

# Mechanical engineering syllabus

## Mechanical engineering examinations

### Group A - Compulsory examinations (six required, A1-A5 and one of A6 & a7)

#### 22-Mec-A1 Applied Thermodynamics and Heat Transfer

Thermodynamics: Review of the fundamental laws of thermodynamics, introductory psychrometry and analysis of the ideal gas compressor cycle, Rankine cycle, Otto cycle, Diesel cycle, Brayton cycle and the vapour compression refrigeration cycle.

Heat Transfer: Application of the principles of steady and transient conduction heat transfer, natural and forced convection heat transfer and radiation heat transfer. Thermal analysis of heat exchangers.

*Textbooks (most recent edition is recommended):*

- Moran, M.J., H.N. Shapiro, B.R. Munson and D.P. DeWitt, Introduction to Thermal Systems Engineering: Thermodynamics, Fluid Mechanics, and Heat Transfer, John Wiley and Sons.
- Sami Ammar, Jean-Yves Trépanier, Massimo Cimmino, Transmission de chaleur : Recueil de formules, Presses internationales Polytechnique.
- Yunus A. Çengel, Mehmet Kanoğlu, Michael A. Boles, Marcel Lacroix, Thermodynamique : une approche pragmatique, Chenelière Éducation.

#### 22-Mec-A2 Kinematics and Dynamics of Machines

Kinematic and Dynamic Analysis: Graphical and analytical methods for kinematic analysis of planar and spatial mechanisms and elementary body motion in space, static and dynamic force analyses of mechanisms, gyroscopic forces, dynamics of rotating machinery, cam and gear mechanisms and specifications.

Vibration Analysis: Free and forced vibration of undamped and damped lumped single and multi degrees of freedom systems with, analytical and numerical techniques of solution, viscous damping, vibrational isolation, vibration measurement and control.

*Textbooks (most recent edition is recommended):*

- Inman, D.J., Engineering Vibrations, Prentice-Hall.
- Waldron, K.J., and Kinzel, G.L., Kinematics, Dynamics and Design of Machinery, John Wiley & Sons.

For Kinematic and dynamic part only in French:

- J.L. Meriam, L.G. Kraige, J.N. Bolton, Mécanique de l'ingénieur-Dynamique, Éditions Raynald Goulet.

#### 22-Mec-A3 System Analysis and Control

Open-loop and feedback control. Laws governing mechanical, electrical, fluid, and thermal control components. Mathematical models of mechanical, hydraulic, pneumatic, electrical and control devices. Block diagrams, transfer functions, response of servomechanisms to typical input signals (step function, impulse, harmonic), frequency response, Bode diagram, stability analysis, and stability criteria.

Improvement of system response by introduction of simple elements in the control circuit. Regulation of physical process: proportional, integral, and derivative control. Theory of linear controller design.

*Textbooks (most recent edition is recommended):*

- Bissell, C.C., Control Engineering, Taylor & Francis.

- Franklin, G.F., Feedback Control of Dynamic Systems, Pearson.

## 22-Mec-A4 Design and Manufacture of Machine Elements

Theory and methodology related to conceptual design; review of the methods used in stress analysis; simple design factor approach; variable loads; stress concentrations; bolts and bolted joints; welded joints; springs; shaft and bearing design; clutches, brakes, and braking systems.

The role, characterization and limitations of manufacturing processes and technologies: casting, forming, machining, welding and joining; composites manufacturing, nano-and-microfabrication technologies, rubber processing, glass working, coating processes; process selection.

*Textbooks (most recent edition is recommended):*

- Juvinall, Robert C., and Kurt M. Mershek, Fundamentals of Machine Component Design, Wiley.
- Groover, Mikell P., Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, Wiley.

## 22-Mec-A5 Electrical and Electronics Engineering

DC circuits, Single phase and polyphase circuits Magnetic circuits and transformers (ideal and practical), DC machines: motors and generators. AC machines: induction motors, synchronous motors, and alternators. Power factor correction. Analogue and digital semiconductor devices. Transistor amplifiers and switches. Power semiconductor devices, rectifiers, DC power supplies and voltage regulation. Operational amplifiers and application circuits. Combinational and sequential digital logic circuits. Practical approach to electronic instrumentation, measurement systems and transducers.

