APPENDIX 'A'

AIR NAVIGATION

THE SYLLABUS OF AIR NAVIGATION IS AS FOLLOWS

1. Air Navigation

a) Basics of Navigation

- The solar system
  - seasonal and apparent movements of the sun

- The earth
  - Great circle, small circle, rhumb line
  - convergency, conversion angle
  - latitude, difference of latitude
  - longitude, difference of longitude
  - use of latitude and longitude co-ordinates to locate any specific position

- Time and time conversions
  - apparent time
  - UTC
  - LMT
  - Standard times
  - international dateline
  - determination of sunrise, sunset and civil twilight

- Directions
  - terrestrial magnetism: declination, deviation and compass variations
  - magnetic poles, isogonals, relationship between true and magnetic
  - gridlines, isogrives

- Distance
  - units of distance and height used in navigation: nautical miles, statute miles, kilometers, metres, yards and feet
  - conversion from one unit to another
  - relationship between nautical miles and minutes of latitude

b) Magnetism and Compasses

- General principles
  - terrestrial magnetism
  - resolution of the earth's total magnetic force into vertical and horizontal components

- the effects of change of latitude on these components
- directive force
- magnetic dip
- variation

- Aircraft magnetism
  - hard iron and vertical soft iron
  - the resulting magnetic fields
  - the variation in directive force

- Change of deviation with change of latitude and with change in aircraft's heading
- turning and acceleration errors
- keeping magnetic materials clear of the compass
- knowledge of the principles, standby and landing or main compasses and remote reading compasses
  - detailed knowledge of the use of these compasses
  - serviceability tests
  - advantages and disadvantages of the remote indicating compasses
  - adjustment and compensation of direct reading magnetic compass

c) **Charts**

- General properties of miscellaneous types of projections
  - Mercator
  - Lambert Conformal Conic
  - Polar Stereographic
  - Transverse Mercator
  - Oblique Mercator

- The representation of meridians, parallels, great circles and rhumb lines
  - Direct Mercator
  - Lambert Conformal Conic
  - Polar Stereographic
- The use of current aeronautical charts
  - plotting positions
  - methods of indicating scale and relief
  - conventional signs
  - measuring tracks and distances
  - plotting bearings

d) Dead Reckoning Navigation (DR)

- Basics of dead reckoning
  - track
  - heading (compass, magnetic, true, grid)
  - wind velocity
  - airspeed (IAS, CAS, TAS, Mach number)
  - ground speed
  - ETA
  - drift, wind correction angle
  - DR-position, fix

- Use of the navigational computer
  - speed
  - time
  - distance
  - fuel consumption
  - conversions
  - heading
  - airspeed
  - wind velocity

- The triangle of velocities, methods of solution for the determination of
  - heading
  - ground speed
  - wind velocity
  - track and drift angle, track error
  - time and distance problems

- Determination of DR position
  - need for DR
  - confirmation of flight progress (mental DR)
  - lost procedures
  - heading and TAS vector since last confirmed position
  - application of wind velocity vector
  - last known track and ground speed vector
  - assessment of accuracy of DR position

- Measurement of DR elements
  - calculation of altitude, adjustments, corrections, errors
  - determination of temperature
  - determination of appropriate speed
  - determination of mach number

- Resolution of current DR problems by means of
  - mercator charts
  - lambert charts
  - polar stereographic projections

- Measurement of
  - maximum range
  - radius of action
  - point-of-safe-return and point-of-equal-time

- Miscellaneous DR uncertainties and practical means of correction

e) **In-flight Navigation**

- Use of visual observations and application to in-flight navigation

- Navigation in climb and descent
  - average airspeed
  - average wind velocity
  - ground speed/distance covered during climb or descent

- Navigation in cruising flight, use of fixes to revise navigation data as
  - ground speed revision
  - off-track corrections
  - calculation of wind speed and direction
  - ETA revisions

