Reg. No.										

Manipal Institute of Technology, Manipal

(A Constituent Institute of Manipal University)

VI SEMESTER B.TECH (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, MAY 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. Why the flapping hinges are used on the helicopter rotor system? **(02)**

1B. Explain and discuss the potential benefits to be gained by using blade twist, planform taper, low solidity, large radius, and low rotational speed for the main rotor of a heavy lift helicopter that is designed to operate primarily in hover. **(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.
(f) Find the ratio of profile power coefficient to the induced power coefficient.

2A. Estimate the additional effect of the root-cutout on the induced power factor of a hovering rotor. **(02)**

2B. When designing a hovering rotor for maximum aerodynamic efficiency with the disk loading fixed, should a designer choose a high or low value of tip speed? To further increase the rotors figure of merit, should the designer choose a high or low solidity, and why? If the rotor was to be powered by jets located at the blade tips, so that it had to operate at a high tip speed, should the designer choose a high or low solidity and why? **(03)**

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

a. Coning angle
b. Induced Power
c. Tip Path Plane
d. Figure of Merit
e. Autorotation

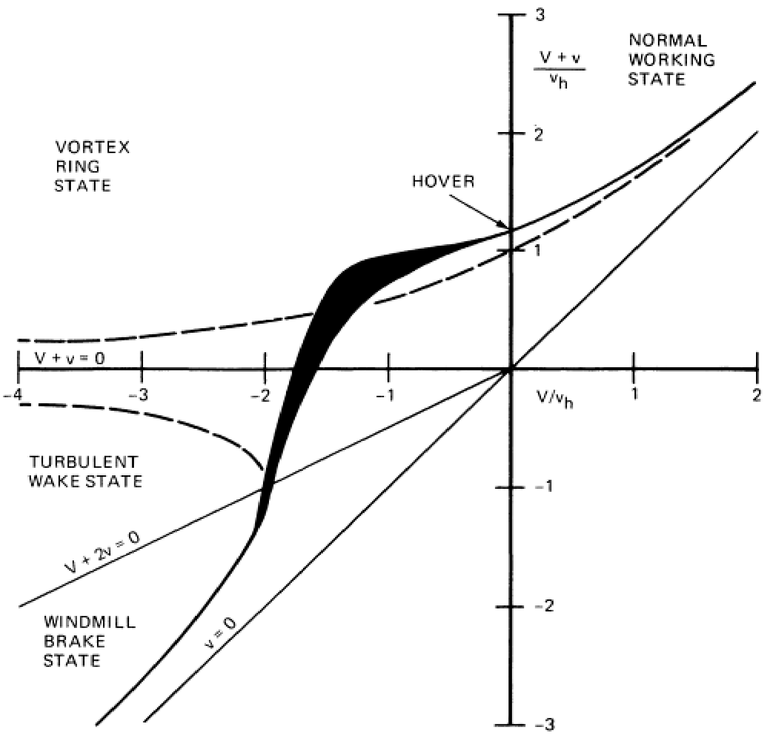
3A. In the engine failure condition, what should the pilot do with the pitch of the rotor blades? **(02)**

3B. Describe the different flow states of helicopter rotor in axial flight. **(03)**

3C. A preliminary design of a tandem rotor helicopter with a gross weight of 8845.2 kg suggests a rotor diameter of 13.72 m, a blade chord of 0.508 m, three blades, and a rotor tip speed of 213.43 m/s. Estimate the total shaft power required to hover if the induced power factor for the front rotor is 1.20 and that for the rear rotor is 1.15. The rotor airfoil to be used has a zero lift drag coefficient of 0.01. Estimate the installed power if transmission losses amount to 5% and the helicopter must demonstrate a vertical rate of climb of 304.9 m/min at sea level. **(05)**

4A. How to reduce the stress at the blade root by the Coriolis effect due to flapping of the blades? **(02)**

4B. Estimate the descent rate from the universal inflow curve for real autorotation occurs at higher rate of descent in the turbulent wake state. **(03)**



4C. Illustrate and explain the autorotation diagram for investigating the equilibrium conditions at the blade element during engine failure condition. **(05)**

5A. Why can't a helicopter fly faster than it does? **(02)**

5B. A helicopter is operating in level forward flight at 63.6 m/s under the following conditions: shaft power supplied = 488.4 kw, W = 2722 Kg, ρ = 1.038 Kg/m^3. The rotor parameters are R = 5.75 m, σ = 0.08, ΩR = 212.2 m/s, K=1.15, C_{d0} = 0.01. **(03)**

(a) How much power is required to overcome induced losses?
(b) How much power is required to overcome profile losses?
(c) What is the equivalent flat-plate area (f)?

