THE DYSON INSTITUTE

Module Information for 2021

Year four

dyson

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Year 4	
Name of module	**Stress Analysis and FEM**
Module description	This module reviews concepts of statics and strength of materials used to determine the stress, strain and deflection of structures, and introduces fundamental approaches to failure prevention for static and repeated loading. The module continues by introducing mathematical and numerical methods to simulate structural problems by modern engineering tools and packages. It will further enhance both theoretical and practical appreciation of CAD and matrix analysis of structures, whilst introducing the supporting role of Finite Element Method (FEM).
Outline Syllabus	Stress Analysis • Introduction to mechanical properties of engineering materials and their stress-strain behaviour • Load/force analysis; refresher on the first-year module; • Analysis and Design of Shafts for Torsion • Analysis and Design of Beams for Bending • Multiple loadings and Complex Stresses • Principal Stresses / Stress Transformation • Design based on Failure criteria; • monotonic failure; failure mechanisms associated with rotating machines • Fatigue failure analysis o S-N diagrams, o The effect of stress concentration and surface finish FEM • Review of Linear Algebra, Matrix calculations • Fundamental Relationships of Structural Analysis • The Finite Element Method o Basic Concepts and definitions o Fundamental equations of FEM o Shape functions and the interpolation concept • 1D FE Analysis o Bar element o 3-Node Bar Element o Selection of boundary/load conditions o Matrix Condensations o Assembling the global stiffness matrix • 2D FE Analysis o Formation of the Global Analysis Equations for Plane Trusses o Local vs. Global coordinates and coordinate Transformation o Member Stiffness in Local/Global Coordinates o Assembly of Structure Stiffness o 2D (Plane) elements

	○ Plane Stress/Strain considerations ○ CST Element ○ 4-node Quadrilateral Element • **FE formulations of Beam element** • **Plane Frames** • **Implementation of FE formulations in programming languages (e.g. MATLAB)**
Method of assessment and weighting attributed to each area of assessment	40% Unseen Examination 45% Group Coursework Assignment 15% Group Presentation

Name of module	Vibration and Rotordynamics
Module description	The purpose of this module is to demonstrate dynamical performance of rotors and also to solve problems such as synchronous and non-synchronous whirl, sensitivity to unbalance, threshold of instability, torsional behaviour of branched systems, the analysis of steady and cyclic stress distributions caused by unbalance and other vibration phenomena.

Outline Syllabus	• Fundamentals of Machine Vibration and Classical Solutions
	• Torsional Vibration
	  o Torsional Vibration Indicators, Objectives of Torsional Vibration Analysis
	  o Kinetic Energy Expression, Potential Energy
	  o Torsional Vibration Measurement
	  o Carrier Signal Transducers
	  o Frequency-modulated Systems, Amplitude-modulated Systems
	  o Frequency Analysis and the Sideband System
	• Introduction to Rotordynamics Analysis
	  o Objectives of Rotordynamics Analysis
	  o The Spring–Mass Model
	  o Synchronous and Nonsynchronous Whirl
	  o Analysis of the Jeffcott Rotor
	  o Critical Speed Definitions
	  o Effect of Flexible (Soft) Supports
	  o Rotordynamic Effects of the Force Coefficients
	  o Rotordynamic Instability
	  o Gyroscopic Effects
	• Computer Simulations of Rotordynamics
	  o Different Types of Models
	  o Bearing and Seal Matrices
	  o Torsional and Axial Models
	  o Eigen-analysis
	  o Linear Forced Response (LFR)
	• Bearings and Their Effect on Rotordynamics
	  o Fluid Film Bearings, Fixed-geometry Sleeve Bearings, Variable-geometry Tilting Pad Bearings
	  o Load Between Pivots Versus Load on Pivot
	  o Influence of Preload on the Dynamic Coefficients in Tilt Pad Bearings
	  o Influence of the Bearing Length or Pad Length
	  o Squeeze Film Dampers/Applications
	  o Insights into the Rotor–Bearing Dynamic Interaction with Soft/Stiff Bearing Supports
	  o Influence on Natural Frequencies with Soft/Stiff Bearing Supports
	  o Effects of Mass Distribution on the Critical Speeds with Soft/Stiff Bearing Supports

	○ Influence of Overhung Mass/ Gyroscopic Moments on Natural Frequencies with Soft/Stiff Supports • **Fluid Seals and Their Effect on Rotordynamics**
Method of assessment and weighting attributed to each area of assessment	40% Unseen Examination 45% Group Coursework Assignment 15% Group Presentation

