PhD Programme in Engineering/Sciences

Prospectus

Aerodynamics, Propulsion, Flight Control, Avionics

Materials, Surface Structures, Composites

Academy of Scientific & Innovative Research (AcSIR)
CSIR-National Aerospace Laboratories, Bangalore
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Academy of Scientific and Innovative Research (AcSIR)

PhD Programme in Engineering/Sciences

at

CSIR-National Aerospace Laboratories (CSIR-NAL), Bangalore

Academy of Scientific & Innovative Research (AcSIR) has been established in 2011, by an Act of Parliament, as an ‘Institution of National Importance’ with the mandate to create and train some of the best of tomorrow’s Science & Technology leaders through a combination of innovative and novel curricula, pedagogy and evaluation. National Aerospace Laboratories (NAL), Bangalore is a constituent Institution under the Council of Scientific and Industrial Research (CSIR) of India. NAL is a high technology oriented institution concentrating on advanced topics in the aerospace and related disciplines. Aerospace technology encompasses the trans-disciplinary areas of science and engineering and is in the forefront of modern developments and achievements in the fields of aeronautics, space and defence. It involves study of various disciplines namely aerodynamics, propulsion, flight mechanics, avionics, materials and structures. The PhD (Engineering/Sciences) programme being offered at CSIR-NAL, Bangalore through AcSIR aims to provide in-depth exposure to the engineering concepts, scientific principles, research methodology and hands on experience on advanced real life R&D projects in different areas related to aerospace engineering. Students completing this program are expected to be fully research – enabled and industry ready. This helps in meeting the severe shortage of the highly skilled manpower required for developing technologies for the future generation aerospace vehicles.

The first three semesters of the program focuses on the coursework required for equipping the students with the fundamentals of the subjects related to their research problem. In the subsequent semester/s the students work towards preparing two subject proposals before taking a comprehensive examination by selecting topics of high relevance and novelty, and will have state-of-the art review, methodologies, recommendations etc. After successfully completing the comprehensive examination the students will be utilizing their knowledge acquired through the coursework and literature review to solve real-world design challenges by working on advanced R&D topics and for a thesis on the chosen topic. Simultaneously, they will also be involved in a Six–Eight weeks project concerned with societal/rural issues under the ‘CSIR-800 Programs’ which needs to be completed before submission of the thesis.

Eligibility for Admission:

PhD (Engineering):

A Master’s degree in Engineering/Technology (Aeronautical/Aerospace/Mechanical/Structures/Materials/Ceramics/Chemical/Metallurgy/Electronics/Computers/Atmospheric and related areas) with exceptionally good academic record. The candidate should have a valid fellowship such as CSIR-SRF or CSIR-NET-JRF or equivalent and keen interest in carrying out research on topics relevant to aeronautics/aerospace engineering.

PhD (Sciences):

A Master’s degree in Sciences (Physics/Chemistry/Materials and related areas) with exceptionally good academic record. The candidate should have a valid fellowship such as CSIR-SRF or CSIR-NET-JRF or equivalent and keen interest in carrying out research on topics relevant to aeronautics/aerospace engineering.
Note: CSIR Scientists recruited 2009 onwards/Existing Research Fellows/Projects Fellows/ Project Assistants (working at CSIR labs for a minimum of one year)/Industry Sponsored Candidates who fulfil the qualifications are also eligible to apply.

Before applying, Industry Sponsored Candidates should have identified and established contacts with a scientist from NAL who is willing to supervise the thesis work.

For other details (such as Admission Process, Eligibility, Fellowship, Important Dates, fee structure, mode of payment and online application) please visit the AcSIR website http://acsir.res.in/
### Annexure – A: Curriculum of the Programme

#### PhD (Engineering) Programme

<table>
<thead>
<tr>
<th>Qualification at admission</th>
<th>Admitted to</th>
<th>Anticipated Financial Support</th>
<th>End-point</th>
<th>Min. Credit Requirement from Coursework</th>
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<tbody>
<tr>
<td>M.E/M.Tech</td>
<td>PhD (Engineering)</td>
<td>CSIR-SRF or CSIR-NET-JRF or Equivalent Fellowship</td>
<td>PhD (Engineering)</td>
<td>12 + 8</td>
</tr>
<tr>
<td>M.E/M.Tech + CSIR Lab Project Sponsorship</td>
<td>PhD (Engineering)</td>
<td>Sr. Project Fellowship/Project Assistantship from the sponsoring project</td>
<td>PhD (Engineering)</td>
<td>12 + 8</td>
</tr>
<tr>
<td>M.E/M.Tech + Industry Sponsorship</td>
<td>PhD (Engineering)</td>
<td>Salary from the sponsoring organization</td>
<td>PhD (Engineering)</td>
<td>08 + 8</td>
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#### PhD (Sciences) Programme

<table>
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<th>Qualification at admission</th>
<th>Admitted to</th>
<th>Anticipated Financial Support</th>
<th>End-point</th>
<th>Min. Credit Requirement from Coursework</th>
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</thead>
<tbody>
<tr>
<td>MSc</td>
<td>PhD (Sciences)</td>
<td>CSIR-SRF or CSIR-NET-JRF or Equivalent Fellowship</td>
<td>PhD (Sciences)</td>
<td>12 + 8</td>
</tr>
<tr>
<td>MSc + CSIR Lab Project Sponsorship</td>
<td>PhD (Sciences)</td>
<td>Sr. Project Fellowship/Project Assistantship from the sponsoring project</td>
<td>PhD (Sciences)</td>
<td>12 + 8</td>
</tr>
<tr>
<td>MSc + Industry Sponsorship*</td>
<td>PhD (Sciences)</td>
<td>Salary from the sponsoring organization</td>
<td>PhD (Sciences)</td>
<td>08 + 8</td>
</tr>
</tbody>
</table>

* Subject to approval by AcSIR

**Total Credits for the PhD (Engineering/Sciences) Programme:** Min. credit requirement from Coursework + Completion of thesis

*Two 4 credit courses are mandatory as per the following:

1. Two subject proposals to be prepared before comprehensive by selecting topics of high relevance and novelty, and will have state-of-the-art review, methodologies, recommendations etc. (2 credits each)
2. Six–Eight weeks have to be dedicated on a project concerned with societal/rural issues under the CSIR-800 Programs (4 credits). This needs to be completed before submission of thesis.

