Aerospace / Aeronautical Engineering Examinations

Group A Examinations (Seven Of Eight Required)

20-Aero-A1 Aerodynamics [Aero I]

Aerodynamic forces and moments, centre of pressure and aerodynamic centre, flow similarity, conservation laws, flow concepts, Bernoulli's equation and its applications, Laplace's equation and elementary flows, non-lifting and lifting flows over a circular cylinder, the Kuta-Joukowsky theorem, source panel method, airfoil nomenclature and characteristics, the Kutta condition, Kelvin's circulation theorem, classical thin airfoil theory for symmetric and cambered airfoils, vortex panel method, estimating skin friction drag for airfoils, downwash and induced drag, vortex filament concept, the Biot-Savart law, Helmholtz's theorems, Prandtl's lifting line theory for elliptical and general planform wings. Use of numeric modelling as a design and predictive tool.

Textbooks (most recent edition is recommended):

- Anderson, J. D., Jr.: Fundamentals of Aerodynamics, McGraw-Hill

20-Aero-A2 Flight Mechanics and Performance [Aero II]

Fundamental concepts of aircraft aerodynamics (lift and drag, geometric and inertial properties), propulsion (power and thrust). Equations of motion for steady and accelerated flight. Methods of estimating aircraft performance for take-off, climb, cruise, turning and descent. Range and endurance trade-offs in aircraft design. Mathematical models for aircraft performance analysis. Methods for calculating load factors, V-n diagrams and flight envelopes. Modeling and assessing longitudinal, lateral and directional motion and maneuverability. Use of numeric modelling as a design and predictive tool.

Textbooks *(most recent edition is recommended):*

- Anderson, J. D., Jr.: Aircraft Performance and Design, McGraw-Hill
- Roskam, J. and Lan, C.-T.: Airplane Aerodynamics and Performance, DARcorporation
- Sadraey, M. H.: Aircraft Performance, An Engineering Approach, CRC Press
- Shevell, R.D.: Fundamentals of Flight, Prentice Hall

20-Aero-A3 Aircraft Structures and Design

The analysis and design of aircraft structure includes design criteria, structural-component design concepts, aircraft loads and load paths, aircraft materials including metallic and composite materials, design to static strength - buckling and crippling, mechanical joints, durability and damage tolerance, practical aircraft stress analysis and design considerations, certification of structure - aging and repair. Use of numeric modelling as a design and predictive tool.

Textbooks: *(most recent edition is recommended):*

- Megson, T.H.G.: Aircraft Structures for Engineering Students, Butterworth-Heinemann

Supplementary examples:

- Bruhn, E.F.: Analysis and Design of Flight Vehicle Structures, Jacobs Publishing
- Peery, D.J. and Azar, J.J.: Aircraft Structures, McGraw Hill

20-Aero-A4 Propulsion

Thermodynamics and fluid dynamics: mass, momentum and energy conservation, compressible fluid flow,

isentropic flow, heat transfer. Propellers: momentum theory of propellers, blade element theory, velocity triangles, performance parameters. Internal combustion engines: spark-ignition, compression-ignition, supercharging. Jet engines: Cycle analysis of turbojets, design of intakes, compressor design, centrifugal compressors; axial-flow turbines, combustors, turbines, afterburners, exhaust nozzles, cycle analysis of turbofans, cycle analysis of turboprop engines, ramjets, scramjets. Rocket engines: thrust and specific impulse, nozzle theory and configuration, flight vehicles, chemical rockets, liquid propellants fundamentals, engine systems, solid rockets and propellants, hybrid rockets, rocket motor design, electric propulsion, rocket plumes. Aircraft fuel systems. Use of numeric modelling as a design and predictive tool.

Textbooks *(most recent edition is recommended)*:

- Farokhi, S.: Aircraft Propulsion, Wiley
- Hill, P. G. and Peterson, C.: Mechanics and Thermodynamics of Propulsion, Prentice-Hall
- Sutton, G.: Rocket Propulsion Elements, Wiley

20-Aero-A5 Aerospace Materials

Properties, behaviour and manufacturing methods for aerospace materials used in aerospace structures, space structures, and propulsion components, including metals, polymers, composites, and ceramics. Materials integrity, selection, and monitoring in harsh environment, re-entry from space.

