid mechanics and external aerodynamics principles to reduce drag, control flow separation, and optimize vehicle body shapes for improved fuel efficiency and high-speed stability.
- Competence in analyzing vehicle stability under aerodynamic loads, including crosswind effects, yaw moments, lift forces, and lateral load transfer for safe vehicle operation.
- Expertise in aerodynamic performance optimization of components such as spoilers, diffusers, underbody panels, and air dams to enhance downforce and reduce drag.
- Skill in wind tunnel experimentation, including model scaling, similarity principles, force

measurement, flow visualization techniques (smoke, tufts), and blockage correction methods.






- Knowledge of instrumentation and transducers such as pressure sensors, strain gauges, accelerometers, and data acquisition systems for on-road aerodynamic performance evaluation.
- Ability to interpret aerodynamic data using contour plots, streamline visualization, Cp distribution, and drag polar analysis to make engineering design decisions.
- Understanding of sustainability considerations, including drag reduction strategies for improving fuel economy and reducing vehicle emissions.
- Strong technical documentation and communication skills for preparing aerodynamic analysis reports, simulation summaries, and presenting design recommendations to industry professionals.

Project Management:

- Experience working in multidisciplinary teams, integrating aerodynamics with vehicle dynamics, structural design, thermal management, and powertrain systems.
- Competence in selecting appropriate turbulence models, meshing strategies, and solver settings based on accuracy requirements and computational cost.
- Capability to perform grid independence studies and validation exercises to ensure reliability and robustness of aerodynamic predictions.
- Proficiency in managing experimental campaigns, including scheduling wind tunnel tests, calibrating instruments, collecting data, and analyzing performance trends.
- Skill in presenting aerodynamic optimization strategies to improve vehicle performance, safety, and regulatory compliance in automotive industries.

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 |  <p>QUALITY EDUCATION</p> | <p>Quality Education: The course enhances advanced analytical, computational, and problem-solving skills among students, fostering critical thinking and innovation in fluid flow and heat transfer simulations. Through project-based learning and research-oriented assignments, students engage in experiential learning that aligns with industry 4.0 skills and lifelong professional growth in aerodynamics, thermal sciences, and computational engineering.</p> |
| 9 |  <p>INDUSTRY, INNOVATION AND INFRASTRUCTURE</p> | <p>Industry, Innovation, and Infrastructure: Students learn to simulate and optimize aerodynamic and thermal systems, leading to efficient design of turbines, nozzles, ducts, and cooling systems. The course promotes computational prototyping that reduces physical testing, thereby accelerating innovation and sustainable industrial development.</p> |
| 11 |  <p>SUSTAINABLE CITIES AND COMMUNITIES</p> | <p>Sustainable Cities and Communities: Students acquire the ability to simulate air flow around high-rise buildings, tunnels, and transport systems, contributing to the development of energy-efficient, climate-adaptive urban environments that improve air quality and occupant comfort.</p> |
| 12 |  <p>RESPONSIBLE CONSUMPTION AND PRODUCTION</p> | <p>Responsible Consumption and Production: Through numerical modeling and optimization techniques, CFD enables resource-efficient design and minimizes waste in product development and testing. By using virtual simulations instead of extensive physical experiments, students and engineers reduce material usage, energy consumption, and emissions, thereby supporting eco-efficient and responsible engineering practices in manufacturing and design processes.</p> |
| 13 |  <p>13 CLIMATE ACTION</p> | <p>Climate Action: The CFD course equips students to model and analyze atmospheric flows, heat transfer, and renewable energy systems, directly supporting climate research and mitigation strategies. Simulation of wind energy systems, heat exchangers, and cooling technologies helps in optimizing designs for reduced carbon footprint. Students learn to develop sustainable solutions for green aviation, energy conservation, and emission control, contributing to global climate resilience efforts</p> |