The balance credits to meet the min. from course work can be attained through foundation/core/elective courses offered at NAL or any other CSIR lab through AcSIR.
## Annexure – C: Summary of the Courses

### Foundation Courses (Level 1)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Code</th>
<th>Name of the Course</th>
<th>L-T-P-C</th>
<th>Course Coordinator</th>
<th>Division</th>
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<tbody>
<tr>
<td>1</td>
<td>ENG(NAL)-1-661</td>
<td>Applied Mathematical Methods</td>
<td>3-0-0-3</td>
<td>Dr AK Onkar</td>
<td>STTD</td>
</tr>
<tr>
<td>2</td>
<td>ENG(NAL)-1-662</td>
<td>Applied Numerical Methods</td>
<td>3-0-0-3</td>
<td>Dr M Manjuprasad</td>
<td>STTD</td>
</tr>
<tr>
<td>3</td>
<td>ENG(NAL)-1-663</td>
<td>Aircrafts and Systems</td>
<td>3-0-0-3</td>
<td>Mr. Vineet Kumar</td>
<td>CCADD</td>
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<tr>
<td>4</td>
<td>ENG(NAL)-1-664</td>
<td>Aerodynamics</td>
<td>2-0-0-2</td>
<td>Dr V Ramesh</td>
<td>CTFD</td>
</tr>
<tr>
<td>5</td>
<td>ENG(NAL)-1-665</td>
<td>Aerospace Propulsion</td>
<td>2-0-0-2</td>
<td>Mr. P Manjunath</td>
<td>PR</td>
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<tr>
<td>6</td>
<td>ENG(NAL)-1-666</td>
<td>Flight Mechanics</td>
<td>2-0-0-2</td>
<td>Dr Jatinder Singh</td>
<td>FMCD</td>
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<td>7</td>
<td>ENG(NAL)-1-667</td>
<td>Avionics</td>
<td>2-0-0-2</td>
<td>Dr CM Ananda</td>
<td>ALD</td>
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<td>8</td>
<td>ENG(NAL)-1-668</td>
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<td>Dr M Sujata</td>
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<td>ENG(NAL)-1-669</td>
<td>Structural Mechanics</td>
<td>2-0-0-2</td>
<td>Dr DVTG Pavan Kumar</td>
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### Core Courses (Level 2)

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<td>ENG(NAL)-2-661</td>
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<td>CTFD</td>
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<tr>
<td>12</td>
<td>ENG(NAL)-2-663</td>
<td>Gas dynamics</td>
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<td>ENG(NAL)-2-664</td>
<td>Low speed aerodynamics</td>
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<td>EAD</td>
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<td>14</td>
<td>ENG(NAL)-2-665</td>
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<td>ENG(NAL)-2-666</td>
<td>Gas Turbine Propulsion</td>
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<td>16</td>
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<td>Heat Transfer in Propulsion Systems</td>
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<td>FMCD</td>
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<td>Dr CM Ananda</td>
<td>ALD</td>
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<td>19</td>
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<td>Advanced Avionics</td>
<td>3-0-0-3</td>
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<td>ALD</td>
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<td>21</td>
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<tr>
<td>22</td>
<td>ENG(NAL)-2-673</td>
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<td>23</td>
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<td>24</td>
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<td>25</td>
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<td>ENG(NAL)-2-677</td>
<td>Surface Modification Technologies</td>
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<tr>
<td>27</td>
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<td>29</td>
<td>ENG(NAL)-2-680</td>
<td>Finite Element Methods</td>
<td>3-0-0-3</td>
<td>Dr M Manjuprasad</td>
<td>STTD</td>
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<td>30</td>
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<td>Structural Dynamics</td>
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<td>Dr S Raja</td>
<td>STTD</td>
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<td>31.</td>
<td>ENG(NAL)-2-682</td>
<td>Stability of Structures</td>
<td>3-0-0-3</td>
<td>Dr AK Onkar</td>
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<tr>
<td>32.</td>
<td>ENG(NAL)-2-683</td>
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<td>33.</td>
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<td>Design of Composite Structures</td>
<td>3-0-0-3</td>
<td>Dr Byji Varughese</td>
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<tr>
<td>34.</td>
<td>ENG(NAL)-2-685</td>
<td>Analysis of Composite Structures</td>
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<td>35.</td>
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<td>Processing &amp; Characterization of Composite Materials</td>
<td>3-0-0-3</td>
<td>Dr Shylaja Srihari</td>
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**Specialization Courses (Level 3)**