Name of module	CFD and Turbulence
Module description	The aim of this module is to introduce advanced numerical methods which can be used to solve the governing equations of fluid flow and turbulence. This numerical approach is often referred to as Computational Fluid Dynamics (CFD). In this module, students will learn to utilise conservation laws to derive the governing equations of fluid dynamics and then to apply the finite volume method to transform these governing equations into a set of linear algebraic equations which can then be solved computationally. Students will also be provided with a general understating of turbulence and the nature and structure of turbulent flows as well as turbulence modelling and its application in CFD. These skills will be applied to solve a number of complex but industrially relevant flow problems using Matlab and Ansys.
Outline Syllabus	• Review of basic fluid mechanics and governing equations (conservation laws). • Finite difference method (FDM): Taylor series revision, upwind and central differences, stability and accuracy. • Finite volume method (FVM): methodology, approximation of diffusion and convection-diffusion problems. • Pressure-velocity coupling: the staggered mesh, SIMPLE and related methods. • Solution of discretised equations: the TDMA, point-iterative methods (Jacobi, Gauss-Seidel, etc.), multigrid methods. • Unsteady problems: implicit/explicit schemes and associated stability/accuracy issues. • General CFD code strategies: grid generation (complex geometries: body-fitted grids, curvilinear grids, block-structured grids, unstructured grids), BCs, solver, post-processing, uncertainties in CFD modelling. • Modelling turbulent flow: RANS, LES, DNS • Case studies for Applied CFD & Turbulence
Method of assessment and weighting attributed to each area of assessment	40% Unseen Examination 45% Group Coursework Assignment 15% Group Presentation

Name of module	Mechanical Design
Module description	This module briefly reviews concepts of stress analysis used to determine the stress, strain and deflection of mechanical parts, and also fundamental approaches to failure prevention under static and repeated loading. The module mostly focuses on the study of kinematics and design of machinery and related mechanical components, with the aim to introduce fundamental principles of interaction between load and deflection in machinery design, and to develop practical design methodology with emphasis on applications (sizing of parts and selection of materials) and synthesis of mechanical components such as shaft, joints, belts, bearings, and gears.
Outline Syllabus	• Review on stress analysis & Failure criteria: refresher on material strength and stiffness; discussion of major loadings associated with the rotating components; failure mechanisms including creep and fatigue. • Introduction to mechanical engineering design: fundamentals of the design process; standards and codes; factor of safety; reliability. • Shafts and shaft components: shaft materials; shaft design for stress; deflection considerations; critical speeds for shafts. • Joints: screws, fasteners; design for adhesive bonding; special case of design optimisation by component strain matching. • Rolling-contact bearings: bearing types; bearing reliability versus life; relating load, life, and reliability; combined radial and thrust loading; selection of ball and cylindrical roller bearings; design assessment for selected rolling-contact bearings; hydrodynamic lubrication: derivation of Reynold's equation in one dimension; solutions for wide plane thrust bearings and journal bearings; friction and temperature rise associated with hydrodynamic bearings • Traction drives and belts. • Gears: types of gears: spur, helical, bevel, worm; conjugate action; involute properties; contact ratio; interference; force analysis in gears.
Method of assessment and weighting attributed to each area of assessment	40% Unseen Examination 45% Group Coursework Assignment 15% Group Presentation

Name of module	Machine Learning
Module description	This module focuses on how to extract information from datasets by algorithms that automatically build models from historical data and predict future behaviours of systems. Data analysis using supervised learning is particularly powerful where there is no mathematical model available and classical statistics offer limited insights (e.g., market analysis, PID parameter tuning). Students will learn the fundamental concepts of the supervised machine learning and will apply these concepts to analyse data by using the most advanced software tools and programming languages. Also, an introduction to unsupervised learning will be included in this module. By contrast with supervised learning, data diagnostics with unsupervised learning reflect the statistical structure of the overall collection of data, without any support from historical data.
Outline Syllabus	Regression of labelled data Least square error estimation Logistic Regression K Nearest Neighbours Regression Regression Trees Support Vector Machines Artificial Neural Networks Classification of labelled data Classification trees Support Vector Machines Linear and Quadratic Discriminant Analysis Artificial Neural Networks Clustering of unlabelled data K Nearest Neighbours Classification Hierarchical Clustering Graph based clustering
Method of assessment and weighting attributed to each area of assessment	45 % - Assignment 15 % - Assignment demonstration/presentation 40 % - Examination