- Flight log (including navigation records)

f) **Electronic Flight Instrument System (EFIS)**

- information display types
- data input
- control panel, display unit
- example of a typical aircraft installation

g) **Flight Management System (FMS)**

- general principles
- inputs and outputs of data

h) **Ground Proximity Warning System (GPWS)**
- function
- warning modes

i) **Traffic Collision Avoidance System (TCAS)**
- function
- warning modes

2. **Mass and Balance**

a) Introduction to Mass and Balance

- Centre of gravity (cg): Definition, importance in regard to aircraft stability
- Mass and balance
- consult aeroplane flight manual for: cg limits for take-off, landing, cruise configurations
- maximum ramp and taxi mass
- factors determining maximum permissible mass: structural limitations, performance limitations such as – runway available for take-off and landing, weather conditions (temperature, pressure, wind, precipitation); rate-of-climb and altitude requirements for obstacle clearance; engine-out performance requirements
- factors determining cg limits: aircraft stability, stability of flight controls and surfaces to overcome mass and lift pitching moments under all flight conditions, changes in cg location during flight due to consumption of fuel, raising and lowering of undercarriage, and intentional relocation of passengers or cargo, transfer of fuel, movement of centre of lift because of changes in position of wing flaps

b) Loading

- Terminology: empty mass, dry operating mass (empty mass + crew + operating items + unusable fuel), zero fuel mass, standard mass – crew, passengers and baggage, fuel, oil water (volume/mass conversion factors), carry-on luggage, useful load (traffic load + usable fuel), equipment lists
- Procedure for determining aeroplane mass and balance documentation: Determine Dry Operating Mass (crew, equipment, etc.), add mass of passengers and cargo

(including passengers baggage) (standard mass), add mass of fuel, check that applicable maximum gross mass limits are not exceeded (mass within legal limits)

- Effects of overloading: high take-off and safety speeds, longer take-off and landing distances, lower rate-of-climb, influence on range and endurance, decreased engine-out performance, possible structural damage in extreme cases

c) Centre of Gravity (CG)

- basis of CG calculations (load and balance documentation)
  - Datum – explanation of term, location, use in CG calculation
  - Moment arm – explanation of term, determination of algebraic signs, use
  - Moment – explanation, moment = mass x moment arm
  - Expression in percentage of mean aerodynamic chord (% MAC)
- Calculation of CG; calculation of CG longitudinal and lateral
  - movement of CG with addition of fuel, load and ballast
  - practical methods of calculation – computation method using eight mathematical computations or specially designed slide rule, graph method, table method
- Securing of load
  - importance of adequate tie-down
- Effect of load-shift
  - movement of CG. Possible out of limits
  - possible damage due to inertia of a moving load
  - effect of acceleration of the aircraft load

3. Performance

- **Performance of Aeroplanes**

Take-off

- definitions of terms and speeds used
  - appropriate speed definitions associated with take-off performance, with emphasis on:
    - V_1: decision speed in event of engine failure on take-off

- V_R: rotation speed
- V_2: take-off safety speed

- appropriate distance definitions associated with take-off:
  - balanced field length
  - take-off run available (TORA)
  - take-off distance available (TODA)
  - accelerate stop distance available (ASDA)
  - clearways, stopways
  - mass / altitude / temperature limits
- other appropriate speeds: V_{MCG}, V_{MCA}, V_{MU}, V_{LOF}, V_{MBE}
- Runway variables
  - length, slope, surface
  - strength of runway (load classification number, single isolated wheel loading)
- aeroplane variables: mass, flap angle, reduced power settings, increased V_2, use of anti-ice and de-ice, used of bleed air (ECS)
- Meteorological variables: pressure altitude and temperature (density altitude), wind gust factor, surface conditions (standing water, snow, ice etc.)
- take-off speeds: computation of V_1, V_R and V_2; initial climb speed, landing gear and flap retraction speeds
- take-off distance
  - computations of take-off distance
  - include consideration of aeroplane, runway, and meteorological variables when computing take-off distance and take-off speed
  - effects of early or late rotation on take-off distance; possibility of ground stall with early rotation

b) **Accelerate-stop distance**

- concept of balanced field length
  - review of definitions
  - relationship between balanced/unbalanced field length and V_1
- use of flight manual charts
  - computing accelerate-stop distances
    - decision time and deceleration procedure assumptions
    - time-to-decide allowance
    - use of brakes
    - use of reverse thrust