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<th>Division</th>
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<td>36.</td>
<td>ENG(NAL)-3-661</td>
<td>Grid generation techniques for CFD</td>
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<td>Dr JS Mathur</td>
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<td>37.</td>
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<td>Dr JS Mathur</td>
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<td>38.</td>
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<td>Turbulent Flows</td>
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<td>Dr L Venkatakrishnan</td>
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<td>Dr Channa Raju</td>
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<td>40.</td>
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<td>Mechanical aspects of Turbo Machinery</td>
<td>3-0-0-3</td>
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<td>41.</td>
<td>ENG(NAL)-3-666</td>
<td>Propulsion Systems for Light Aero Vehicles</td>
<td>3-0-0-3</td>
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<td>ENG(NAL)-3-667</td>
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<tr>
<td>43.</td>
<td>ENG(NAL)-3-668</td>
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<tr>
<td>47.</td>
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<td>49.</td>
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<td>50.</td>
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<td>Dr Prasanta Chowdhury</td>
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<tr>
<td>51.</td>
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<td>Computational Structural Dynamics and Aeroelasticity</td>
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<td>52.</td>
<td>ENG(NAL)-3-677</td>
<td>Computational Nonlinear Structural Mechanics and Vulnerability</td>
<td>2-0-2-3</td>
<td>Dr M Manjuprasad</td>
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<tr>
<td>53.</td>
<td>ENG(NAL)-3-678</td>
<td>Computational Stochastic Structural Mechanics and Reliability</td>
<td>2-0-2-3</td>
<td>Dr M Manjuprasad</td>
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<td>54.</td>
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<td>Applied Aeroelasticity</td>
<td>3-0-0-3</td>
<td>Dr S Raja</td>
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<tr>
<td>55.</td>
<td>ENG(NAL)-3-680</td>
<td>Smart Materials and Structures</td>
<td>3-0-0-3</td>
<td>Dr S Raja</td>
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<td>56.</td>
<td>ENG(NAL)-3-681</td>
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<td>57.</td>
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<td>3-0-0-3</td>
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<td>58.</td>
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<td>59.</td>
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<td>Mechanical Design and CAD/CAM</td>
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<td>Dr G Balamurugan</td>
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<tr>
<td>60.</td>
<td>ENG(NAL)-3-685</td>
<td>Mechanical Systems Design and Aircraft Systems</td>
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<tr>
<td>61.</td>
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<tr>
<td>62.</td>
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<td>Dr S Sathiyararayan</td>
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<tr>
<td>63.</td>
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<td>64.</td>
<td>ENG(NAL)-3-689</td>
<td>Digital Signal Processing and Applications</td>
<td>2-0-2-3</td>
<td>Mr. PS Vijayakumar</td>
<td></td>
</tr>
<tr>
<td>65.</td>
<td>ENG(NAL)-3-690</td>
<td>Manufacturing Techniques for Composites</td>
<td>2-0-2-3</td>
<td>Dr Ramesh Sundaram</td>
<td></td>
</tr>
<tr>
<td>66.</td>
<td>ENG(NAL)-3-691</td>
<td>Repair Technology for Aircraft Structures using Composites</td>
<td>2-0-2-3</td>
<td>Mr. D Saji</td>
<td></td>
</tr>
<tr>
<td>67.</td>
<td>ENG(NAL)-3-692</td>
<td>Experimental Techniques for Composites</td>
<td>2-0-2-3</td>
<td>Mr. D Saji</td>
<td></td>
</tr>
<tr>
<td>68.</td>
<td>ENG(NAL)-3-693</td>
<td>Non-Destructive Testing and Evaluation</td>
<td>2-0-2-3</td>
<td>Mr. M Ramesh Kumar</td>
<td></td>
</tr>
<tr>
<td>69.</td>
<td>ENG(NAL)-3-694</td>
<td>Introduction to Continuum mechanics</td>
<td>3-0-0-3</td>
<td>Dr VL Sateesh</td>
<td></td>
</tr>
<tr>
<td>70.</td>
<td>ENG(NAL)-3-695</td>
<td>Textile Reinforcements for Composites</td>
<td>2-0-2-3</td>
<td>Dr BS Sugun</td>
<td></td>
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</table>
Annexure – D: Syllabus of the Courses

Foundation Courses (Level 1)

ENG(NAL)-1-661: Applied Mathematical Methods: 3-0-0-3
Course Coordinator: Dr AK Onkar
Associated Faculty: Dr VL Sateesh, Dr SR Viswamurthy and Dr Lalitha Chattopadhyay

Linear Algebra: Matrices and matrix algebra, system of linear equations, LU decomposition, introduction to vector spaces, linear transformation, orthogonalization, eigensystems, diagonalization, singular value decomposition, introduction to tensor and tensor eigensystems. Ordinary Differential Equations: Introduction to first order ODEs, method of separation of variables, exact solutions, introduction to second order ODEs, homogeneous linear equations, equations with constant and variable coefficients, nonhomogeneous equations, series solutions of ODEs, Legendre and Bessel functions, Strum Louville problems, Laplace transform and its application to ODEs. Partial Differential Equations: Introduction to first order PDEs, method of characteristics, method of separation of variables, classification of second order PDEs, reduction to standard form, heat and wave equations in one and two dimensions, two dimensional Laplace equation, PDEs in infinite and semi infinite spatial domain, integral transform, Fourier transform, solving PDEs using Fourier and Laplace transforms, non-homogeneous PDEs

ENG(NAL)-1-662: Applied Numerical Methods: 3-0-0-3
Course Coordinator: Dr M. Manjuprasad
Associated Faculty: Ms. S Manju, Mr. PS Vijayakumar


ENG(NAL)-1-663: Aircrafts and Systems: 3-0-0-3
Course Coordinator: Mr. Vineet Kumar
Associated Faculty: Mr. Lakshminarayana and Mr. Bhaskar Chakravarthy

Evolution of heavier-than air aircraft for several applications: passenger, transport, freight, military applications. Configurations of various types of aircraft: Fixed wing aircraft, various types of aircraft, identification of various structural parts, materials used and their functions. Interplay of aerodynamics, structural mechanics, propulsion, avionics and controls in their conceptualization and performance. Introduction to aircraft specifications: Standards for both Military and Civil aircraft, Airworthiness certification aspects aircraft introduction to flight-testing: Purpose and Scope of Flight Testing; introduction to general flying and handling characteristics of aircraft. Flight test plans and procedures, Flight test data acquisition, analysis and interpretation. Aircraft systems: Mechanical, Electrical and Avionics subsystems integration.

ENG(NAL)-1-664: Aerodynamics: 2-0-0-2
Course Coordinator: Dr V Ramesh

Introduction, relevant properties of a fluid, pressure, temperature, density, viscosity, bulk elasticity, Thermodynamic properties. Hydrostatics, aerostatics and the atmosphere. Aeronautical definitions: Wing geometry, airfoil geometry, aerodynamic force, force and moment coefficients, pressure distribution on an airfoil, estimation of the lift, drag and pitching moment coefficients, Trailing vortex drag, lift dependent drag, airfoil characteristics. Basic Fluid mechanics: One dimensional flow: The basic equations of conservation, measurement of air speed, compressible one-dimensional flow, speed of sound, one-dimensional normal shock waves.

ENG(NAL)-1-665: Aerospace Propulsion: 2-0-0-2
Course Coordinator: Mr. P Manjunath
Associated Faculty: Dr S Jana, Mr. R Senthil Kumaran, Mr. Ashfaque Ahmad Khan

ENG(NAL)-1-666: Flight Mechanics: 2-0-0-2
Course Coordinator: Dr Jatinder Singh
Associated Faculty: Dr GK Singh, Mr. PVS Murthy, Ms. P Lathasree, Dr C Kamali


ENG(NAL)-1-667: Avionics: 2-0-0-2
Course Coordinator: Mr. CM Ananda
Associated Faculty: Ms. J Jayanthi, Dr SM Vaitheeswaran