SECTION 11C: Course Articulation Matrix of COs to POs

| SECTION 11C: Course Articulation Matrix of COs to POs | | | | | | |
|--------------------------------------------------------------|-------------------------------|------------------------------------|----------|------------------------------------------|----------|----------------------------------|
| 0 No Contribution (0-5%) | | 1 Low (≥ 5 - <40%) | | 2 Moderate (≥ 40 - <60%) | | 3 High ($\geq 60\%$) |
| Course Outcomes | Program Outcomes (POs) | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 |
| CO1 | 3 | 2 | 3 | - | - | - |
| CO2 | - | 3 | 2 | 2 | - | - |
| CO3 | - | - | 2 | 3 | 2 | - |
| CO4 | 3 | - | 3 | - | 2 | - |
| CO5 | - | 2 | - | 3 | 3 | - |
| CO6 | - | 2 | - | 3 | 3 | - |
| Total | 6 | 9 | 10 | 11 | 10 | - |
| Average | 3 | 2 | 2 | 3 | 2 | - |

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

| Number | Programme Outcomes | Proficiency Assessed by | Contribution Level (from 1 to 3) |
|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|-----------------------------------------|
| PO 1 | An ability to Independently carry out research/investigation and development work to solve practical problems. | CIE / SEE / AAT:1 – 2 Assignments / Open-ended problems | 3 |
| PO 2 | Students should be able to 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. | CIE / SEE / AAT:1 – 2 | 3 |
| PO 5 | Conceptualize and design Aerospace engineering components considering various socio-economic factors. | CIE / SEE / AAT:2 – 2 Complex Engineering Problems | 3 |

SECTION 12: Course Content

| | |
|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MODULE I | OVERVIEW AND INTRODUCTION |
| | Historical developments and trends, fundamentals of fluid mechanics, flow phenomenon related to vehicles, external and internal flow problem, resistance to vehicle motion, mechanics of air flow around a vehicle, pressure distribution, aerodynamic forces, vehicle drag and types, side and lift forces, performance potential of vehicle aerodynamics. |
| MODULE II | AERODYNAMIC DRAG AND SHAPE OPTMIZATION OF CARS |
| | Cars as a bluff body, flow field around a car, analysis of aerodynamic drag, drag coefficient of cars, strategies for aerodynamic development, low drag profiles. Front end modification, front and rear wind shield angle, boat tailing, hatch back, fast back and square back, dust flow patterns at the rear, effect of rear configuration, effect of fasteners. |
| MODULE III | VEHICLE HANDLING AND STABILITY |
| | Origin, characteristics and effects of forces and moments on a vehicle, lateral stability problems. Vehicle dynamics under sidewinds, dirt accumulation on the vehicle. Wind noise: Mechanisms and generation design features, measurement and techniques. |

| | |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MODULE IV | RACE CAR AERODYNAMICS |
| | Basic vehicle body concepts, aerodynamics of the complete vehicle, flow over wheels, sliding seal and skirts, under body channels, simply add on: spoilers, strakes and wickers, internal flow, race car wings, most current examples in detail design. |
| MODULE V | MEASUREMENT AND TEST TECHNIQUES |
| | Wind tunnel scope, fundamental techniques, simulation limitations, prototype tests, wind tunnel types and testing methods, test techniques: scope, measuring equipment and transducers, road testing methods. |

| SECTION 13: Tentative Schedule of Instructions | | |
|-------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| Week Number | Topics | Duration (Hours) |
| 1 | 1.1 Historical developments and trends 1.2 fundamentals of fluid mechanics 1.3 flow phenomenon related to vehicles | 3 |
| 2 | 2.1 external and internal flow problem 2.2 resistance to vehicle motion 2.3 mechanics of air flow around a vehicle | 3 |
| 3 | 3.1 pressure distribution, aerodynamic forces 3.2 vehicle drag and types 3.3 side and lift forces | 3 |
| 4 | 4.1 performance potential of vehicle aerodynamics. 4.2 Cars as a bluff body, flow field around a car 4.3 analysis of aerodynamic drag | 3 |
| 5 | 5.1 drag coefficient of cars 5.2 strategies for aerodynamic development 5.3 low drag profiles | 3 |
| 6 | 6.1 Front end modification 6.2 front and rear wind shield angle 6.3 boat tailing, hatch back | 3 |
| 7 | 7.1 fast back and square back, dust flow patterns at the rear 7.2 effect of rear configuration 7.3 effect of fasteners | 3 |
| 8 | 8.1 VEHICLE HANDLING AND STABILITY and Origin, 8.2 characteristics and effects of forces and moments on a vehicle 8.3 lateral stability problems. | 3 |
| CONTINUOUS INTERNAL EXAMINATION (CIE- I) | | |
| 9 | 9.1 VEHICLE HANDLING AND STABILITY 9.2 Vehicle dynamics under sidewinds 9.3 dirt accumulation on the vehicle | 3 |
| 10 | 10.1 Wind noise: Mechanisms 10.2 Wind noise: generation design features 10.3 measurement and techniques | 3 |
| 11 | 11.1 Basic vehicle body concepts 11.2 aerodynamics of the complete vehicle 11.3 flow over wheels | 3 |
| 12 | 12.1 sliding seal and skirts 12.2 under body channels 12.3 simply add on: spoilers | 3 |
| 13 | 13.1 strakes and wickers 13.2 internal flow, race car wings 13.3 most current examples in detail design | 3 |
| 14 | 14.1 Wind tunnel scope 14.2 fundamental techniques | 3 |

