AM (Applied Mathematics)

Instructions:
The exam is CLOSED BOOK, CLOSED NOTES but students are allowed to carry up to and including 5 A4-sized pages with handwritten matter on both sides and a non-programmable electronic calculator.

Syllabus:
Ordinary Differential Equations: First-order equations (Separable, Exact, Homogeneous, Linear); Second-order linear differential equations (homogeneous and nonhomogeneous); Solution methods such as undertermined coefficients and variation of parameters; Two-point boundary value problems of the Sturm-Liouville type; System of first-order ordinary differential equations; Green's function.

Special Functions: Bessel and Legendre functions and their properties; Orthogonality.

Linear Algebra: Vectors and vector spaces; Matrices and linear systems; Solution of AX = b; Least squares fit of data; Eigenvalues, eigenvectors; Diagonalization; Symmetric positive definite matrices, orthogonal matrices, quadratic forms.

Vector Calculus: Parametrization of curves and surfaces; Vector differentiation; Directional derivative and the gradient; Divergence theorem and the Stokes' theorem; Orthogonal coordinate systems.

Partial Differential Equations: Linear partial differential equations (Parabolic, Elliptic and Hyperbolic) in rectangular, cylindrical polar and spherical coordinate systems; Solution techniques such as separation of variables, eigenfunction expansions, integral transforms (Fourier and Laplace transforms); D'Alembert's solution for the Wave equation; Maximum principle for Elliptic equations.

References:

- Dennis Zill and Warren Wright, Advanced Engineering Mathematics, Fourth Edition, Jones and Bartlett Student Edition, 2011 (Indian Edition).
- Peter O'Neil, Advanced Engineering Mathematics, Seventh Edition, Cengage Learning, 2012 (Indian Edition).
- Michael Greenberg, Advanced Engineering Mathematics, Second Edition, Pearson Education, 2002 (Indian Edition).
- William Boyce and Richard DiPrima, Elementary Differential Equations and Boundary Value Problems, Ninth Edition, Wiley Student Edition, 2012 (Indian Edition).

TFE1 (Fluid Mechanics)

Instructions:
This is a closed book, closed notes examination. All questions are compulsory. Calculator is allowed. Make suitable assumptions if required and state them clearly. Simplify the answers to the extent possible. Useful equations are given in the Appendix. Please answer to the point and write legibly."

Syllabus:
Introduction: Review of vector calculus, cartesian tensor notation.

Kinematics of Fluid Flow: Description of fluid motion: Eulerian and Lagrangian approaches; Pathlines, Streaklines, Streamlines; Kinematic decomposition of velocity field.

Fundamental Governing Equations: Conservation equations in Integral and Differential form; Stresses in fluid; Rates of deformation and development of the constitutive equations of Fluid Dynamics (Stokes' relations); The Navier-Stokes (N-S) Equations; Special forms of the N-S equations; Initial and Boundary conditions; Differential form of Thermal and Mechanical energy equations; Introduction to non-dimensionalization and scaling; Non-dimensional numbers of interest in incompressible flow; Classification of incompressible flow on the basis of Reynolds number.

Laminar Flow: Creeping flow (Stokes' solution for flow past a sphere, Hele-Shaw flow); Exact solutions to the incompressible N-S equations (e.g., Couette and Poiseuille flows, Flow between rotating cylinders, Stokes' First and Second problems, Stagnation point flow, Flow over porous walls, etc.).

Potential Flow: High Reynolds number approximation - inviscid flow; Circulation and Vorticity; Kelvin's theorem; Irrotationality; Simple Potential Flows; Superposition; Technique of images; Introduction to use of complex variables for plane Potential Flows; Introduction to lifting surfaces.

Vortex Dynamics: Helmholtz theorems; Vorticity transport equation; Potential and Rankine vortex; Interaction of vortices.

Laminar Boundary Layers: Concept of a boundary layer in High Reynolds number flow; Scale analysis and development of Prandtl's boundary layer equations; Blasius' solution to flat plate; Boundary layer with pressure gradient (Falkner-Skan solutions); von-Karman-Pohlhausen integral analysis method; Boundary layer separation and control.

Introduction to Turbulent Flow: Introduction to instability and transition; Origin of turbulence - role of vorticity and viscosity; Statistical description; Reynolds' averaging of N-S equations; Reynolds' stresses; Kinetic energy budget in turbulent flow; Wall turbulence: eddy diffusivity, Prandtl's mixing length hypothesis, von-Karman's similarity hypothesis; Universal velocity profile.

Introduction to Compressible Flow: A brief review of concepts from Thermodynamics; Acoustic waves; Normal shock waves; Basic one-dimensional compressible flow in a duct with varying cross-sectional area; One-dimensional compressible flow with friction and heat transfer.

References:

1. Fluid mechanics by Kundu-Cohen-Dowling
2. Introduction to Fluid Mechanics by Fox-McDonald
3. Fluid Mechanics by Cengel-Cimbala

TFE2 (Heat Transfer)

Instructions:

- A hard copy of the textbook Fundamentals of Heat and Mass Transfer, Incropera, DeWitt et al. (any edition) is permitted. No other material (any other textbook, notes, photocopies, electronic devices) is permitted.
- Scientific calculators are permitted.