ENG(NAL)-1-668: Aerospace Materials: 2-0-0-2
Course Coordinator: Dr M Sujata
Associated Faculty: Mr. D Saji
Aerospace Materials: Design requirements for aerospace structural materials, general perspectives of advanced aerospace materials with regard to fuselage, propulsion and space vehicle applications. Metallic Materials: Aluminium alloys-Physical metallurgy and mechanical properties with emphasis on aeronautical requirement, temper designations, processing and properties, alloy specifications of aerospace grade Al-alloys; magnesium alloys used for aerospace applications; structural steels-various grades of steels used for landing gear, transmission systems and fatigue critical applications; Titanium alloys-Physical metallurgy, mechanical properties, processing and applications of aerospace grade alloys; Ni-base superalloys-evolution of materials for aero-engine applications, recent developments for aero-gas turbine, advanced thermal barrier coatings on superalloys used for gas turbine. Polymeric based composite (PMC) materials-Introduction, quasi-static strength of PMCs, reinforcements and matrices in PMCs, interfaces, processing and properties of composites, advantages of composites; carbon fibres, Carbon fibre-reinforced plastics (CFRP) and glass fibre reinforced plastics (GFRP), joining and repair of composites, Introduction to Damage tolerant composites, Destructive and Non-destructive testing, fracture and toughness of composites, fatigue strength of PMCs. Metal-based composite materials-Introduction, metal-ceramic composites, laminates, and applications of MMCs. Recent advances in smart materials’ applications in aerospace, superplastic forming and diffusion bonding processing of aerospace alloys. Life prediction of materials and structures in aerospace-fatigue and fracture of metallic materials, random load fatigue and life prediction, physical reason for the existence of effective $\Delta K$, crack growth and life prediction, special testing techniques-SCC, fracture toughness, microstructural degradation, stress rupture etc.,

ENG(NAL)-1-669: Structural Mechanics: 2-0-0-2

Course Coordinator: Dr DVTG Pavan Kumar

Associated Faculty: Dr VL Sateesh

Basic elasticity- Stress and Strain, Equations of equilibrium, Plane stress and strain, Boundary conditions, Principal stresses and strains, Compatibility equations, Mohr's circle, Stress-strain relationships, Hooke's law; Two-dimensional elasticity problems in Rectangular and Polar coordinates: Stress functions, Bending of an end-loaded cantilever, Plate with a hole; Torsion of solid sections; Stresses in Simple Structural Members: Axially loaded members, Stresses in beams, Deflection of beams by integration, Euler column buckling, Thin-walled pressure vessels, Yield and fracture criteria, Introduction to bending of thin plates.
Core Courses (Level 2)

ENG(NAL)-2-661: Fluid Dynamics: 3-0-0-3
Course Coordinator: Dr V Ramesh


ENG(NAL)-2-662: Computational Fluid Dynamics: 3-0-0-3
Course Coordinator: Dr JS Mathur
Associated Faculty: Dr V Ramesh


ENG(NAL)-2-663: Gas Dynamics: 3-0-0-3
Course Coordinator: Dr L Venkatakrishnan
Associated Faculty: Mr. A Sathia Narayanan, Mr. C Manisankar and Mr. P Suriyanarayanan

Fundamentals of thermodynamics; propagation of small disturbances in gases; normal and oblique shock relations, nozzle flows; one-dimensional unsteady flow; small disturbance theory of supersonic speeds, generation of supersonic flows in tunnels, supersonic flow diagnostics, supersonic flow over two-dimensional bodies; shock expansion analysis, method of characteristics; one-dimensional rarefaction and compression waves; flow in shock tube. Laboratory classes for demonstrating the concepts and conducting of experiments.

ENG(NAL)-2-664: Low speed aerodynamics: 3-0-0-3
Course Coordinator: Dr L Venkatakrishnan
Associated Faculty: Mr. P Suriyanarayanan

Elementary flows, Introduction to small perturbation theory, 2-D airfoils in subsonic flow, numerical methods for 2-D airfoils, similarity rules, Multhops method, vortex lattice and double lattice methods, aerodynamics of wing-fuselage system and aerodynamics of control surfaces. High angle of attack aerodynamics: non-linear aerodynamics, unsteady aerodynamics. 2D numerical solutions. Thin aerofoil theory, lifting line theory.
ENG(NAL)-2-665: Boundary Layer Theory: 3-0-0-3
Course Coordinator: Dr R Mukund
Associated Faculty: Mr. M Viji

Navier-Stokes equation and its importance, Prandtl’s boundary layer approximations, Significance of scaling, 2D boundary layer equations, asymptotic theory, Blasius solutions, momentum integral methods, Axisymmetric and 3D boundary layer, thermal boundary layer, compressible boundary layer, Unsteady boundary layer, Instability, turbulent boundary layer, Reynolds stress, turbulent boundary layer on flat plate, pipe flows, introduction to perturbation techniques.

ENG(NAL)-2-666: Gas Turbine Propulsion: 3-0-0-3
Course Coordinator: Mr. Dileepkumar Alone
Associated Faculty: Mr. Kishore Kumar, Mr. K Sathiyamoorthy, Mr. G Muthu Selvan


ENG(NAL)-2-667: Heat Transfer in Propulsion Systems: 3-0-0-3
Course Coordinator: Mr. R Senthil Kumaran
Associated Faculty: Mr Y Giridhara Babu, Mr. J Felix, Mr. C Jayaprakash

**ENG(NAL)-2-668: Aircraft Stability and Control: 3-0-0-3**

Course Coordinator: Dr GK Singh
Associated Faculty: Mr. PVS Murthy, Mr. R Guruganesh, Mr. S Viswanathan

Introduction to open- and closed-loop control systems and examples, Differential equation models of physical systems and solution methods, choice of linear models, Laplace transforms, transfer functions, and block diagrams, State-variable system models, relative stability, gain and phase margins, Bode plots, Nyquist stability Criterion, Nichols chart, linear design process, Root locus design methods, System bandwidth, Feedback system characteristics, Design of feedback systems in the frequency- and time-domain, Pole placement method, Observability and controllability, angle-of-attack limiter, sideslip angle and sideslip rate feedback, roll rate feedback, design of command paths, nonlinear design and verification, control power requirements for unstable aircraft, control actuator rate requirements, limits on static instability, control surface sizing, center-of-gravity limits, inertia cross coupling, roll coupling, autorotation, roll reversal, Longitudinal and Lateral stability Augmentation, Fundamentals of Inertial Navigation, Basic autopilot control laws

**ENG(NAL)-2-669: Systems Engineering: 3-0-0-3**

Course Coordinator: Dr CM Ananda
Associated Faculty: Mr. A Pankaj, Ms. Manju Nanda


**ENG(NAL)-2-670: Advanced Avionics: 3-0-0-3**

ENG(NAL)-2-671: Advanced Embedded Systems and Software Engineering: 3-0-0-3
Course Coordinator: Ms. J Jayanthi
Associated Faculty: Dr CM Ananda, Ms. Manju Nanda