Textbooks *(most recent edition is recommended):*

- Kalpakjian, S. and Schmid, S.: Manufacturing Engineering Technology, Pearson
- Callister, W., Jr. and Rethwisch, D.G.: Materials Science and Engineering, Wiley

20-Aero-A6 Stability and Control

Review of forces and moments associated with aircraft aerodynamics (lift and drag, geometric and inertial properties), propulsion (power and thrust) airspeed and flight attitude. Equilibrium states; Physical effects of the wing, fuselage, and tail on aircraft motion Stability derivatives; Longitudinal static stability including pitch stiffness, neutral point and elevator trim. Lateral static stability including yaw and roll coupling, rudder power and adverse yaw. Certification requirements for lateral static stability. Analysis of the short-term response to perturbations from dynamic equilibrium (stability) including linearized equations for small disturbance analysis. Dynamic characteristics for free and forced response, lateral and longitudinal dynamics. Natural frequencies and damping, longitudinal Phugoid motion, lateral and rolling instabilities. Aircraft configurations and their relationship to stability derivatives and characteristic longitudinal and lateral-directional motions. Medium-term response to control inputs (control), equilibrium states, longitudinal, lateral and directional trim. Handling (flying) qualities across flight conditions. Control methods and systems with emphasis on flight vehicle stabilization by classical and modern control techniques; control techniques for aircraft stabilization including both autonomous and pilot-in-the-loop considerations. Sensors, actuators, stability augmentation and dynamic control systems. V/STOL stability, dynamics, and control during transition from hover to forward flight; parameter sensitivity; and handling quality analysis of aircraft through variable flight conditions. Use of numeric modelling as a design and predictive tool.

Textbooks *(most recent edition is recommended):*

- Etkin, B. and Reid, L.D.: Dynamics of Flight, Stability and Control, McGraw-Hill
- Nelson, R.C.: Aircraft Stability and Automatic Control, McGraw-Hill

20-Aero-A7 Fluid Mechanics

Fluid mechanics in the context of aerospace performance and control. Kinematics: Fluid motion, acceleration, Euler’s equations, irrotational and potential flows, plane potential flows. Bernoulli equation. Control volume approach and mass conservation, continuity equation. Momentum conservation and applications, Navier-Stokes equations. Energy conservation: energy, work and power; hydraulic and energy grade lines. Dimensional analysis and similitude: Buckingham π theorem, dimensional analysis, modeling. Viscous flows: boundary layer description, laminar and turbulent boundary layers, pressure gradient effects on boundary layers. Flow in conduits; laminar and turbulent flow in pipes; Moody diagram, losses in pipes. Use of numeric

modelling as a design and predictive tool. Differential analysis of fluid flows, vorticity, stream function, stresses, and strains. Flow over immersed bodies, boundary layers, separation, and thickness. Drag, lift and applications. Introduction to compressible flows, speed of sound, Mach cone, and some characteristics of supersonic flows.

Textbooks *(most recent edition is recommended):*

- Munson, B.R., Okiishi, T.H., Huebsh, W.W., and Rothmayer, A.P.: Fundamentals of Fluid Mechanics, Wiley
- White, F.: Fluid Mechanics, McGraw-Hill

20-Aero-A8 Thermodynamics

Thermodynamics in the context of aerospace systems. Thermodynamic systems, states, properties; specific volume, pressure and temperature, processes, and equilibrium. First law of thermodynamics; energy of a system; energy transfer by heat, energy balance for closed systems, energy analysis of cycles. Second law of thermodynamics; irreversible and reversible processes; application to thermodynamic cycles; Kelvin temperature scale; maximum performance measures for cycles operating between two reservoirs; Carnot cycle. Entropy: Clausius inequality, definition of entropy change, entropy balance for closed systems, isentropic processes; heat transfer and work in internally reversible, steady-state flow processes. Gas Power Systems: internal combustion engines; air-standard Otto cycle; air-standard Diesel cycle; gas turbine power plants; air-standard Brayton cycle. Mixtures of gases, gases and vapours, air conditioning processes. Combustion and combustion equilibrium. Applications of thermodynamics to power production and utilization systems: study of basic and advanced cycles for gas compression, internal combustion engines, power from steam, gas turbine cycles, and refrigeration. Real gases

Thermodynamics of upper atmosphere and re-entry vehicles; radiation in spacecraft thermal control; radiation of black, gray, and real bodies; emissivity and absorbency; geometric coefficients; emissive power and radiosity; radiation in a closed space; Stefan Boltzmann law, Planck distribution law and Wien displacement law for blackbody surface thermal radiation. Use of numeric modelling as a design and predictive tool.