Name of module	Vision and Processing
Module description	Digital image processing has a broad range of applications such as remote sensing, image and data storage for transmission and industrial automation. This module aims to provide the fundamentals of digital signal processing and develop students' knowledge from basic signal processing techniques to advanced image processing. It covers the principles of image formation, sampling and quantization, which will allow investigation of image-processing techniques. Students will acquire knowledge related to image intensity transformations and spatial filtering and apply it for image enhancement in both spatial and frequency domains. Dealing with different types of noise models and achieving image restoration is also covered. The module will familiarize students with morphological image processing, colour image processing and image segmentation to help students apply these techniques in real world problems.
Outline Syllabus	Digital image fundamentals Elements of visual perception. Image perception. Image sensing and acquisition. Image sampling and quantization. Arithmetic, set and logical operations. Single-pixel operations Intensity transformation and spatial filtering Intensity transformation functions. Contrast stretching. Histogram processing. Smoothing spatial filters. Sharpening spatial filters. Filtering in the frequency domain Discrete Fourier transform. Image smoothing using frequency domain filters. Image restoration Noise models. Restoration in the presence of noise only. Colour image processing Colour fundamentals. Colour models. Pseudocolour image processing. Colour transformations. Smoothing and sharpening. Using colour in image segmentation. Morphological image processing Erosion and dilation. Opening and closing. Basic morphological algorithms. Morphological reconstruction. Image segmentation Point, line and edge detection. Thresholding. Region segmentation. Segmentation using morphological watersheds.

	Image compression and coding Image compression models. Huffman coding. LZW coding. Automotive case studies, e.g. image recognition for object detection in vehicle motion path, 3D vision systems.
Method of assessment and weighting attributed to each area of assessment	45 % - Assignment 15 % - Assignment demonstration/presentation 40 % - Examination

Name of module	Cryptography and Cybersecurity
Module description	The module will provide students with an understanding of the key issues and techniques involved with securing data and computer-based communication. This will include an introduction to the fundamental theory, concepts and applications of cryptography. It will also ensure students understand how to systematically address threats, vulnerabilities and the negative consequences that occur should a threat exploit an organisation's vulnerability in cyber engagement.
Outline Syllabus	• Information security – threats, risks, forms of attack, risk management, human factors, security testing • Techniques for securing access to data and prevention against accidental loss • Authentication, authorisation, non-repudiation, confidentiality and integrity • Symmetric cryptography – block and stream ciphers, DES, AES • Public-key cryptography – RSA, El Gamal, Elliptic Curve Cryptography • Key exchange, digital signatures • Hashing • Cryptanalysis and codebreaking
Method of assessment and weighting attributed to each area of assessment	45 % - Assignment 15 % - Assignment demonstration/presentation 40 % - Examination

Name of module	High Performance Electric Drives
Module description	This module aims to show how power electronics, modern electric motors and control theory underpin modern electric drives. Characteristics of standard and bespoke AC motors will be analysed in context of different control approaches, focusing on vector control and direct-torque control. Applications will include appliances, robotics and electric vehicles.
Outline Syllabus	• Motors revision • Applications (e.g. automotive, home appliances, robotics) • Modelling and analysis of DC, induction, PM and reluctance motors • Modelling AC motors in orthogonal d-q reference frames • Heating and Thermal effects in electric drives, Losses and where losses occur • Performance tests • Steady-state characteristics of motors under controlled DC or AC supply • Principles of single-loop and cascaded control systems for drives • Scalar control, vector control, direct torque control • Performance issues regarding sensors' accuracy and/or parameter sensitivity (Position sensing) • Types of generic and bespoke power electronic converters • Current-regulated pulse-width modulation for low-power drives • Limitations of power electronics in high-power drives • Typical frequency converter – modes of operation, interfaces, parameter adjustment • Electric drives design/specification
Method of assessment and weighting attributed to each area of assessment	40% Unseen Examination 45% Group Report 15% Group Presentation

Name of module	Electronics Manufacturing and Assembly
Module description	The module aims to present the principles and techniques of electronics design for manufacture and assembly into a final product. The module will provide students with the theoretical and practical aspects of electronics design from prototyping to mass production encompassing product requirements, design constraints, manufacturing, assembly and testing methods. The module will introduce the students to the fundamentals of integrated circuits, device packaging, schematics design and layout design of printed circuits boards.
Outline Syllabus	• Electronic components, integrated circuits and packaging • IC integration: hybrid, monolithic, chip on board. • IC packaging, surface mount and through hole technologies, footprints. • Resistors, capacitors, diodes, transistors, connectors (types and packaging). • Printed circuit boards (PCBs) • Single sided, double sided, multi-layer, flexible printed boards. • Substrate and metallization materials, finishing, layers definition, copper weight. • General design of printed circuit boards • Schematic design and components footprints and symbols. • Tracks, pads, vias, polygons, routing, solder lands, thermal relief, component placement, necking. • Electromagnetic interference, high frequency design considerations, cooling methods. • Design for manufacture • Standardization, design rules, tolerances, resolution, board size and shape, cost. • Design for testability • Test points, accessibility to components (soldering, testing probes), connectors. • Circuit manufacturing and mass production • Manufacturing techniques and basic processes, submitting the design files, specifications, panels, stencils, tooling strips. • Circuit assembly and testing • PCB population, soldering methods, wire bonding techniques, in-circuit testing.
Method of assessment and weighting attributed to each area of assessment	40% Unseen Exam 45% Individual Report 15% Individual Presentation

