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Question Paper Code : 40055

B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2021.

Fifth Semester

Aeronautical Engineering

AE 8501 – FLIGHT DYNAMICS

(Common to: Aerospace Engineering)

(Regulations 2017)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Among the piston engines, turboprop engines and turbojet engines, which one is the most suitable engine for low speed aircrafts flying at low altitude?

2. What are the conditions for minimum drag of an aircraft?

3. What is the condition for maximum endurance of a propeller driven aircraft?

4. Why longer ground run is required for aircrafts when aerodrome is situated at higher altitudes?

5. What is meant by a coordinated turn?

6. Will the aircraft dynamically stable when it is statically stable? Justify your answer.

7. What is the difference between inherently stable and marginally stable aircraft?

8. Which of the components (viz., fuselage, wings, canards, and control surfaces) of the aircraft structure contributes destabilizing effect to the static longitudinal stability for a conventional aircraft.

9. What is meant by Rudder lock?

10. What is meant by Dutch roll and what is its significance?

PART B — ($5 \times 13 = 65$ marks)

11. (a) Consider an Unmanned Aerial Vehicle (UAV) has the following characteristics: wingspan = 14.85 m, wing area = 11.45 m^2, maximum weight 1020 kg, and fuel weight = 295 kg. The power plant is a Rotax four-cylinder, four-stroke engine of 85 horsepower driving a two-blade, variable-pitch pusher propeller. Assume that the Oswald efficiency factor is 0.7, the zero-lift drag coefficient is 0.03, the propeller efficiency is 0.9, and the specific fuel consumption is 0.2 kg, of fuel per horsepower per hour. Calculate the maximum velocity of the Predator at sea level. (13)

Or

(b) A glider having W = 2000 N, s = 8.0 m^2, Aspect Ratio = 16, e = 0.95, and C_{D0} = 0.015 is launched from a height of 300m. Determine the maximum range, corresponding glide angle, forward velocity, and lift coefficient at sea level. (13)

12. (a) Estimate the maximum rate of climb of the following airplane flying at sea-level and its angle of climb given: W = 8000 kg, S = 25 m^2, $C_D = 0.018 + 0.16\, C_L^2$, Thrust= 2500 kg. Calculate also the maximum rate of climb at 5 km (density =0.745 kg/m^3) with engine thrust as 1800 kg. (13)

Or

(b) An airplane weighing 10000 N is going through such a flight at sea-level at a speed of 135 kmph and goes through 90 degrees in 15 seconds The wing loading(W/S) is 1200 N/m^2 and at this speed the lift-to-drag ratio is 10. Calculate the radius of turn, load factor, and the power required. (13)

13. (a) Given the differential equations that follow,

$$\dot{x}_1 + 0.5x_1 - 10x_2 = -1\delta$$

$$\dot{x}_2 - x_2 + x_1 = 2\delta$$

where x_1 and x_2 are the state variables and δ is the forcing input to the system.

(i) Rewrite these equations in state space form.

(ii) Find the tree response eigenvalues

(iii) What do these eigenvalues tell us about the response of this system?

Or

(b) An airplane has the following stability and inertia characteristics:

W=255826 kg, $l_x = 18.6 \times 10^6$ kg.m², $l_y = 41.4 \times 10^6$ kg.m^2 $l_z = 58.4 \times 10^6$ kg.m^2, Planform area (S)=510.96 m², Wing span (b)=59.64 m, Mean aerodynamic chord=8.32 m, Velocity=85.34 m/s, $C_L = 1.11$, $C_D = 0.102$, lift curve slope=5.7 rad^{-1}, $C_{D\alpha} = 0.66$ rad^{-1}, $C_{m\alpha} = -1.26$ rad^{-1} $C_{mq} = -20.8$ rad^{-1}.

(i) Find the frequency and damping ratio of the short- and long-period modes.

(ii) Find the time to half-amplitude for each mode

(iii) Discuss the influence of the coefficients C_{mq} and $C_{m\alpha}$ on the longitudinal motion. (13)

14. (a) The transfer function for an aircraft cruising at an altitude of 9 km and 0.46 Mach follows, Find the natural frequency, damping ratio, damped frequency, and time constant for the short period and phugoid modes.

$$\frac{\alpha}{\delta_e} = -0.0924 \frac{(s + 336.1)(s^2 + 0.0105s + 0.0097)}{(s^2 + 4.58s + 21.6)(s^2 + 0.0098s + 0.0087)} \quad (13)$$

Or

(b) Write a short note on the following: (13)

(i) Elevator power

(ii) Most forward C.G. for free flight

(iii) Stick free neutral point

(iv) Aileron reversal

(v) Aileron control power

15. (a) The transfer function given below is for one of the longitudinal dynamic responses (SPO) of angle of attack of aircraft (α) for elevator control input δ_e

$$\frac{LT(\alpha)}{LT(\delta_e)} = \frac{-0.8952s - 250.3}{820s^2 + 1633.9s + 6542.9}$$

Find the natural frequency and damping ratio for this mode. Using the final value theory or otherwise, find the steady state value of angle of attack in response to step elevator input of -3°. (13)

Or

(b) The characteristic equation of coupled longitudinal and lateral-directional aircraft motion is known to be an 8th order equation. A typical set of 8 roots of such a characteristic equation for some flight condition is given below:

$\lambda_{1,2} = -4.4 \pm i65.5$, $\lambda_3 = -2, \lambda_4 = 0.05$, $\lambda_{5,6} = -0.35 \pm i12.5$, and $\lambda_{7,8} = -1.4 \pm i41.5$

Show these roots in the $\lambda(\eta,\omega)$ plane indicating the nature of dynamic modes of the aircraft, associated with the 3 pairs of complex conjugate roots – period (short/medium/long period) and damping (highly/moderately/lightly damped) and the 2 real roots (highly/negatively damped). Also name the aircraft modes associated with at all the 8 roots including 2 real roots. Obtain the time to half ($T_{1/2}$) or time to double T_2 as applicable for all the modes and the period T for periodic modes. (13)

PART C — (1 × 15 = 15 marks)

16. (a) Engine manufacturers are constantly trying to reduce Thrust Specific Fuel Consumption (TSFC) in order to reduce the weight of fuel consumed for a given flight of given time duration. By reducing the fuel weight, the payload weight can be correspondingly increased. However, design changes that result in reductions in TSFC also frequently result in slight increases in the engine weight itself, which will then reduce the payload weight. The break-even point is where the decrease in fuel weight is exactly cancelled out by the increase in engine weight, giving no increase in the payload weight. Designating the new reduced thrust-specific fuel consumption by $(TSFC)_{new} = (TSFC)\left(1-\varepsilon_f\right)$ and the new weight of the airplane increased by the increase in engine weight by $W_{new} = W\left(1+\varepsilon_w\right)$, where ε_f and ε_w are small fractional values, prove that the break-even point for changes in engine weight and TSFC are given by

$$\varepsilon_f = \varepsilon_W\left(1+\frac{W}{W_f}\right) = \varepsilon_W\left[1+(L/D)/(TSFC)t\right]$$

where W and W_f are the average weight of the airplane during, cruise and the weight of fuel used during cruise, respectively, both before any design perturbation in engine weight or TSFC, and t is the total cruising time of flight. (15)

Or

(b) Explain in detail the different modes of Oscillation following a disturbance? Also explain in detail the various characteristic modes of oscillation involved in stick fixed and stick free dynamic longitudinal stability. (15)

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