Textbooks *(most recent edition is recommended):*

- Cengel, Y.A. and Boles, M.A.: Thermodynamics: An Engineering Approach, McGraw-Hill
- Noran, M. and Shapiro, H.: Fundamentals of Engineering Thermodynamics, Wiley
Group B Examinations (Three Required)

Group B - Examinations (three required)

20-Aero-B1 Aeroelasticity

Collar’s triangle, notion of stability, free and forced vibration of the one-degree-of-freedom system, divergence and control reversal of rigid wings on elastic supports, steady-flow strip theory, divergence and control reversal of uniform elastic wings, roll effectiveness, airload distribution for uniform elastic wings, typical section model, steady, quasi-steady, and Theodorsen’s unsteady aerodynamic theories for a pitching-plunging typical section model, flutter analysis methods (p method, classical flutter analysis, k method, p-k method), flutter boundary characteristics. Use of numeric modelling as a design and predictive tool.

Textbooks (most recent edition is recommended):

- Hodges, D. H. and Pierce, G. A.: Introduction to Structural Dynamics and Aeroelasticity, Cambridge University Press

20-Aero-B2 Certification, Standards and Regulations

Overview of Transport Canada and other international aviation regulations and standards (e.g. FAA, EASA). Aircraft systems design including requirements associated with Aircraft Type Design (Canada), Type Certification (FAA), regulations, criteria and demonstration of compliance. Risk-based regulatory development and hazard assessment approaches. Certification and test of safety-critical software. Aircraft

categories and associated regulations. Ongoing airworthiness regulations including maintenance and repair. Delegation of authority; Approval of design, manufacturing, operation and maintenance organizations including delegation of authority. Licencing and training of individuals including flight crew and maintenance personnel. Operational safety and regulations concerning Air Traffic Control and the National Air Space (NAS). Environmental considerations, remotely piloted systems and the development process for new regulations.

Textbooks *(most recent edition is recommended):*

- De Florio, F.: Airworthiness: An Introduction to Aircraft Certification and Operations, Butterworth-Heinemann

20-Aero-B3 Numerical Methods

Roots of algebraic and transcendental equations; function approximation; numerical differentiation; numerical integration; solution of systems of linear equations, curve fitting, polynomial interpolation and splines. Computational techniques and state-of-the-art algorithms for solving ordinary/partial differential equations, nonlinear systems, and unconstrained/constrained optimization problems; error analysis and efficient implementation of these algorithms for aerospace applications such as aerostructures, aerodynamics, dynamics and control, and aerospace systems.

Textbooks *(most recent edition is recommended):*

- Chapra, S.C. and Canale, R.P.: Numerical Methods for Engineers, McGraw-Hill
- Rao, S.S.: Applied Numerical Methods for Engineers and Scientists, Pearson
- Gilat, A. and Subramaniam, V.: Numerical Methods for Engineers and Scientists, Wiley

20-Aero-B4 Advanced Aerodynamics

Compressible Fluid Flow: Wave propagation in compressible media, isentropic flow of a perfect gas, flow in convergent-divergent ducts, de Laval nozzles, diffusers. Shockwaves: normal shockwaves, oblique shockwaves, reflected shockwaves, expansion waves, supersonic inlets, Prandtl-Meyer flow. Linearized flow: transonic flow, compressibility correction, critical Mach number. Aerodynamics: area rule, supercritical airfoils, lifting surfaces, slender bodies. Hypersonic flow: chemically reaction flow, thin shock layers, Newtonian laws. Use of numeric modelling as a design and predictive tool.

Textbooks *(most recent edition is recommended)*:

- Anderson, J.D.: Modern Compressible Flow, McGraw-Hill.
- Anderson, J.D.: Fundamentals of Aerodynamics, McGraw-Hill

20-Aero-B5 Human/Machine Interface Design

Introduction to human/machine design engineering in an aerospace context. Human sensory perceptions and information processing models. Psychology of information processing and perception. Implementation of aircraft control: control surfaces and their operations, development of thrust and its control; basic and advanced concepts avionics and aircraft systems, including avionics systems framework and design; autopilot systems, their algorithms, dynamics and interaction problems; flight instruments, principles of operation and dynamics; crew-plane interface, displays and human-machine interaction; cockpit layouts—basic configuration, ergonomic design, control field forces; HUD; flight management systems, and communication equipment; introduction to flight simulation: overview of visual, audio and motion simulator systems; advanced concepts in flight simulators; Matlab/Simulink; characteristics and performance of linear feedback control systems**;** adaptive control systems. Software integration with crew and transparency of automated control systems.