*Textbooks (most recent edition is recommended):*

- Edminister, J. A., and M. Nahvi, Electric Circuits, Schaum's Outlines.
- Nasar, S., Electric Machines and Electromechanics, Schaum's Outlines.
- Rizzoni, G., Principles and Applications of Electrical Engineering, McGraw Hill.

## 22-Mec-A6 Fluid Machinery

Dimensional analysis and similitude. Performance characteristics. Specific speed and machine selection. Idealized velocity diagram as applicable to turbines, compressors, pumps and fans. System characteristics and operating point and matching a pump to a piping system. System regulation, momentum and energy transfer, thermodynamic analysis, and efficiency definitions. Two-dimensional cascade analysis and performance. Application to pumps, fans, compressors, and turbines. Performance limits due to unsteady flow stalling and cavitation.

*Textbooks (most recent edition is recommended):*

- Finnemore, E.J. & J.B. Franzini, Fluid Mechanics with Engineering Applications, McGraw-Hill.
- Dixon, S.L., Fluid Mechanics and Thermodynamics of Turbomachinery, Butterworth-Heinemann.

## 22-Mec-A7 Advanced Strength of Materials

Stress-Strain Analysis: Stress and strain, transformations, principal stresses, graphical representation by Mohr's circles of biaxial and triaxial cases, generalized Hooke's law including thermal strains, equations of equilibrium and compatibility, plane strain and plane stress problems. Failure theories and limit analysis. Euler critical loads for columns, curved beams, thick-walled cylinders and rotating disks, contact stresses, strain gauges and their application, stress concentrations, introductory fracture mechanics.

Energy Methods: Strain energy principles, virtual work, Castigliano's theorem. Applications to cases of axial, bending, and torsional loadings. Applications to statically indeterminate problems.

*Textbooks (most recent edition is recommended):*

- Ugural, Ansel, & Saul Fenster, *Advanced Strength & Applied Elasticity*, Prentice Hall.
- Boresi, A.P., and R.J. Schmidt, *Advanced Mechanics of Materials*, John Wiley & Sons.

## Group B - Optional examinations (three required)

### 22-Mec-B1 Advanced Machine Design

Stress analysis and design of machine elements under conditions of: shock, impact, inertial forces, initial and residual stresses, corrosion environments, wear, elevated temperatures (creep), and low temperatures (brittle fracture). Hydrodynamic lubrication. Applications to the design of: journal bearings, power screws, clutches, brakes, couplings, and linkages. Introduction to probabilistic methods in mechanical design.

*Textbooks (most recent edition is recommended):*

- Shigley and Mischke, *Mechanical Engineering Design*, McGraw Hill.

### 22-Mec-B2 Environmental Control in Buildings

Heating, ventilating, and air conditioning: Psychrometrics, heating load, cooling load, comfort, ventilation, and room air distribution. Humidifying and dehumidifying, duct and fan design, piping and pump design. Heating, ventilating and cooling systems, and components. Refrigeration.

Noise control: Sound wave characteristics, measurement instruments. Sources of noise, absorption, and transmission. Free field and reverberant conditions. Noise control techniques in buildings.

Energy management technology: Energy usage in buildings, control systems and instrumentation, lighting systems operation, engineering/economic analysis principles, energy audit procedures.

*Textbooks (most recent edition is recommended):*

- F.C. McQuinston & G.D. Parker, *Heating, Ventilating, & Air Conditioning – Analysis & Design*, John Wiley & Sons.
- Jennings, *Environmental Engineering*, International Test Book Co.

### 22-Mec-B3 Energy Conversion and Power Generation

Fuel sources and characteristics: hydrocarbon fuels and nuclear fuels. Fuel reserves. Applications of steam and gas cycles for large-scale commercial power generation. Theory and practice of fossil boilers, nuclear reactors, steam turbines, gas turbines, and hydro turbines. Methods of improving conversion efficiency of power generation systems. Energy storage methods and limitations. Renewable energy methods: wind, solar, hydroelectric, geothermal, and ocean energy. Environmental and economic issues.