ENG(NAL)-2-672: Mechanical behavior of materials: 3-0-0-3
Course Coordinator: Dr M. Sujata
Associated Faculty: Dr S.K. Bhaumik, Dr V. Ranganath, Dr CM Manjunatha, Dr Shylaja Srihari


**ENG(NAL)-2-673: Processing and Characterization of Metals: 3-0-0-3**

Course Coordinator: Dr K Venkatswarulu  
Associated Faculty: M Suresh Kumar


**ENG(NAL)-2-674: Advanced Ceramics Materials: 3-0-0-3**

Course Coordinator: Dr PK Panda  
Associated Faculty: Dr R Ramachandra Rao, Dr L Rangaraj, Mr. A Udaya Kumar

Physical Ceramics: Introduction and classification of ceramics, oxide ceramics (alumina, silica, zirconia, magnesia etc.), non oxide ceramics (SiC, Si₃N₄, SiAlON, Boron Carbide etc), chemical bonding and crystal structure, defects in crystal, x-ray diffraction, Bragg’s law, phase analysis of ceramics by XRD technique, morphology and ceramic microstructure by scanning electron microscopy (SEM), phase equilibria of binary and ternary ceramic systems. Processing of Ceramics: Hydrothermal synthesis, sol-gel, co-precipitation, reaction synthesis, colloidal processing, slip casting and tape casting, injection moulding, isostatic pressing, Gas phase synthesis: chemical vapor deposition (CVD), chemical vapor infiltration
Fabrication of ceramic components by CVI/CVD, sintering and crystallization, hot pressing, nucleation and grain growth, hot isostatic pressing, spark plasma sintering. Liquid phase synthesis: melt infiltration and polymeric derived ceramics (PDC). Characterization of Ceramics: particle size and surface area analysis, porosity and density, theoretical fracture strength, Griffith's theory of brittle fracture, toughness and fracture toughness, factors influencing the strength of ceramic materials, toughening mechanisms in ceramics, Mechanical testing of ceramic materials: modulus of rupture (MOR), 3-point and 4-point bend, Tensile strength, Fracture toughness ($K_{IC}$) by indentation, Single Edge Notched Beam (SENB) and $R$ curve methods, Hardness measurements, creep and fatigue, thermal properties (heat capacity, thermal conductivity, coefficient of thermal expansion) of ceramics, thermal stress and thermal shock resistance (Kingery's and Hasselmann theory), thermal fatigue etc. Electrical properties: dielectric, ferroelectric, piezoelectric properties, barium titanate and lead zirconate titanate (PZT), sensors and actuators, magnetic properties (diamagnetic, paramagnetic and ferromagnetic). Applications of ceramic materials for aerospace applications, high temperature structural application, as sensors and actuators etc.

**ENG(NAL)-2-675: Piezoelectric Materials and Devices: 3-0-0-3**

**Course Coordinator:** Dr Soma Dutta  
**Associated Faculty:** Dr Anjana Jain, Dr PK Panda


**ENG(NAL)-2-676: Corrosion Engineering: 3-0-0-3**

**Course Coordinator:** Dr JN Balaraju  
**Associated Faculty:** Ms. Meenu Srivastava, Dr. Amitha Rani
Electrochemical and thermodynamic principles, Nernst equation and electrode potentials of metals, EMF and galvanic series, merits and demerits; origin of Pourbaix diagram and its importance to iron, aluminium and magnesium metals. Exchange current density, polarization - concentration, activation and resistance, Tafel equation; passivity, electrochemical behaviour of active/passive metals, Flade potential, theories of passivity. Atmospheric, pitting, dealloying, stress corrosion cracking, intergranular corrosion, corrosion fatigue, fretting corrosion and high temperature oxidation; causes and remedial measures. Susceptibility tests for IGC, stress corrosion cracking and pitting, sequential procedure for laboratory and on-site corrosion investigations, corrosion auditing and corrosion map of India, Salt Spray Test and standards. Corrosion prevention by design improvements, anodic and cathodic protection, metallic, non-metallic and inorganic coatings, mechanical and chemical methods and various corrosion inhibitors.

**ENG(NAL)-2-677: Surface Modification Technologies: 3-0-0-3**

Course Coordinator: Dr ST Aruna
Associated Faculty: Dr C Anandan, Ms. Meenu Srivastava

Introduction to Surface Modification – Importance and Methods. Surface degradation-tribology, wear and corrosion- types of wear, adhesive, abrasive, oxidative, corrosive, erosive and fretting wear, role of friction and lubrication; overview of different forms of corrosion, Tribocorrosion. Chemical and electrochemical polishing, chemical conversion coatings- phosphating, chromating, chemical colouring, anodization; Electro/electroless deposition - deposition of copper, zinc, nickel and chromium, alloy and composite plating by electro/electroless methods, sol-gel coatings, their properties and applications. Thermochemical and plasma chemical processes- nitriding, carburising, ion implantation etc. Vacuum deposition techniques - physical vapour deposition (PVD), evaporation, sputtering, ion plating, plasma nitriding, chemical vapour deposition (CVD), plasma assisted CVD. Thermal spraying, techniques, advanced spraying techniques - plasma surfacing, detonation gun and high velocity oxy-fuel processes, laser surface alloying, laser cladding, specific industrial applications.

**ENG(NAL)-2-678: Nanostructured Coatings and Materials: 3-0-0-3**

Course Coordinator: Dr Harish C. Barshilia
Associated Faculty: Dr ST Aruna, Dr Prasanta Chowdhury, Dr PK Panda, Dr. CM Manjunatha

Introduction: Concept of nanomaterials – scale / dimensional aspects, nano and nature, effect of size reduction on various properties, advantages and limitations at the nano level. Methods to produce nanomaterials: Plasma methods, chemical vapour deposition, sol-gel process, electro/electroless deposition, ball milling, severe plastic deformation, combustion synthesis etc. Applications: Fullerenes, carbon nano tubes, nano composites, nanosensors, nanomedicines, multilayered coatings, Superhard coatings, Magnetic materials etc. Health Issues: Understanding the toxicity of nanoparticles and fibers, exposure to quartz, asbestos, air pollution. Environmental issues: Effect on the environmental and other species. Societal implications: Implications of nanoscience and technology in society, government regulations. Introduction to characterization of nanomaterials. Nanofibers, methods of preparation, electrospinning, polymer and ceramic nanofibers by electrospinning, applications of nanofibers.