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)**

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

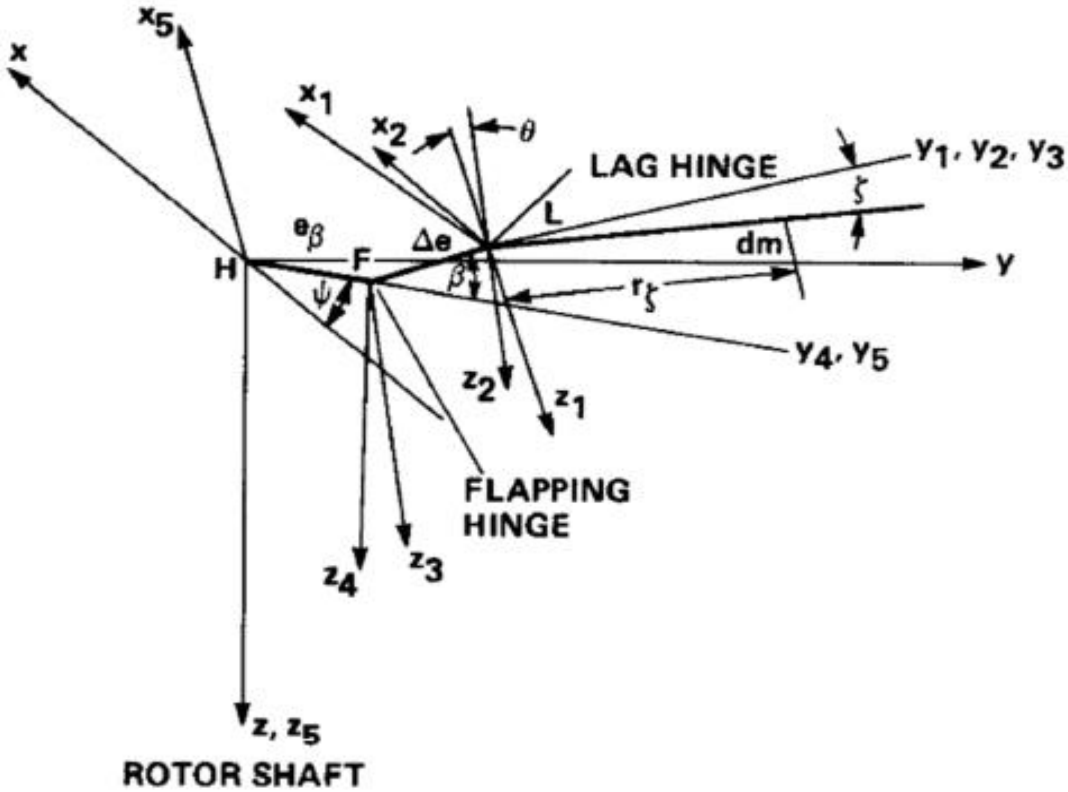
And include the radial flow component in the calculation of the profile power.

a. Use the simple energy method to calculate the rotor horsepower 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).

6A. What is meant by "equivalence of flapping and feathering"? **(02)**

6B. A rotor in a given flight condition has the following flapping motion with respect to the control plane: β (ψ) = 6−4°cosψ−4°sinψ (a) Sketch a side view and rear view of the rotor. (b) How much is the TPP inclined in the fore and aft direction? Forward or backward? (c) How much is the TPP inclined laterally? Is the advancing or retreating blade high? (d) What angle does the blade make with the control plane at ψ=0°,90°,180°,270° degrees (e) At what azimuth angle is the flapping angle greatest? What is the flapping angle at this point? **(03)**

6C. Derive the position of the blade element from the hub center (XYZ) for the F-L-P hinge sequence directly from those for the F-P-L hinge sequence by omitting the transformation caused by the blade pitch rotation. (**Note: Given diagram is of F-P-L hinge sequence**) **(05)**


x
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x1
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θ
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FLAPPING
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ROTOR SHAFT