Syllabus

- Heat conduction:
  - Basic laws, governing equations in differential form.
  - One dimensional steady conduction, heat generation, fin analysis, optimization of fin dimensions and insulation thickness.
  - Two dimensional steady conduction, separation of variables, superposition.
  - Unsteady state problems: lumped capacitance method and its validity, semi-infinite solid, unidirectional conduction - separation of variables, concentrated source and sink, superposition.
  - Duhamel's theorem and applications for time varying boundary conditions.
- Radiation heat transfer:
  - Black body: intensity, emissive power, spectral emissive power.
  - Real surfaces: emissivity, absorptivity and reflectivity.
  - Shape factor algebra.
  - Radiosity approach for gray diffuse surfaces, network modeling.
  - Gas radiation, well stirred furnace model.
- Convective heat transfer:
  - Derivation of governing equations.
  - 2D laminar Couette flow, non-dimensional numbers. Adiabatic wall temperature.
  - Flow over a flat plate, boundary-layer theory – scale analysis, similarity solution, integral solution.
  - Pipe flow – developed temperature profile and solutions for constant wall flux and constant wall temperature boundary conditions, entry length problem for constant wall and constant wall flux boundary conditions.
  - Natural convection - scale Analysis, integral solution, similarity solution.
  - Convection in turbulent flows. Turbulent momentum and thermal boundary layers.
- Boiling and condensation: Regimes of boiling. Basic models, Heat transfer in critical heat flux. Film and dropwise condensation.

Reference:

Fundamentals of Heat and Mass Transfer, Incropera, DeWitt et al. (any edition)

DES1 (Solid Mechanics)

Instructions:
The exam will be closed books and closed notes. Students can bring one self-handwritten on one side A4 sized cheat sheet. Students can bring their own non programmable scientific calculator. No other devices are permitted

Syllabus:
Stress analysis: Body force, surface force, stress/traction vector, state of stress at a point, normal and shear components, plane stress, stress transformations, Mohr's circle, principal stresses, principal planes, stress invarients, differential equations of equilibrium in Cartesian, cylindrical and spherical polar coordinates

Analysis of Deformations: Small deformation theory, definition of strains, strain at a point, normal and shear strain, plane strain, strain transformations, Mohr's cricle, principal strains, principal axes of strains, compatibility equations, strain gauge rosettes, strain displacement relations in cylindrical and spherical polar coordinates

Stress Strain Temperature Relations: Idealization/Types of stress strain curves, thermal strains, stress strain temperature relations for linear elastic isotropic body, interpretation of different elastic constants, relations between elastic constants. Stress strain relations for orthotropic and transversely isotropic materials

Formulation and Solutions to 2D problems: Types of boundary conditions, uniqueness theorem, Airy's stress function, principle of superposition, Saint Venant's principle

Energy methods: Strain energy, reciprocal theorem, principle of virtual work, Castigliano's theorem, principle of minimum potential energy, Rayleigh-Ritz method for approximate solutions

Theory of Failures: Maximum normal stress theory, Mises yield criteria, Tresca yield criteria

Torsion: Torsion of circular straight rods, torsion of shafts with rectangular cross-sections, torsion of hollow shafts, torsion of thin tubes, shafts subjected to combined loads Torsion of shafts with arbitrary cross-sections, Prandtl stress function approach, membrane analogy.

Bending: Stress and deflections in symmetrical elastic beams, symmetrical beams subjected to combined loads, bending of unsymmetrical beams, bending of curved beams

Asymmetric problems: Thick and thin cylinders subjected to internal pressure, rotating disk problems

Buckling: Equilibrium approach, potential energy approach, eigenvalue problems, beam buckling with various boundary conditions, approximation of buckling loads using potential energy methods.

References:

- Saad, M. H., Elasticity: Theory, Applications and Numerics
- Timoshenko, S. P., Theory of Elasticity
- Srinath, L. S, Advanced Mechanics of Solids
- Crandal, S, Lardner, T, Dahl, N and Sivakumar, M. S., An Introduction to Mechanics of Solids

DES2 (Kinematics and Dynamics)

Instructions:
CLOSED BOOK EXAM, Students are however allowed to bring one A4 size sheet filled (both sides) with information as deemed useful; exchange of these A4 size sheets will not be allowed; calculators are permitted; Basic drawing instruments (pencil, scale, eraser, compass and protractor) are permitted.

Syllabus:
System of particles: Position, velocity, and acceleration analysis; reference frames and their relative motion; constrained motion of connected particles; work, kinetic and potential energy; impulse and momentum (linear and angular).

Motion of Rigid Bodies: Translation and rotation of rigid bodies; centripetal and Coriolis acceleration. Three-dimensional rigid bodies: analysis of motion and energy; gyroscope – precession and nutation; governor mechanism.

Lagrange dynamics: Hamilton's principle; Lagrange's equations; principle of virtual work. Application of Lagrange's equation problems of rigid body dynamics.