Textbooks *(most recent edition is recommended)*:

- Martinussen, M. and Hunter, D.R.: Aviation Psychology and Human Factors, CRC Press
- Salas, E. and Maurino, D.: Human Factors in Aviation, Academic Press

20-Aero-B6 Instrumentation and Measurement

Design knowledge of the multiple signal processing chains required in aerospace applications, from transducer, transmission, processing and conditioning and use in avionics systems and displays. Characterisation of each stage in the process in terms of performance, error production and necessary signal conditioning, e.g. measurement of physical quantities; static and dynamic characteristics of instruments — calibration, linearity, precision, accuracy, and bias and sensitivity drift; sources of errors; experiment planning; data analysis techniques; signal generation, acquisition and processing; principles and designs of systems for measurement of position, velocity, acceleration, pressure, force, stress, temperature, flow-rate, proximity detection.

Discrete-time processing of continuous-time signals. Linear Time Invariant (LTI) systems. Unit impulse response and convolution. The Fourier transform representation of signals and systems. Basic structures for Finite-Impulse-Response and Infinite-Impulse-Response filters. Computer-based MATLAB simulation. Textbooks *(most recent edition is recommended)*:

- Mandal, M. and Asif, A.: Continuous and Discrete Time Signals and Systems, Cambridge University Press
- Oppenheim, V. and Schafer, R.W.: Discrete-Time Signal Processing, Prentice Hall

20-Aero-B7 Orbital Mechanics/Attitude Dynamics

Keplerian two-body problem: Kepler's laws, orbital elements, orbit determination. Orbital perturbations: oblateness of the Earth, atmospheric drag. Orbital maneuvers and interplanetary flights, Spacecraft Formation Flying. Applications of Newtonian and Lagrange methods in orbital motion and attitude motion; orbital elements, orbital perturbations, interplanetary trajectory design procedure, orbital maneuvers; coordination transformation; design of spacecraft attitude dynamics (spacecraft dynamics and attitude stability) and controllers. Use of numeric modelling as a design and predictive tool.

Textbooks (*most recent edition is recommended*):

- Prussing, J.E. and Conway, B.A.: Orbital Mechanics, Oxford University Press
- Chobotov, V.A.: Orbital Mechanics, AIAA Education Series
- Sidi, M.J.: Spacecraft Dynamics and Control, Cambridge University Press

20-Aero-B8 Spacecraft/Space System Design

Space mission analysis; implications for systems and missions; exploration missions; space environment and its effect on spacecraft design; spacecraft structures and mechanisms; spacecraft propulsion and launch; Spacecraft payloads (remote sensing, imaging systems, astronomy instrumentation etc.); spacecraft thermal control; spacecraft electrical power systems; communications.

Textbooks *(most recent edition is recommended):*

- Aguirre, M.A.: Introduction to Space System Design and Synthesis, Springer
- Fortescue, P.: Spacecraft Systems Engineering, Wiley
- Wertz, J.R.: Space Mission Analysis and design, Microcosm Press

20-Aero-B9 Space Environment

Upper atmosphere and Ionosphere, Atmospheric oxygen and UV, Solar system, Solar wind, Gravitational fields, Atmospheric drag, Electric and Magnetic fields, Earth’s environment and impacts on spacecraft design, Effect of radiation, Thermal effects, Plasma interactions, Surface contamination and charging, Space debris.

Textbook *(most recent edition is recommended):*

- Pisacane, A.: The Space Environment and Its Effects on Space Systems, AIAA

20-Aero-B10 Aerospace Communications Systems

Analogue and digital aerospace communications systems includes crew radios, maintenance data systems, satellite data links. Radio communications; link analysis and performance, terrestrial and satellite communications.

Fundamentals; decibel, intermodulation, idB compression, dynamic range, SNR, noise figure, noise temperature, antenna gain, EIRP, G/T. Line-of-sight links; receiver, diversity, fade margin. Satellite links; link calculations, multiple accessing, earth stations. Fiber links, fiber types, sources, detectors, systems.

Review of signals, linear systems and Fourier theory; signal bandwidth and spectra; digital waveform coding; introduction to analog and digital modulation systems; synchronization; characterization and effects of noise; link budgets; communications media and circuits; applications to current communications systems.