**ENG(NAL)-2-679: Advanced Structural Mechanics: 3-0-0-3**
Thin plates: Kirchhoff theory – strain-displacement relations, stress-strain relations, stress resultants, equilibrium equations, boundary conditions; Analysis of rectangular and circular plates with different boundary conditions and loadings; Buckling of plates; Thermal stresses in plates; Membrane theories for the analysis of circular cylindrical, spherical and conical shells; Bending, shear and torsion of open and closed, thin-walled beams; Bending of open and closed section beams, General stress, strain and displacement relationships for open and single cell closed section thin-walled beams, Shear of open section beams, Shear of closed section beams, Torsion of closed section beams, Torsion of open section beams, Analysis of combined open and closed sections; Stress analysis of aircraft components: Tapered Beams, Fuselage, Wing. Introduction to fatigue, fracture and damage tolerance analysis of aircraft structural components.

ENG(NAL)-2-680: Finite Element Methods: 3-0-0-3
Course Coordinator: Dr M Manjuprasad
Associated Faculty: Ms. S Manju, Dr Amit Kr. Onkar


ENG(NAL)-2-681: Structural Dynamics: 3-0-0-3
Course Coordinator: Dr S Raja
Associated Faculty: Mr. B Balakrishnan

Introduction to vibration and airframe structures, single and multi degrees of freedom systems, different structural models (physical, spatial, modal), vibration of beams & plates, numerical techniques in structural vibration, measurement devices & instrumentation, structural testing methodologies, structural coupling and vibration controls.

ENG(NAL)-2-682: Stability of Structures: 3-0-0-3
Course Coordinator: Dr Amit Kr. Onkar
Concepts of stability, bifurcation and limit point instability, stability of discrete systems, linear and nonlinear behavior, stability of beams and columns, energy methods, static and dynamic formulations, axial-flexural buckling, lateral-torsion buckling, buckling of beams on elastic foundations, imperfection sensitivity analysis, stability of plates, axial-flexural buckling, shear-flexural buckling, buckling under combined loads, introduction to inelastic buckling and dynamic stability, parametric instabilities and stability under non-conservative forces, introduction to aeroelasticity, divergence and flutter.

ENG(NAL)-2-683: Mechanics of Composites: 3-0-0-3
Course Coordinator: Dr SR Viswamurthy

Classification of composites, behaviors of unidirectional composites, prediction of elastic constants using micromechanics, Homogenization theory, Voigt and Reuss approximation, two and three phase composite cylinder models; strength of composites, failure modes, macromechanical analysis of lamina; Properties of laminates and their constitutive equations, classical laminate and shear deformation theories, analysis of laminates, interlaminar stresses, failure theories, analysis of laminates after initial failure. Analysis of laminated composite beams.

ENG(NAL)-2-684: Design of Composite Structures : 3-0-0-3
Course Coordinator: Dr Byji Varughese
Associated Faculty: Mr. Lohith, Ms. Kumari Asha, Ms. Manisha M Banker


ENG(NAL)-2-685: Analysis of Composite Structures: 3-0-0-3

ENG(NAL)-2-686: Processing & Characterization of Composite Materials: 3-0-0-3

Introduction to composites, classification of composites (based on matrices-PMC, MMC & CMC, based on reinforcement – particulate, continuous reinforcements, special class of composites – hybrid, bio composites, Nano composites), PMC for aerospace application (thermoset/ thermoplastic based composites), Polymer matrix composite processing technologies, characterisation / testing of composites (physical/ thermal/ mechanical/thermomechanical/hygrothermal), hygrothermal effects on the properties of composites (hotwet degradation & certification aspects)
Specialization Courses (Level 3)

ENG(NAL)-3-661: Grid Generation Techniques for CFD: 2-0-2-3
Course Coordinator: Dr JS Mathur
Associated Faculty: Mr. K Madhu Babu

Introduction various grid generation techniques, structured grid generation, Algebraic grid generation methods, introduction to PDE based grid generation techniques, concept of grid control and grid control functions, examples of simple grid generation methods in 2D and 3D, multi-block approach for complex configurations. Introduction to unstructured grid generation, Delaunay triangulation method, 2D and 3D unstructured meshes, concept of isotropic and un-isotropic tetrahedral meshes, concept of hybrid grids. Unconventional methods, the Cartesian Grid and Mesh free approach. A brief hands-on training on the POINTWISE software for grid generation.

Course Coordinator: Dr JS Mathur
Associated Faculty: Dr V Ramesh and Mr. Keshav S. Malagi

An introduction to kinetic schemes for CFD, The moment method strategy for computation of inviscid flows. Concept of up-winding at the kinetic level, introduction to 1-D FDM,FVM kinetic upwind schemes, stability and consistency studies for kinetic schemes, introduction to multi-dimensional problems, variants of kinetic schemes, the kinetic mesh free methods.

ENG(NAL)-3-663: Turbulent Flows: 3-0-0-3
Course Coordinator: Dr L Venkatakrishnan
Associated Faculty: Mr. N Karthikeyan and Mr. Kiran Chutkey

Characteristics of turbulent flows, RANS equations, vortex dynamics, concepts of equilibrium and similarity, Free shear layers, wall bounded flows, Stability of fluid flows, laminar-turbulent transition, statistical aspects of turbulence, scales in turbulence, spectrum of turbulence, basics of turbulence modelling, turbulent measurement techniques.

ENG(NAL)-3-664: Experimental Aerodynamics: 3-0-0-3
Course Coordinator: Dr Channa Raju
Associated Faculty: A Sathia Narayanan and P Suriyanarayanan

Introduction to aerodynamic testing in various speed regimes; requirements of aerodynamic testing; Design aspects of low speed wind tunnels; flow visualization methods; Measurement methods for flow variables. Wind tunnel balances; Elements of computer based instrumentation ; measurements and analyses methods; Model Design, Pressure, Flow, and Shear Stress measurements; Forces and moments from balance measurements, Sources of error in wind tunnel data, scale effects in data usage, general test procedures for aircraft. Introduction to advanced optic based flow diagnostics.
ENG(NAL)-3-665: Mechanical Aspect of Turbo Machinery: 3-0-0-3
Course Coordinator: Dr S Jana
Associated Faculty: Mr. SS Kulkarni


ENG(NAL)-3-666: Propulsion Systems for Light Aero Vehicles: 3-0-0-3
Course Coordinator: Mr. K. Monickavasagom Pillai
Associated Faculty: Mr. HS Muralidhara, Mr. AJ Steve Mithran


ENG(NAL)-3-667: Experimental Techniques in Propulsion: 2-0-2-3
Course Coordinator: Mr. P Manjunath

ENG(NAL)-3-668: Flight Vehicle Identification – Tools & Techniques: 3-0-0-3
Course Coordinator: Mr. Basappa
Associated Faculty: Dr Sachin Tharewal


ENG(NAL)-3-669: Digital Image Processing and Applications: 3-0-0-3
Course Coordinator: Dr VPS Naidu

Digital image fundamentals, intensity transformations and spatial filtering, frequency domain processing, image enhancement, image restoration, color image processing, morphological image processing, image segmentation, stereo vision and correspondence problem, image registration, image fusion, matlab examples, and case studies.