Name of module	Internet of Things
Module description	This module introduces the concept, implementation and applications of digitally enabled objects that can transfer data over a network without requiring human-to-human or human-to-computer interaction. The potential of Internet of things (IoT) in an industrial context for automating specific tasks such as industrial machine control, self-diagnostics in machines and predictive maintenance will be introduced. Different IoT systems architecture and programming techniques will be taught to acquire and process data using hardware kits such as Raspberry Pi, microcontrollers, energy monitors and PLCs.
Outline Syllabus	• Basic function and architecture of a sensor • Knowledge of different hardware devices • Basic programming technique • Industry related protocols • Network systems (Protocols) • Gathering and sharing data between different devices • Connecting Sensors to the Cloud • Collection and storage of IoT sensor data • Data Aggregation • Processing IoT Data • Privacy and security • Analysis and visualization of data • How things work together: Cloud and IoT • Embedded operating systems • Linux (and Windows) based IoT • Cloud-based data collection • On-Going IoT Operations • Controlling/Operating devices/systems • Hardware devices (regulations, power management, etc.)
Method of assessment and weighting attributed to each area of assessment	40% Unseen Examination 45% Group Report 15% Group Presentation

Name of module	Robotics
Module description	The module provides a further understanding of the principles of operation of mobile robots and future robotic applications outside the factory. It focuses on the methodology for modelling, planning, control and localization of mobile robots in both structured and unstructured environments. The focus is on wheeled robots, which are the most common, however the techniques introduced are general enough to be applied to any mobile robot. A part of the course is devoted to recent techniques in robotic perception and on-board intelligence that are deemed to play a relevant role in the coming years.
Outline Syllabus	• Applications, Problems, Architectures • Configuration space • Mechanics, Kinematics • Path/trajectory planning-tracking • Regulation • Retraction and cell decomposition • Probabilistic planning • Artificial potential fields • Sensors for mobile robots • Odometric localization • Bayes theorem • Kalman Filters • Landmark-based and SLAM • Practical Robotics, consistency and correlation
Method of assessment and weighting attributed to each area of assessment	40% Unseen Examination 45% Group Report 15% Group Presentation

Name of module	Final Year Project
Module description	The aim of project work is to undertake a piece of independent study that will draw on the knowledge and skills acquired during the programme. The project will deepen comprehension of principles and methods by applying them to a problem in the workplace. Students will develop enhanced knowledge and understanding of the engineering-related aspects of their project. Typically, students will develop skills in qualitative and quantitative analysis, risk assessment, problem solving using appropriate methodologies, research and information gathering as well as planning and designing an experiment. Generic skills developed during projects will include using appropriate engineering analysis software and IT tools, adhering to research ethics processes and health & safety requirement, oral/written communication, project and time management, computing and IT, self-discipline and self-motivation.
Outline Syllabus	The student's project shall focus on a problem relevant to Dyson that may relate to the Dyson's products, its engineering processes or the management of the business from a technical perspective. As the project can cover any one of a broad range of topics, the student will be responsible for the initiation, planning and management of the task. This means that the knowledge and skills they acquire during this module will differ quite significantly from those acquired elsewhere on the course. Unlike other classroom-based modules, tuition during the Work-Based Project is facilitated partly via group seminars, online exercises and report style guides but primarily via tailored advice and guidance from the student's supervisors at key points in the project's lifecycle. That tuition will cover the following topics and techniques: • Approaches to identifying and describing a problem in or improvement to the workplace that, if remedied to a professional standard, will deliver meaningful outcomes for the company. • Techniques for planning an approach to solving the selected problem or delivering the anticipated improvement within the constraints imposed by the time and resources available for the project. • Methods for assessing any risks that may hinder or otherwise diminish the effectiveness of the work done to achieve/deliver the specified outcome of the project. • Methods for risk assessment and risk control in the context of occupational health and safety. • Techniques for conducting a review of relevant literature in order to identify and apply theories, methods or concepts that may guide the planning and execution of the project.

	• Requirements for engineering activities to promote sustainable development, knowledge of relevant legal issues, codes of practice and industry standards. • Approaches to managing and executing the project in accordance with the plan specified previously, monitoring progress and responding appropriately to any change in resource or circumstance that might affect its outcome or the effectiveness of the eventual solution. • Methods of reflecting on and evaluating the outcome of the project with respect to its aims in order to estimate the impact of the improvement brought to the workplace by the proposed solution or improvement. • Estimating the contribution of the project to a more sustainable products, processes and practice. • Techniques for disseminating the outcome of the project to both technical and non-technical audiences, including the awareness of intellectual property issues.
Method of assessment and weighting attributed to each area of assessment	10 % Proposal 15 % Progress Review 15 % Presentation 60 % Final report