MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
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V SEMESTER B.TECH. AERONAUTICAL ENGINEERING

END SEMESTER EXAMINATIONS, NOV/DEC 2022

SUBJECT: FLIGHT DYNAMICS [AAE -3157]

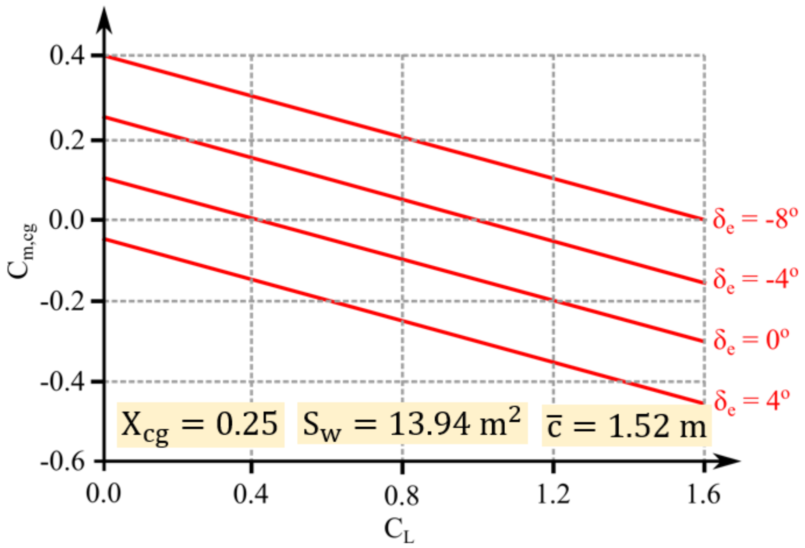
REVISED CREDIT SYSTEM

(22/11/2022)

Time: 3 Hours MAX. MARKS: 50

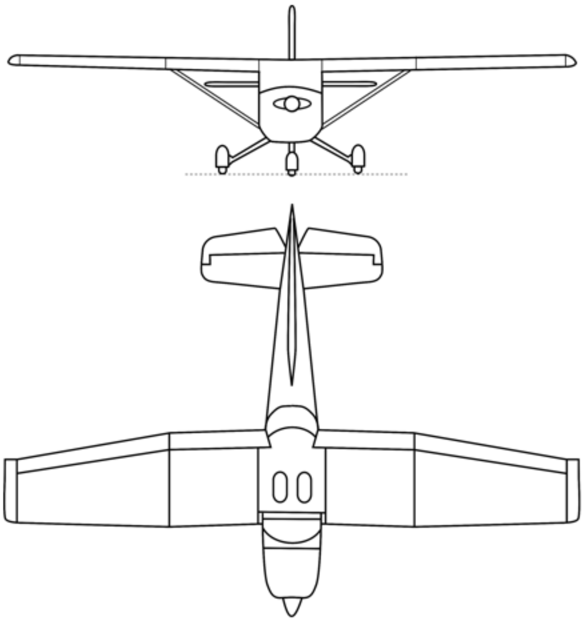
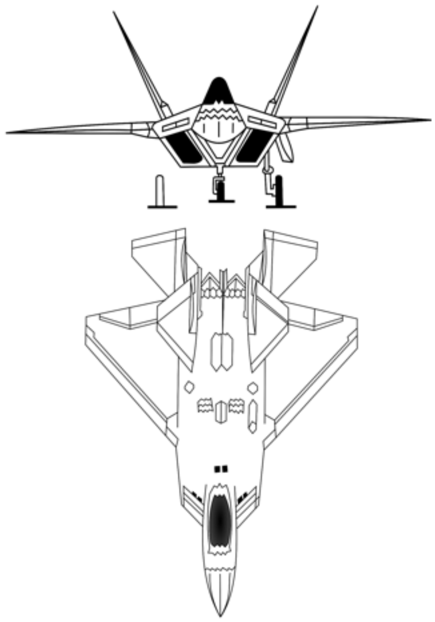
Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.

Q No	Question	Marks	CO attained	BT level
1A	When a statically stable trimmed aircraft experiences a gust and the angle of attack reduces momentarily, what will happen to the center of pressure?	(02)	CO2	L2
1B	A statically-stable aircraft has a lift-curve slope ($C_{L\alpha}$) of 5 (where the angle of attack is measured in radians). The coefficient of the moment of the aircraft about the center of gravity is given as $C_{M,cg} = 0.05 - 4\alpha$. The mean aerodynamic chord of the aircraft wing is 1 m. Find the location of the neutral point of the aircraft from the center of gravity. By changing the size of the horizontal stabilizer and the airfoil, Is it possible to change the position of the neutral point? **Justify the statement**.	(03)	CO2	L3
1C	The pitching moment characteristics of a general aviation airplane are given in the following figure: 	(05)	CO2	L3