ENG(NAL)-3-670: Multi Sensor Data Fusion: 3-0-0-3
Course Coordinator: Dr VPS Naidu

Multi sensor data fusion introduction, algorithms for data fusion, Multi sensor estimation, Decentralized data fusion, Multi sensor multi target tracking, Fundamentals of image processing, Image registration, Image fusion, Flight vision, Matlab examples and case studies.
ENG(NAL)-3-671: INS/GPS Multi-sensor Kalman Filter for Navigation: 3-0-0-3
Course Coordinator: Mr. N Shantha Kumar
Associated Faculty: Dr Sudesh K Kashyap, Dr C Kamali

Inertial sensing principles and technology, Simple low cost INS implementations, Inertial mechanization / Error models, GPS principles, signals, receivers, Simple multi-sensor Kalman Filter, Error modeling applications, INS/ GPS multi-sensor integration.

ENG(NAL)-3-672: Vision based Guidance and Control: 3-0-0-3
Course Coordinator: Dr SM Vaitheeswaran
Associated Faculty: Ms. Veena Shantaram, Mr. H Lokesha


ENG(NAL)-3-673: Advanced Experimental Techniques in Materials Science: 2-0-2-3
Course Coordinator: Dr C Anandan
Associated Faculty: Dr Venkateswarlu, Dr Anjana Jain, Dr M Sujata

ENG(NAL)-3-674: Materials for Energy Conversion: 3-0-0-3
Course Coordinator: Dr ST Aruna
Associated Faculty: Dr C Anandan, Dr Parthasarathi Bera, Dr B Shri Prakash

Fundamental of electrochemical energy conversion – Thermo dynamical and kinetic aspects – Relevance in aerospace applications- Principles of Batteries and Fuel cell operations – Types of batteries and fuel cells - Components of batteries and fuel cells and their material aspects - Experimental techniques. Introduction to solar radiation and heat transfer, various types of solar collectors, solar water heating, solar cooling, solar industrial process heat and types of solar thermal power systems, photovoltaics, Hydrogen energy - production and storage.

ENG(NAL)-3-675: Nano-Dimensional Magnetic Thin Films: 2-0-2-3
Course Coordinator: Dr P Chowdhury
Associated Faculty: Dr Harish C. Barshilia

Introduction: Magnetism, Magnetostatics, Magnetism of electron, Ferromagnetism, Antiferromagnetism and other ferromagnetic order, Micromagnetism, domain and hysteresis, Nanoscale magnetism, Experimental methods, Application of soft magnetic materials and its application, hard magnetic materials and it’s applications, Spin electronics, Magnetic sensor, Principle of magnetic sensing, Signal and noise, Different type of magnetic sensor, field mapping, Applications of magnetic sensors.

ENG(NAL)-3-676: Computational Structural Dynamics and Aeroelasticity: 2-0-2-3
Course Coordinator: Dr M Manjuprasad
Associated Faculty: Mr. AC Pankaj, Dr Amit Kr. Onkar

Variational Principles, Hamilton’s Least Action Principle, Lagrange’s equations; Vibration of multi-degree of freedom systems; Finite element formulation for elasto-dynamics of continuous systems; bar, beam and plates; Normal mode expansions and direct integration; Static/dynamic condensation and sub-structuring techniques; Torsion and bending of an aircraft wing; Static aeroelasticity and divergence of a wing; Dynamic aeroelasticity and
bending-torsion flutter of a wing; Dynamic response of a wing to gust and atmospheric turbulence; Introduction to system identification based flutter prediction; Concepts of nonlinear vibrations.

ENG(NAL)-3-677: Computational Nonlinear Structural Mechanics and Vulnerability: 2-0-2-3

Course Coordinator: Dr M Manjuprasad
Associated Faculty: Dr DVTG Pavan Kumar, Mr. J Dhayanidhi

Review of linear FEM. FEM for one one-dimensional plasticity: Perfect plasticity, Isotropic and Kinematic strain hardening, finite element formulation, Newton-Raphson solution technique, one-dimensional viscoplasticity, integration algorithms. Continuum theory of plasticity: Yield condition, Flow and hardening rules, loading and unloading conditions, stability, convexity and normality, J2 plasticity /viscoplasticity. FEM for two-dimensional and three-dimensional plasticity: Rate independent plasticity, Explicit and Implicit techniques, Return methods for J2 plasticity, finite element formulation, NR technique. FEM for large deformation elasticity: Continuum Mechanics - Description of motion of body, deformation gradient, Green-Lagrange strain, Rate of deformation, principal stresses, polar decomposition, Cauchy stress and P-K stresses, balance of mass and momentum, Principal of objectivity, Constitutive equation for hyper elasticity, New Hookerion elastic model, finite element formulation for finite strain elasticity, Total Lagrangian and updated lagrangian. Introduction to nonlinear FEM for structural dynamics, Nonlinear FEM for composites, Concepts of structural damage and vulnerability.

ENG(NAL)-3-678: Computational Stochastic Structural Mechanics and Reliability: 2-0-2-3

Course Coordinator: Dr M Manjuprasad
Associated Faculty: Dr Amit Kr. Onkar, Mr. AC Pankaj

Introduction to probability, random variables, different probability distributions; Random process theory, stationarity, ergodicity, non-stationarity, power spectral density; Random field theory, homogeneity, non-homogeneity; Vibration of S.D.O.F. system under random inputs; Input output relation, Extension to M.D.O.F. system; Failure of randomly vibrating systems; Formulation of reliability for structural problems; Exact solution methods – first order and second order reliability methods, transformations; Simulation methods – Direct Monte Carlo and Importance sampling methods; System reliability methods; Introduction to Reliability based design concepts; Concepts of stochastic finite element methods.