Mechanisms: Position, velocity and acceleration analysis of mechanisms; kinematic synthesis – function generation, path generation and rigid body guidance; graphical and analytical techniques of synthesis; dynamic analysis of mechanism - equations of motion, forward and inverse dynamic analysis; systems of interconnected rigid bodies.

Vibrations:
Single degree-of-freedom systems: Equations of motion, differential equa1. S.S. Rao, Mechanical Vibration, Prentice Hall, 2011
2. S. Graham Kelly, Mechanical Vibration: Theory and Applications, Cengage, 2012
3. Meriam J.L., and Kraige L.G., Engineering Mechanics Dynamics, 7th edition, 2012.
4. Rattan S.S., Theory of Machines, 2nd Ed., Tata McGraw Hill, New Delhi, 2005.
5. Uicker J.J., Pennock G.R., and Shigley J.E., Theory of Machines and Mechanisms, 2017tions and their solution, free and forced response, damping.
Multiple degree-of-freedom systems: matrix-vector form of governing equations, the eigenvalue problem and its solution, natural frequencies and mode shapes, orthogonality, generalized coordinates, response to initial conditions and typical excitation forms, proportional and modal damping.

References:
1. S.S. Rao, Mechanical Vibration, Prentice Hall, 2011
2. S. Graham Kelly, Mechanical Vibration: Theory and Applications, Cengage, 2012
3. Meriam J.L., and Kraige L.G., Engineering Mechanics Dynamics, 7th Ed., 2012.
4. Rattan S.S., Theory of Machines, 2nd Ed., Tata McGraw Hill, New Delhi, 2005.
5. Uicker J.J., Pennock G.R., and Shigley J.E., Theory of Machines and Mechanisms, 2017

MFG1 (Manufacturing Processes - 1)

Instructions:
The students are permitted to bring 1 A4 sheet of formula for the exam. Calculators can be brought.

Syllabus:
Casting processes: dispensable and permanent mould processes; analysis of melting, pouring and solidification phenomena; design of pattern, core, feeder and gating system; casting defects and inspection. Joining processes: fusion and solid-state welding; brazing and soldering; weld joint design, cooling rate, and joint properties; welding defects and inspection. Bulk and Sheet Forming processes: rolling, forging, extrusion and drawing; sheet metal working; forming limit diagram; loads, friction and lubrication; forming defects and inspection. Powder processing: Powder manufacture, characterization, compaction and sintering; metal injection moulding; hot and cold isostatic pressing. Polymers and Composites: Thermoplastics, thermosets, elastomers and composites; related processes; injection mould design; moulding defects and inspection. Advanced processes: Free form fabrication (rapid prototyping), and net shape manufacturing processes.

References:
1. Lorraine Francis, Materials Processing, Academic Press (2016)
2. A.Ghosh and A.K. Mallik, Manufacturing Science (2^{nd} Ed), East-West Press Pvt. Ltd. (2018)
3. S. Kalpakjian and S.R. Schmid, Manufacturing Processes (6^{th} Ed), Pearson (2017)

MFG2 (Manufacturing Processes II)

Instructions:
The exam will be closed book. The students are allowed to get one A4 sheet with only formulae written on it on both the sides. Calculators are allowed.

Syllabus:

- Machining (45-55%)
  - Basics of machining processes and chip formation in different processes
  - Mechanics of orthogonal cutting
  - Tool-chip temperature
  - Single point cutting tool geometry
  - Drilling process and tool geometry
  - Tool materials and tool wear
  - Machining optimization
  - Chatter and Lubrication
  - Grinding and finishing processes
- Non-conventional Machining (20-30%)
  - Ultrasonic Machining (USM)
  - Water-Jet Machining
  - Abrasive-Jet Machining
  - Chemical Machining
  - Electrochemical Machining (ECM)
  - Electrical-Discharge Machining (EDM)
  - High-Energy-Beam Machining (Laser and Electron-beam machining)
- Metrology (20-30%)
  - Fundamentals of geometric tolerances
  - Limits and fits
  - Principles of gaging
  - Surface metrology
- Fixturing basics (0-5%)
- Additional topics from IEOR (OPTIONAL*)

  To provide more choices to the students and to cover the manufacturing syllabus in a more comprehensive manner, additional topics in the area of Industrial Engineering and Operation Research has been added to the syllabus of the manufacturing process II qualifying exam.
  - Mathematical Formulation
  - Formulating linear programs
  - Solving linear programs
  - Duality and sensitivity analysis
  - Nonlinear Optimization
  - Discrete Optimization
  - Decision-making using probability distribution
  - Discrete event simulation
  - Shop-floor control and scheduling

  *These will be available as additional optional questions to the students appearing for the manufacturing process II qualifying exam. Hence, this will provide more options to the students appearing for the manufacturing process II qualifying exam since now they will be required to answer fewer questions from a larger pool of questions.

References:

1. A.Ghosh and A.K. Mallik, Manufacturing Science (2nd Ed), East-West Press Pvt. Ltd. (2018)
2. S. Kalpakjian and S.R. Schmid, Manufacturing Processes (6th Ed), Pearson (2017)
3. P.K. Mishra, Non-conventional Machining, Narosa Publication House (1997).