| | | |
|--------------|------------------------------------------------------------------------------------------------------|-----------|
| | 14.3 simulation limitations | |
| 15 | 15.1 prototype tests 15.2 wind tunnel types 15.3 testing methods | 3 |
| 16 | 16.1 test techniques: scope 16.2 measuring equipment and transducers 16.3 road testing methods | 3 |
| Total | | 48 |

SECTION 14: Specific Goals for the Course

The following table shows the knowledge and skills covered by the unit outcomes:

| Knowledge | Skills |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> Understand the fundamental principles of fluid mechanics and external aerodynamics governing airflow around ground vehicles. Gain knowledge of aerodynamic forces such as drag, lift, and side forces and their influence on vehicle performance, fuel efficiency, and stability. Learn the concepts of vehicle dynamics and lateral stability, including yaw motion, load transfer, and understeer–oversteer characteristics. Understand the aerodynamic behavior of race vehicle components such as spoilers, diffusers, wings, and underbody surfaces for downforce generation. Acquire knowledge of experimental aerodynamic testing methods, including wind tunnel testing, similarity principles, and flow visualization techniques. Understand the principles of instrumentation and measurement systems, including transducers and sensors used for vehicle performance evaluation. | <ul style="list-style-type: none"> Ability to analyze aerodynamic flow behavior around ground vehicles using theoretical concepts and engineering analysis. Skill in applying CFD tools and aerodynamic principles to evaluate drag, pressure distribution, and wake structures. Capability to assess vehicle stability and dynamic behavior under various operating conditions such as crosswinds and high-speed maneuvers. Ability to conduct wind tunnel experiments and interpret aerodynamic data for design improvement. Skill in using measurement instruments and data acquisition systems for on-road performance testing of vehicles. Ability to interpret experimental and computational results to optimize aerodynamic performance and vehicle design. |

Administrative Information

SECTION 15: History of changes

| Regulations | Description of change | BOS Date |
|-------------|-------------------------------------------------------------------------------------------------------------------------------|------------|
| R 18 | Changes from R16 to R18 regulation <ul style="list-style-type: none"> New course introduced in this regulation | 10.07.2018 |
| PG 21 | Changes from R18 to PG 21 regulation <ul style="list-style-type: none"> No change | 17.11.2020 |
| MT 23 | Changes from PG21 to MT 23 regulation <ul style="list-style-type: none"> No change | 18.08.2023 |
| MT 25 | Changes from MT23 to MT 25 regulation <ul style="list-style-type: none"> No change | 01.09.2025 |

| Course Outline Approvals | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| Course Coordinator Name: Dr. Juluru Sandeep Signature: Date: 28/10/2025 | Head of the Department Name: Dr. S. Devraj Signature: Date: 28/10/25 |
| Course Outline Approvals: The course outline description approved by Outcome Based Teaching Learning (OBTL) committee on <i>date</i> in meetings <i>IARE - OBTL – COD /104/25</i> | |
| Dean of Outcome Based Teaching and Learning Name: Dr. CH Srinivasulu Signature: Date: 07/03/2026 | Dean of Academics Name: Dr. GVR Seshagiri Rao Signature: Date: 07/03/2026 |

| 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 | ✓ |