ENG(NAL)-3-679: Applied Aeroelasticity: 3-0-0-3

Course Coordinator: Dr S Raja
Associated Faculty: Mr. D Dwarakanathan

Aerodynamic-structural coupling, static aeroelasticity (divergence, control reversal etc), dynamic aeroelasticity (Flutter, Buffet, Gust), flexible loads, introduction to numerical and experimental techniques in Aeroelasticity. Aerodynamic theories (subsonic/supersonic), basics in active controls, aeroservoelasticity (modeling, analysis) & its applications: active flutter control technique, gust load alleviation etc.
ENG(NAL)-3-680: Smart Materials & Structures: 3-0-0-3
Course Coordinator: Dr S Raja
Associated Faculty: Mr. D Dwarakanathan

Introduction to smart materials, constitutive modelling, smart & adaptive structures concepts, numerical & experimental methods for adaptive structures (sensing, actuation, monitoring), active-passive vibration controls, shape control of structures, optimal placement techniques for sensor & actuators.

ENG(NAL)-3-681: Vibration Control Techniques for Aerospace Structures: 3-0-0-3
Course Coordinator: Dr S Raja

Introduction to vibration, sources of vibration, passive vibration control approaches, modelling different vibratory loads & structural system, system identification techniques, introduction to active control system, feedforward & feedback controls, modelling of different actuators and sensors, control system design and analysis, experimental techniques in vibration control.

ENG(NAL)-3-682: Finite Element Methods for Aircraft Structures: 3-0-0-3
Course Coordinator: Dr S Raja
Associated Faculty: Mr. U Ashwin

Introduction to thin walled structures, Isotropic & composite materials, beam, plate & shell theories, R-R method and displacement based FE procedure, novelty in FE coding, numerical experimentation with FE analysis, static & dynamic solutions using numerical approaches.

ENG(NAL)-3-683: Fatigue and Fracture Mechanics: 3-0-0-3
Course Coordinator: Dr CM Manjunatha
Associated Faculty: Dr PK Sahoo

Introduction to fatigue of materials; Mechanisms of fatigue failures; HCF and LCF; Fatigue design concepts; Fatigue testing; S-N curves, factors influencing S-N behavior; Strain-life approach; cyclic stress-strain behavior; Fatigue life estimation under block and spectrum loads. LEFM concepts; crack tip plastic zone; FCGR; crack growth life estimation; statistical aspects of fatigue; variable amplitude fatigue; load sequence effects. Introduction to SIF, SERR, J-integral values, Irwin’s theory, 2D and 3D VCCI and MVCCI methods, MVCCI method, methods of crack growth analysis in metals/composites using FEA.

ENG(NAL)-3-684: Mechanical Design and CAD/CAM: 3-0-0-3
Course Coordinator: Dr G Balamurugan
Associated Faculty: Mr. AC Pankaj, Mr. Mahesh Kadam, Mr. K Vinod Kumar

ENG(NAL)-3-685: Mechanical Systems Design and Aircraft Systems: 3-0-0-3
Course Coordinator: Dr G. Balamurugan
Associated Faculty: Mr. Jaidev Vyas, Mr. Mahesh Kadam, Mr. Apurva N Vyas, Mr. Vinod Kumar


ENG(NAL)-3-686: Optimization Techniques in Engineering Design: 3-0-0-3
Course Coordinator: Dr DVTG Pavan Kumar
Associated Faculty: Dr Amit Kr. Onkar, Dr M. Manjuprasad

**ENG(NAL)-3-687: Impact and Crashworthiness: 3-0-0-3**  
Course Coordinator: Dr S Sathiyanarayan  
Associated Faculty: Mr. J Dhayanidhi, Dr Satish Chandra

Classification of Impact, High velocity and low velocity impacts, Stereo-mechanical Impact, Central Impact, Rotational Impact and Eccentric impact. Vibration aspects, Wave transmission in Elastic solids, Impact of two rods, Impact of rigid mass on a rod, Transverse impact of a mass on a beam. Contact phenomena, Forces and deformations at the contact point, the hertz law of contact, other contact deformation relations, examples. Soft body impact at high velocities, shock waves, bird hit, hail impact. Energy absorption concepts, airbags, foams, gelatine, Crashworthiness of vehicles, Calculation of energy absorbed during low velocity impact. Experimental aspects of impact, measurement of accelerations, velocities of impact, low velocity, high velocity impact, high speed photography. Computational methods for impact analysis, explicit analysis, examples.

**ENG(NAL)-3-688: Finite Element Methods for Composites: 3-0-0-3**  
Course Coordinator: Dr AK Onkar  
Associated Faculty: Ms. S Manju


**ENG(NAL)-3-689: Digital Signal Processing and its Applications: 3-0-0-3**  
Course Coordinator: Mr. PS Vijayakumar  
Associated Faculty: Dr VPS Naidu

Introduction to Signals and signal processing: Characterization and classification of signals, signal processing operations and applications. Fundamentals of Discrete time systems: Introduction, Basic Definitions, Important discrete-time signals, Discrete-Time systems,

**ENG(NAL)-3-690: Manufacturing Techniques for Composites: 2-0-2-3**

Course Coordinator: Dr Ramesh Sundaram  
Associated Faculty: Mr. Satish S Nimbal


**ENG(NAL)-3-691: Repair Technology for Aircraft Structures using Composites: 2-0-2-3**

Course Coordinator: Mr. D Saji


**ENG(NAL)-3-692: Experimental Techniques for Composites: 2-0-2-3**

Course Coordinator: Mr. D Saji

Introduction to composites, Manufacturing processes for polymer matrix composites, Micro and Macro mechanics, Classical laminate theory, Introduction to Fracture Mechanics, types of damages in composites and damage propogation. Fundamental Strain Gage Technology,

Course Coordinator: Mr. M Ramesh Kumar


ENG(NAL)-3-694: Introduction to Continuum Mechanics: 3-0-0-3
Course Coordinator: Dr VL Sateesh


ENG(NAL)-3-695: Textile Reinforcements for Composites: 2-0-2-3
Course Coordinator: Dr BS Sugun

Introduction to textile structures, weaves, knits and braids, Introduction to basic weaves and weaving machinery, yarn and fabric mechanics, woven cloth construction and design, glass and carbon weaving, 3D preforming technologies such as stitching, tufting, multilayer weaving, orthogonal weaving and 3D weaving, woven fabric geometry, weaving calculations, testing and evaluation.