*Textbooks (most recent edition is recommended):*

- Weston, K.C., *Energy Conversion*, West Publishing Co. (available as an online e-book at <http://onlinebooks.library.upenn.edu/webbin/book/lookupid?key=olbp33597>)
- Khartchenko, Nikolai, *Advanced Energy Systems*, CRC Press LLC.

### 22-Mec-B4 Integrated Manufacturing Systems

Production automation and the role of the computer in modern manufacturing systems via a comprehensive overview of applications of advanced technologies in manufacturing and their business impact on the competitive dimensions of cost, flexibility, quality and deliverability. Particular topics include: cellular and flexible manufacturing systems, fundamentals of automation, numerical control programming, material handling and storage, automatically-guided vehicles, manufacturing information systems, production planning and control, automatic identification and data collection, lean and agile manufacturing, computer-aided process planning, quality control.

*Textbooks (most recent edition is recommended):*

- Groover, Mikell P., Automation, Production Systems, and Computer-integrated Manufacturing, Prentice Hall.
- James Cao, William J. Stevenson, Marie-Claude Bolduc, Mehran Hojati, La gestion des opérations, Chenelière.

## **22-Mec-B5 Product Design and Development**

Modern tools and methods for creative product design and development involving product research, establishment of design parameters, experimentation, development of conceptual alternatives, visualization, evaluation, revision, optimization and presentation. Particular topics include: The engineering design process, development processes and organizations, product planning, identifying customers' needs, product specifications, concept generation, concept selection, prototyping, robust design, concept testing, product architecture, industrial design, design for manufacturing, patents and intellectual property, product development economics, and managing projects.

*Textbooks (most recent edition is recommended):*

- Ulrich, Karl T. & Steven D. Eppinger, Product Design and Development, McGraw Hill.

## **22-Mec-B6 Advanced Fluid Mechanics**

Review of basic concepts; elementary two-dimensional potential flow, vorticity and circulation, one-dimensional compressible flow of an inviscid perfect gas, isentropic flow through nozzles, shock waves, frictional compressible flow in conduits, equations of viscous flow, laminar and turbulent boundary layers. Bernoulli's equation and Navier-Stokes equations. Dimensional analysis and similitude.

*Textbooks (most recent edition is recommended):*

- White, F.M., Fluid Mechanics, McGraw-Hill.
- Munson, Mécanique des fluides, Éditions Reynald Goulet.

## **22-Mec-B7 Aero and Space Flight**

Atmospheric characteristics relating to flight; measurement of air speed. Prediction of 2-D lift and drag using momentum and pressure methods; boundary layers and friction drags; dimensional analysis and wind tunnel measurements pertaining to lift and drag; induced drag and total airplane drag. Propulsion systems: turbo-fan and propeller/engine combinations; propulsion efficiency; thrust/power characteristics. Airplane performance; climb rate, time of climb, ceiling, generalized power required curve; range-payload characteristics; turns, take off, and landing; flight performance including stall, structural, and gust envelopes. Static stability and control. Re-entry and launch issues for space flight.

*Textbooks (most recent edition is recommended):*

- Anderson, J.D., Introduction to Flight, McGraw Hill.
- Barnes W. McCormick, Aerodynamics, Aeronautics & Flight Mechanics, Wiley.

## **22-Mec-B8 Engineering Materials**

Working properties and applications of metallic, non-metallic, polymer, and composite materials. High temperature materials, microscale and nanoscale mechanisms responsible for their unique properties (e.g., molecular mobility and phase transitions).

Selection and testing of materials. Testing of engineering materials. Emphasis on those used in aircraft, high-speed ground transportation vehicles, underwater, and space applications.

*Textbooks (most recent edition is recommended):*

- Ashby, Michael and D.R.H. Jones, Engineering Materials 1: An Introduction to Properties, Applications and Design, Butterworth-Heinemann.
- Ashby, Michael and D.R.H. Jones, Engineering Materials 2: An Introduction to Microstructures, Processing and Design, Butterworth-Heinemann.

