Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

A Constituent Institution of Manipal University

VII SEMESTER B.TECH. (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, DEC 2017

SUBJECT: HELICOPTER AERODYNAMICS [AAE 4102]

REVISED CREDIT SYSTEM
(26/12/2017)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

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

1A. How does the disk loading and Figure of Merit influence 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. Consider a rotorcraft with the following data: **(05)**

Weight = 1.333*10^4 N; Rotor radius = 4.88 m; Rotor disk area = 74.7 m^2; Rotor tip speed = 213 m/s; Rotor blade chord = 0.3048 m; Number of blades = 2; Blade profile drag coefficient = 0.01; lift curve slope = 6; Assume that the inflow is uniform.

(a) Find the non-dimensional pressure change $(\Delta P/P_{\infty})$ across the disk.
(b) Find the value of w of the induced velocity far below the rotor, according to the momentum theory.
(c) Find the thrust coefficient.
(d) Find the local lift coefficient at r = 0.5*R
(e) Find the local blade pitch angle at r = 0.5*R, in degrees.

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. Coning angle
b. No Feathering Plane
c. Tip Path Plane
d. Figure of Merit
e. Autorotation

3A. Describe the different flow states of helicopter rotor in axial flight. **(05)**

3B. Illustrate and explain the importance of universal inflow curve for the axial flight condition. **(05)**

4A. Why can't a helicopter fly faster than it does? **(03)**

4B. 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. **(07)**

5A. How the aerodynamic force influences the flapping dynamics of the articulated rotor system with centrally hinged blades? **(02)**

5B. 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)**

5C. Consider a helicopter with the following features: Weight = 3,000 lbs; Radius of the rotor= 15 feet; Solidity ratio = 0.075; Profile drag coefficient = 0.012; Blade Tip speed = 600 ft/secs; Equivalent Flat Plate Area = 8 sq.ft; Density = 0.00238 slug/ft^3. **(05)**

$$\text{Use } \frac{\upsilon}{\Omega R} \approx \frac{C_T}{2\mu};\ \mu \geq 0.1$$

And include the radial flow component in the calculation of the profile power.

a. Use the simple energy method to calculate the rotor hover power required at advance ratio = 0.10 for the given helicopter in forward flight.
b. Calculate rate of climb at the same advance ratio given that the available power is 150% of the horsepower required (main rotor).
c. Calculate rate of descent (minimum) at same advance ratio (power-off)
d. Calculate rate of descent at the same advance ratio given that available power is 50% of hover power required (main rotor)