- brake energy absorption limits: delayed temperature rise
- tyre limitations

c) Initial Climb

- climb segments: undercarriage and flap retraction, take-off mass limitation with regard to climb requirements
- all engines operating : climb speed, rate of climb, noise abatement procedure
- engine inoperative operation: best angle-of-climb speed, best rate-of-climb speed, rates of climb, effect of density altitude on climb performance
- Obstacle clearance requirements : climb to clear obstacles, turning to avoid obstacles, effect turns have on climb performance

d) Climb

- use of flight manual performance charts: effect of aeroplane mass, effect of density altitude change, time-to-climb calculations for reaching cruise altitude
- significant airspeeds for climb
  - flap retraction speeds
  - normal (all engine operating) climb speeds – best rate-of-climb, best angle-of-climb
  - one engine inoperative climb
    - climb airspeeds: best rate-of-climb, best angle-of-climb
    - maximum cruise altitude

e) Cruise

- use of cruise charts: determination of cruise altitudes, maximum attainable cruise altitudes, increase of maximum cruise speeds and power settings
- cruise control
  - maximum range: power settings, speeds, fuel consumption
  - maximum endurance: power settings, speeds, fuel consumption
  - speed / range trade-offs, for cruise power settings
  - maximum cruise power settings: resultant speeds, fuel consumption

- en-route one engine inoperative: engine inoperative charts, range and endurance, one-engine out service ceiling, maximum continuous power settings, ETOPS operations
- obstacle clearance en-route: net flight path, vertical and horizontal, overhead mass limitations, drift-down procedures
- en-route – aeroplanes with three or more engine, two engines inoperative
- requirements and limitations

f) Descent and Landing

- use of descent charts
  - time to start descent
  - fuel consumption in descent
  - limiting speed, e.g. : normal operating airspeed, maximum operating airspeed, speed for max. glide ratio, maximum rate of descent speed (cabin pressure rate of descent)

- maximum permitted landing mass : structural limit specified by aircraft manufacturer and the state airworthiness authorities

- approach and landing data calculations
  - suitability of selected landing runway: landing distance available, computation of maximum landing mass for the given conditions, computation of minimum runway length for the given, other factors – runway slope, surface conditions, wind temperature, density altitude

- computation of expected actual landing mass
- computations of approach and landing speeds
- computations should be completed for alternate aerodromes as well
- definitions of terms and speed used: V_{TH}, threshold speed, discontinued approach climb, landing climb, landing distance, dry, wet and contaminated runways, landing distance required – destination airport, alternate airport
- landing: landing configuration (all engine), approach configuration (one engine out)

g) Practical application of an Airplane Performance Manual

- use of typical turbojet or turboprop aeroplane performance manual: take-off and landing mass calculations, take-off data computations
- effects of runway variables, aeroplane variables and meteorological variables
  - computation of the various 'V' speeds for take-off and initial climb
  - computation of runway distance factors
  - rate and gradient of initial climb
  - obstacle clearance
  - appropriate engine-out calculations
- climb computations:
  - climb rates and gradients
  - time-to-climb – fuel used
  - engine-out calculations
- cruise computations
  - power settings and speeds for maximum range, maximum endurance and normal cruise
  - fuel consumption
  - engine-out operation; pressurization failure, effect of lower altitude on range and endurance
  - ETOPS (EROPS) flight
  - additional considerations concerning fuel consumption: effects of altitude and aircraft mass, fuel for holding, approach and cruise to alternate, in normal and abnormal conditions, after jet engine failure, after decompression

4. Flight Planning and Monitoring

a) Flight Plans for Cross Country Flights

- Navigation Plan
  - selection of routes, speeds, heights (altitudes) and alternate airfield/landing sites
    - terrain and obstacle clearance
    - cruising levels appropriate for direction of flight
    - navigation check points, visual or radio
  - measurement of tracks and distances
  - obtaining wind velocity forecast for each leg
  - computations of headings, ground speeds, and time en-route from tracks, true airspeed and wind velocities
  - completion of pre-flight portion of navigation flight log

- Fuel Plan

    - computation of planned fuel usage for each leg and total fuel usage for the flight
        - flight manual figures for fuel flow during climb, en-route and during descent
        - navigation plan for times en-route
    - fuel for holding and diversion to alternate airfield
    - reserves
    - total fuel requirements for flight
    - completion of pre-flight portion of fuel log