	a. Calculate the location of the stick-fixed Neutral point (NP)? b. For the level flight of the aircraft at sea level and at 42.8 m/s, what is the trim C_L and elevator angle to trim? Weight of the aircraft = 1225 kg. The wing planform area is given as 21 m^2.			
2A	The pilot of a conventional airplane that is flying steady and level at some altitude deflects the port side aileron **Up** and the starboard aileron **Down**. What will be the response of the aircraft?	**(02)**	**CO3**	**L2**
2B	Write a brief note on the following: a. What is the advantage of having variable-sweep wings as in Bell X-5 experimental aircraft? b. Does the variable geometry wing concept (oblique wing in AD-1 aircraft) have any advantages compared to the variable-sweep wing concept? c. How does the forward swept wing is better than the backward swept wing?	**(03)**	**CO3**	**L2**
2C	A transport aircraft has 4 engines symmetrically mounted on its wings of 65 m span and an area of 525 m^2. The inboard and the outboard engines are located respectively at 11.7 m and 21.7 m from the plane of symmetry. The Sea Level maximum thrust (F0) per engine is 282 kN. The engine thrust F at any altitude is related to density ratio σ by $F = F_0\sigma$. The aircraft encounters failure of the outboard engine on the port side at a flight speed of 160 m/s at 2000 m altitude (σ = 0.8216). All the engines were set at 75% throttle for the trimmed-level flight before the engine failure. After the engine failure, the Pilot manages to maintain level flight by increasing the throttle setting of the remaining 3 working engines at an identical condition of 100% throttle. a. Calculate the yawing moment due to engine failure and the resulting imbalance in yawing moment coefficient due to asymmetric thrust. Given rudder control power $\mathbf{C_{N_{\delta r}}}$ = - 0.0014/deg obtain the rudder deflection required to trim the asymmetric yawing moment and maintain zero side slip angle. b. At the time of engine failure an atmospheric side gust (crosswind) of 12 m/sec was experienced from the failed engine side (port side). Given directional stability $\mathbf{C_{N_\beta}}$ = 0.032, calculate the side slip angle β due to the side gust and obtain the additional rudder deflection required to trim the yawing moment due to the side gust so that the aircraft heading can be maintained in the crosswind flight condition. c. What is the combined requirement of rudder deflection to trim the yawing moments due to engine failure and the side gust from failed engine side as above? Given the maximum available rudder deflection to be ±20º, verify the adequacy of the rudder control for the above flight case. d. Given $\mathbf{C_{y_\beta}}$ = -0.0008, $\mathbf{C_{y_{\delta r}}}$ = 0.00035, what is the bank angle (**Φ**) required to trim the side force for the above flight condition with an engine failure with crosswind?	**(05)**	**CO3**	**L3**
3A	The aircraft is assumed to be a rigid body and point mass to simplify the equations of motion. When do these assumptions are valid?	**(02)**	**CO1**	**L2**
3B	Linearize the following equation of motion of an aircraft for the given condition: steady-level, straight flight. $$Z + mg\cos\Theta\cos\Phi = m\left(\dot{W} + pV - qU\right)$$	**(03)**	**CO4**	**L4**

	$M = I_{yy}\dot{q} + (I_{xx} - I_{zz})rp + I_{xz}(p^2 - r^2)$			
3C	The longitudinal dynamics of a B747 aircraft under some conditions are given by the space representation: $\dot{X} = AX + BU$ Where the state matrix is given by $A = \begin{bmatrix} -0.00687 & 0.01395 & 0 & -32.2 \\ -0.09055 & -0.3151 & 773.98 & 0 \\ -1.19\times10^{-4} & -0.001026 & -0.4285 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$ a. Find the roots of A and determine the eigenvalues that are related to the phugoid mode and short-period mode. b. Find the natural frequency and damping ratio of the phugoid mode. c. Find the natural frequency and damping ratio of the short-period mode.	**(05)**	**CO5**	**L3**
4A	How is the stability of the tailless flying wing configuration can be maintained from the design aspects?	**(02)**	**CO2**	**L2**
4B	Define the following: a. Rise time b. Settling time c. Percent overshoot	**(03)**	**CO5**	**L1**
4C	The equations of motion for a civil aircraft are given as, $\dot{\alpha} = -0.313\alpha + 56.7q + 0.232\delta_e$ $\dot{q} = -0.0139\alpha - 0.426q + 0.0203\delta_e$ $\dot{\theta} = 56.7q$ Derive the transfer function $\alpha(s)/\delta_e(s)$ and $\theta(s)/\delta_e(s)$ using Cramer's rule.	**(05)**	**CO5**	**L3**
5A	Convert the following differential equation into a state space model. $\frac{d^4x}{dt^4} - 3\frac{d^3x}{dt^3} + 2\frac{d^2x}{dt^2} + 6\frac{dx}{dt} + 4x = 3p + 5q$	**(02)**	**CO1**	**L3**
5B	The Dutch roll motion of the aircraft is described by the following relationship $\begin{bmatrix} \Delta\dot{\beta} \\ \Delta\dot{r} \end{bmatrix} = \begin{bmatrix} -0.26 & -1 \\ 4.49 & -0.76 \end{bmatrix} \begin{bmatrix} \Delta\beta \\ \Delta r \end{bmatrix}$	**(03)**	**CO5**	**L3**

	Find the undamped natural frequency (rad/s) and damping ratio.			
5C	Compare the design features of the Cessna 172 and F-22 Raptor in terms of geometry and stability. Why the F-22 aircraft is highly unstable? Is F-22 a software-driven or pilot-driven aircraft? Justify the statement.  **CESSNA - 172 SKYHAWK**  **Lockheed Martin F-22A Raptor**	**(05)**	**CO5**	**L5**