Analog communications and frequency multiplexing; pulse-code-modulation and time multiplexing; additive white Gaussian noise; matched filter and correlator receiver; maximum likelihood receiver and error probability; intersymbol interference, pulse shaping filter; Signal Space Analysis; Union Bound on the probability of error; Pass-band communication Systems; coherent and non-coherent communication systems. Introduction to synchronization.

Textbooks *(most recent edition is recommended):*

- Black, B.A. et al: Introduction to Wireless Systems, Prentice Hall
- Sklar, B.: Digital Communications: Fundamentals and Applications, Prentice Hall
- Haykin, S. and Moher, M.: Introduction to Analog and Digital Communications, Wiley
- Haykin, S.: Communication Systems, Wiley
- Lathi, B.P.: Signal Processing and Linear Systems, Oxford University Press
- Haykin, S. and Van Veen, B.: Signals and Systems, Interactive Solutions, Wiley
- Couch, L.W.: Digital and Analog Communication Systems, Prentice Hall
- Lathi, B.P.: Modern Digital and Analog Communication Systems, Oxford University Press
- Tooley, M. and Wyatt, D.: Aircraft Communications and Navigation Systems, Routledge

20-Aero-B11 Electromagnetics and Electromagnetic Compatibility

Controlling radiated and conducted emissions and susceptibilities. Electric and magnetic field screening mechanisms. Digital/Analogue circuits as noise sources. Shielding and enclosures, electric and magnetic field screening mechanisms, shielding effectiveness, grounding considerations, bonding and safety of fuel systems. EMC test facilities, screened rooms, TEM cells, signals and spectra, intermodulation, cross-modulation, the spectrum analyzer. Noise and pseudo-random noise, noise performance of measurement/receiving systems, noise equivalent bandwidth, noise figure, antenna noise temperature and S/N ratio.

Hazards of EM radiation to ordnance (HERO) and aircraft. Coupled transmission lines. Modes of coupling. EMI impact on flight control systems and flight management systems.

Systems integration from an EMC perspective. EMC control plans and specifications. EMC certification testing (461/462, CISPR, EU, FCC, FAR/CAR). Grounding, bonding, shielding. Lightning/ESD resistance. EMC and the space environment. EMC and flight-safety critical systems. Models and simulation of EMC threats.

Control of threats from lightning, HIRF, atmospheric phenomena, control of charge distribution on aerospace vehicles. Hardening of aerospace systems. Threats of the space and near-space environment. Interference from passenger-operated electronics. Techniques in Electromagnetic Compatibility

Textbooks *(most recent edition is recommended):*

- Hayt, William H. & John A. Buck, Engineering Electromagnetics, McGraw Hill.
- Ott, H.W., Electromagnetic Compatibility Engineering, Wiley.
- Paul, C.R., Introduction to Electromagnetic Compatibility, Wiley.
- Perez, R.J., Handbook of Aerospace Electromagnetic Compatibility, Wiley.
- Ulaby, Farwwaz, Fundamentals of Applied Electromagnetics, Prentice Hall.

20-Aero-B12 Navigation Systems

Theory and analysis of modern electronic navigation instrumentation, communication and radar systems, approach aids, airborne systems, transmitters and antenna coverage; noise and losses, target detection, digital processing, display systems and technology; demonstration of avionic systems using flight simulator. Earth coordinate and mapping systems.

Integration of avionics systems; review of Earth’s geometry and Newton’s laws; inertial/laser ring navigation sensors and systems (INS); errors and uncertainty in navigation; Global Positioning System (GPS); differential and carrier tracking GPS applications; terrestrial radio navigation systems; Kalman filtering; integration of navigation systems using Kalman filtering; integration of GPS and INS using Kalman filtering.

Integration of navigation systems to aircraft systems. Navigation systems for use beyond land. Fault-tolerant navigation and control systems. Airborne mapping, doppler and multimode radar. Integrated communication/navigation systems.

Textbooks *(most recent edition is recommended):*

- Farrell, J.: Aided navigation: GPS with high rate sensors, McGraw Hill
- Kayton, M.: Avionics Navigation Systems, Wiley
- Moir, I., Seabridge, A. and Jukes, M.: Civil Avionics Systems, Wiley
- Moir, I. and Seabridge, A.: Aircraft Systems, Wiley
- Tooley, M. & Wyatt, D.: Aircraft Communications and Navigation Systems, Routledge