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Manipal Institute of Technology, Manipal

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VI SEMESTER B.TECH (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, JULY 2016

SUBJECT: HELICOPTER ENGINEERING [AAE 322]

REVISED CREDIT SYSTEM

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ANY FIVE FULL** the questions.
- Missing data may be suitable assumed.

1A. How the disk loading and Figure of Merit influences the performance of a rotor blade? **(02)**

1B. A helicopter with a gross weight of 1363.6 kg, a main rotor radius of 4 m, a rotor tip speed of 207.3 m/s, and has 205 kW delivered to the main rotor shaft. The tail rotor radius is 0.701 m and the tail rotor is located at 4.66 m from the main rotor shaft. Calculate the thrust and power required by the tail rotor for hovering conditions at sea level. Assume that the FM of the tail rotor is 0.70. **(03)**

1C. For a hovering helicopter with coaxial rotors, estimate the hovering horsepower required and the pitch setting for the rotor blades if chord of the blade = 0.635 m; Radius of the blade = 4.7 m; Number of blades = 2; Total thrust = 2948.35 kg; Twist of the blade = Ideal twist; Profile drag coefficient = 0.012; Lift curve slope = 5.73 per radian; Neglect slipstream contractions in calculating rotor interference effects. **(05)**

2A. What is the essential assumption in the so-called “combined blade element momentum theory”? **(02)**

2B. In a hypothetical helicopter rotor design, the use of blade taper has been shown to increase the figure of merit of the main rotor by 1%. Estimate the percentage increase in vertical lifting and payload capability of the helicopter with all other factors being assumed constant. **(03)**

2C. Explain the following with respect to a Helicopter. **(05)**

a. Ideal Rotor
b. Optimum Rotor
c. Mean Lift Co-efficient
d. Root cutout
e. Prandtl’s tip loss factor

3A. How the momentum theory does become invalid for vortex ring state and turbulent wake state? Justify your answer. **(02)**

3B. Illustrate and explain the importance of universal inflow curve for the axial flight condition. **(03)**

3C. A tilt rotor has a gross weight of 25,500 kg. The rotor diameter is 12 m. On the basis of the simple momentum theory, estimate the power required for the helicopter to hover at 2 km altitude. Assume that the figure of merit of the rotors is 0.80 and transmission losses amount to 5%. If each of the two turbo-shaft engines delivers 4,500 kW, estimate the maximum vertical rate of climb at sea level. **(05)**

4A. What is meant by autorotation? **(02)**

4B. Estimate the autorotative rate of descent in forward flight at sea level conditions for a light weight helicopter with the following characteristics: Weight = 1370 lbs, rotor radius = 12.6 feet; rotor solidity = 0.030; Tip speed = 700 ft/sec; flight speed = 70 knot. **(03)**

4C. Explain the circumstances when an autorotation maneuver might be necessary with a helicopter. What characteristics of the helicopter affect the autorotative performance? By means of a blade element diagram, carefully show and explain why: (a) The mean flow velocity must be vertically upwards through the rotor for autorotation to occur. (b) The blade pitch angles must be low in an autorotation compared to hover or climb. Show where and explain why in autorotation the rotor blades will absorb power from the airstream at some blade locations and consume power at other blade stations. **(05)**

5A. The profile power in forward flight is larger or smaller than the profile power at hover? Justify your answer. **(02)**

5B. For helicopter operations at high speed, it is possible that a "reverse flow" region can exist at the root end of the blade on the retreating side of the rotor disk. Show that the reverse flow region on the rotor disk is a circle of diameter μ with a center located at $(r, \psi) = (\mu/2, 3\pi/2)$. **(03)**

5C. Explain the following terms and their changes with the forward speed **(05)**

(a) Induced Power
(b) Profile Power
(c) Parasitic Power
(d) Climb Power
(e) Drag Power

6A. How the aerodynamic force influences the flapping dynamics of the articulated rotor system with centrally hinged blades? **(02)**

6B. Find the maximum and minimum flapping angle and the corresponding azimuth angle for a rotor in a given flight condition has the following flapping motion with respect to the control axis: $\beta(\psi) = 5° - 3° \cos\psi - 3° \sin\psi$ **(03)**

6C. Derive the transformation matrix, for a rotor with F-P-L hinge sequence. Consider there are five coordinate systems in which $X_5Y_5Z_5$ represents the rotating shaft system and the $X_4Y_4Z_4$ system is identical to $X_5Y_5Z_5$ system by shifting its origin from hub center to Flapping hinge which is offset by e_β from $X_5Y_5Z_5$, $X_3Y_3Z_3$ has its origin also located at Flapping hinge and is obtained by rotating about X_4 by an angle β; $X_2Y_2Z_2$ is obtained from $X_3Y_3Z_3$ system by shifting its origin from flapping hinge to Lag hinge at a distance Δe from $X_3Y_3Z_3$; Finally $X_1Y_1Z_1$ is obtained from $X_2Y_2Z_2$ by a rotation θ about Y_2 axis. Blade is attached to $X_1Y_1Z_1$ system. **(05)**