## 22-Mec-B9 Advanced Engineering Structures

Materials and mechanics issues. Constitutive models for macroscale representation of the material response to mechanical load, temperature changes, electric field, etc. High and low temperature problems. Strength theories for triaxial cases, stress concentration, fatigue analysis and endurance limit, plastic behaviour, residual stresses, creep and stress relaxation. Fatigue and crack propagation. Design and analysis of structures: torsion of shells and box beams. Bending of thin-walled beams with open and closed sections. Flexural axis, shear lag, effects of stringers and booms. Pressure cabin problems, introduction to dynamic loading, normal modes, response to gust and landing loads. Aeroelastic effects, flutter and divergence.

*Textbooks (most recent edition is recommended):*

- Dowling, Norman E., Mechanical Behavior of Materials, Prentice Hall.
- Megson, T.H.G., Aircraft Structures for Engineering Students, Butterworth-Heinemann.

## 22-Mec-B10 Finite Element Analysis

Linear static analysis: basic concepts, shape functions, bar and beam elements, direct and energy-based formulations, simple coordinate transformations, element assembly, boundary conditions, equation solution. Planar model formulations, work equivalent loads. Isoparametric element formulation: Jacobian matrix, numerical integration, stress averaging. Modeling, common errors, convergence, and accuracy issues. Introductory 3D solids, solids of revolution, plates and shells. Thermal analysis: matrix formulation, steady state and transient response. Introductory nonlinear modeling and procedures: simple material nonlinearity, stress stiffening, contact interfaces.

*Textbooks (most recent edition is recommended):*

- Cook, R.D., Finite Element Modeling for Stress Analysis, John Wiley & Sons.
- Logan, A First Course in Finite Element Method, P.W.S. Engineering.

## 22-Mec-B11 Acoustics and Noise Control

Function of hearing system, acquired deafness, acoustics standards and recommendations. Basic principles and calculations of acoustics phenomenon. Instrumentation about noise measurement, frequency-analysis sound meter. Acoustics reflection and transmission, characterization and selection of acoustics materials. Room acoustics, preventive calculation of noise level in rooms. Sound propagation in conduits, muffler design. Noise analysis and application of noise reduction techniques.

*Textbooks (most recent edition is recommended):*

- Barron, Randall F., Industrial Noise Control and Acoustics, Marcel Dekker.

## 22-Mec-B12 Robotics

Robot components (sensors, actuators, and end effectors, and their selection criteria); basic categories of robots (serial and parallel manipulators, mobile robots); mobility/constraint analysis; workspace analysis; rigid body kinematics (homogeneous transformation, angle and axis of rotation, Euler angles, cylindrical and spherical coordinates); manipulator kinematics and motion trajectories (displacement and velocity analyses, differential relations, Jacobian matrix); non-redundant and redundant sensing/actuation of manipulators; manipulator statics (force and stiffness); singularities; and manipulator dynamics.

*Textbooks (most recent edition is recommended):*

- Craig, J.J., Introduction to Robotics: Mechanics and Control, Addison-Wesley Publishing Co.

## **22-Mec-B13 Biomechanics (04-Bio-A4)**

The musculoskeletal system; general characteristics and classification of tissues and joints. Elastic and viscoelastic mechanical characterization of biological tissues including bone, cartilage, ligament and tendon. Principles of viscoelastic and the rate sensitivity of biological materials. The stress-strain-time or constitutive equations for soft connective tissue components. Biomechanics and clinical problems in orthopaedics. Modelling and force analysis of musculoskeletal systems. Passive and active kinematics. Mechanical properties of biological and commonly used biomedical engineering materials.

*Textbooks (most recent edition is recommended):*

- Berger, S.A., W. Goldsmith and E.R. Lewis, Introduction to Bioengineering, Oxford University Press.
- Nordin, Margareta and Victor H. Frankel, Basic Biomechanics of the Musculoskeletal System, Lippincott Williams & Wilkins.

## **22-Mec-B14 Computational Fluid Dynamics**

Numerical methods for modelling fluid flows: Finite volume, finite difference, and finite elements methods, grid generation and grid independence, flow equations and their discretization, solution techniques, and turbulence modelling. Verification and validation techniques. Post-processing and flow visualization methods. Features for commercial CFD codes.

*Textbooks (most recent edition is recommended):*

- Versteeg H. K., Malalasekera W., An Introduction to Computational Fluid Dynamics - The finite volume method, Pearson Education Limited.