- Flight monitoring and in-flight re-planning
    - in-flight fuel computations
        - recording of fuel quantities remaining at navigational checkpoints
    - calculation of actual consumption rate
        - comparison of actual and planned fuel consumption and fuel state
    - Revision of fuel reserve estimates
    - in-flight re-planning in case of problems
        - selection of cruise altitude and power settings for new destination
        - time to new destination
        - fuel state, fuel requirements, fuel reserves

- Radio communication and navigation aids
        - communication frequencies and call signs for appropriate control agencies and in-flight service facilities such as weather stations
        - radio navigation and approach aids, if appropriate
        - type
        - frequencies
        - identification

b) ICAO ATC Flight Plan

- types of flight plan
    - ICAO flight plan – format
        - information included in completed plan
        - repetitive flight plan
- completing the flight plan
    - information for flight plan obtained from
        - navigation flight plan
        - fuel plan

- operator's records for basic aircraft information
- mass and balance records

- Filling the flight plan
  - procedures for filing
  - agency responsible for processing the flight plan
  - Adherence to flight plan

c) Practical Flight Planning -

- Chart preparation
  - Plot tracks and measure directions and distances

- Navigation plans
  - Completing the navigation plan using:
    - tracks and distances from prepared charts
    - wind velocities as provided
    - true airspeeds as appropriate

- Simple fuel plans
  - Preparation of fuel logs showing planned values for:
    - fuel used on each leg
    - fuel remaining at the end of each leg
    - endurance, based on fuel remaining and planned consumption rate, at end of each leg

- Radio planning practice
  - Communications
    - frequencies and call signs of air traffic control agencies and facilities and for in-flight services such as weather information

  - Navigation Aids
    - frequencies and identifiers of en-route terminal facilities, if appropriate

d) IFR (Airways) Flight Planning

- meteorological considerations
  - analysis of existing weather patterns along possible routes
  - analysis of winds aloft along prospective routes
  - analysis of existing and forecast weather conditions at destination and possible alternates

- Selection of routes to destinations and alternates
  - preferred airways routings
  - extraction of tracks and distances from NAV chart
  - Frequencies and identifiers of en-route radio navigation aids
  - minimum en-route altitudes, minimum crossing and reception altitudes
  - Standard Instrument Departures (SIDs) and Standard Arrival Routes (STARs)

- General flight planning tasks
  - checking of AIP and NOTAM for latest airfield and en-route status information
  - selection of altitudes or flight levels for each leg of flight
  - application of wind velocity on each leg to obtain heading and ground speeds
  - calculation of en-route times for each leg to the destination and to the alternate and determination of total time en-route
  - completion of fuel plan
  - preliminary study of instrument approach procedures and minima at destination and alternate
  - filling out and filing air traffic flight plan

e) Jet Aeroplanes Flight Planning (Additional considerations)

Additional Flight Planning aspects for Jet aeroplanes (advanced Flight Planning)

- Fuel planning
  - en-route contingency fuel
  - destination, holding and diversion fuel
  - isolated destination reserves
  - importance of altitude selection when planning for diversion to alternate
  - use of performance chart to plan fuel usage and requirements based on planned climb, en-route cruise and descent
  - reserve fuel requirements
  - influence of centre of gravity on fuel consumption

- Computation of point-of-equal-time (PET) and point-of-safe return (PSR)

ETOPS
Computerized Flight Planning

- General principles of present system
  - advantages
  - shortcomings and limitations

f) Practical Completion of a 'Flight Plan' (flight plan, flight log, Nav log ATC plan, etc.)

- Extraction of data
  - extraction of navigational data
  - extraction of meteorological data
  - extraction of performance data
  - completion of navigation flight plan
  - completion of fuel plan
    - time and fuel to top-of-climb
    - cruise sector times and fuel used
    - total time and fuel required to destination
    - fuel required for missed approach, climb en-route altitude, and cruise alternate
    - reserve fuel

- Computation of PET (point-of-equal-time), including equi-fuel and equi-time points, and PSR (point-of-safe-return)