Ref. No .Ex PG/ME/T/116F/2024

MME 1st semester Examination 2024

SUBJECT: Flight Dynamics

Time: Three hours | Full Marks 100

USE SEPARATE ANSWERSCRIPT FOR EACH PART

PART I

Answer any three

2 marks for neatness

Q1. For rotation of a body about an axis derive the following relations

Derive $\bar{v} = \bar{v}_{rel} + \bar{\omega} \times \bar{\rho}$

$\bar{a} = \bar{a}_{rel} + \bar{\omega} \times (\bar{\omega} \times \bar{\rho}) + \bar{\alpha} \times \bar{\rho} + 2\bar{\omega} \times \bar{v}$

Q2. Derive Euler's equations of motion from moment-angular momentum relation.

[Turn over

Q3. The spacecraft shown (Figure Q3) has a mass m with mass centre G. Its radius of gyration about its z-axis of rotational symmetry is k and that about either the x −axis or y −axis is k'. In space, the spacecraft spins within its $x - y - z$ reference frame at the rate $p = \dot{\phi}$. Simultaneously, a point C on the z-axis moves in a circle about the z_0-axis with a frequency f (rotations per unit time). The z_0 axis has a constant direction in space. Determine the angular momentum $\bar{H}_G$ of the spacecraft relative to the axes designated. Note that the x-axis always lies in the $z - z_0$ plane and that the y-axis is therefore normal to z_0.

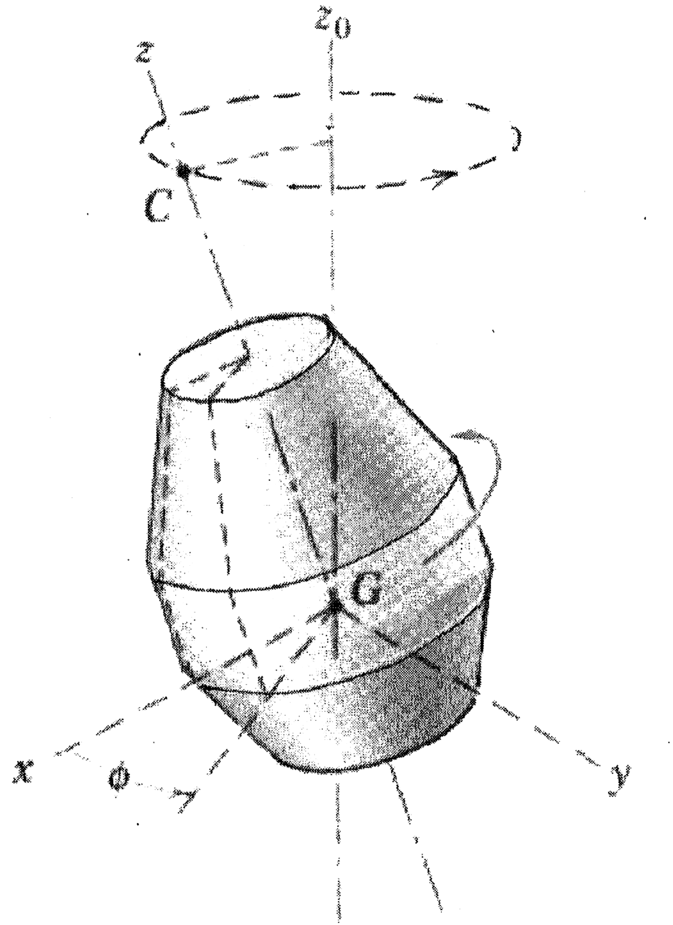

Figure Q3

Q4. The bar OP of length 24m is revolving about the vertical axis OZ at a constant rate of 2 rev/min in the direction shown in fig Q1. Simultaneously OP is being lowered at a constant rate of $\dot{\beta}$ = 0.1 rad/sec. Calculate –

Angular acceleration of OP

Velocity and acceleration of point P

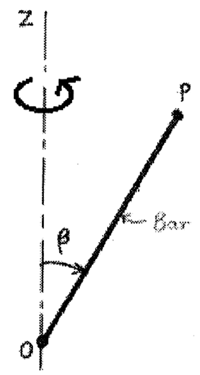

Figure Q4

PART II

[Answer Question No. 1 and any two from the rest]

Q1. a. Consider a model of wing-body shape mounted in a wind tunnel. The flow conditions in the test section are standard sea level properties with a velocity of 100m/s. The wing area and chord are 1.5 sqm and 0.45m respectively. The zero lift moment about centre of gravity is found to be - 12.4Nm. When the model is pitched to another angle of attack, the lift and moment about CG are measured to be 3675N and 20.67Nm respectively. Find the location of aerodynamic centre and calculate the moment co-efficient about the same.
b. If a mass is added in a way that the CG is shifted rearwards by 0.2*c*, calculate the moment about CG when the lift is 4000N.
c. Assume a horizontal tail with no elevator is added to this model. The distance of the tail's aerodynamic centre from the CG of the airplane model is 1.0m. The area of the tail is 0.4 sqm, the tail setting angle being 2 degree. The lift slope of the tail is 0.12 per degree. From experimental measurements, α_a = 5degree, $\varepsilon_0 = 0.01$ and $\delta\varepsilon/\delta\alpha = 0.42$. If the lift at absolute angle of attack if 4134N, calculate the moment about CG. Does this model have longitudinal static stability and balance? [4+4+10]

Q2. a. Discuss about necessary and sufficient conditions of stability of an airplane.
b. Write short notes on: i. Canard Configuration, ii. Induced Drag
[8+4x2]

Q3. a. Discuss about the primary control surfaces of an airplane and their operating principle.
b. Consider an infinitely thin plate of 1 m chord at an angle of attack of 10 degree in a supersonic flow. The pressure and shear stress distribution of upper and lower surfaces respectively are:

$p_u = 4 \times 10^4 (x-1)^{0.2} + 5.4 \times 10^4$

$p_l = 2 \times 10^4 (x-1)^{0.2} + 1.7 \times 10^5$

$\tau_u = 288x^{-0.2}$

$\tau_l = 731x^{-0.2}$

where x is the distance from the leading edge in meter and p and τ are in N/m^2. Calculate the lift and drag, moment about the quarter chord point, all per unit span. Locate the centre of pressure.
[8+8]

Q4. Derive the expressions for moment co-efficient about CG of an airplane including contributions of wing-body and tail. In connection, find the necessary conditions for the longitudinal balance and static stability for the airplane.