UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	FLIGHT MECHANICS
COURSE CODE	:	BDU 20603
PROGRAMME CODE	:	BDC
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS IN **PART A** AND **ONE (1)** QUESTION **ONLY** IN **PART B.** 2.THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED** BOOK. 3.STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK.

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

PART A: ANSWER **ALL** QUESTIONS

Q1 (a) A high-speed subsonic aeroplane with 12 m wingspan and a mean chord of 1.4 m is flying at an altitude of 6 km. The pitot tube at the wing leading edge measures the stagnation pressure as 75 kPa.

(i) Determine the outside air temperature at the 6 km altitude.

(3 marks)

(ii) Determine the aircraft's true airspeed (TAS).

(4 marks)

(b) An aircraft wing, has 0.9 span efficiency, 0.0045 profile drag coefficient, -2° zero-lift angle of attack, and 0.12 lift curve slope. This aircraft fly at 5° angle of attack with 10 m wingspan and a mean chord 1.5 m.

(i) If the aircraft's indicated airspeed (IAS) at mean sea level and 4 km altitude is the same, determine the lift force, drag force and lift-to-drag ratio produced at mean sea level and 4 km altitude.

(10 marks)

(ii) Is the value of aircraft's true speed the same as IAS in **Q1(b)(i)**? Justify your answer

(3 marks)

Q2 An aircraft glides with the engine off at an airspeed of 80 knots. It is found to lose height at the rate of 1500 ft/min.

(a) Determine the glide angle (assume no wind condition).

(6 marks)

(b) Calculate the value of the lift to drag ratio for this aircraft during gliding.

(4 marks)

(c) If the aircraft weight is 4000 N, drag polar is $0.01 + 0.02C_L^2$ and wing area is 10 m^2, assuming glide angle is very small, examine whether 80 knots airspeed can produce the maximum glide range at sea level and no wind condition.

(10 marks)

Q3 (a) Total drag is composed of two parts; the parasite drag and the induced drag. The parasite drag varies directly with speed squared, V^2, while the induced drag varies inversely with speed squared.

The coefficient of induced drag is found to be:

$$C_{Di} = \frac{C_L^2}{\pi e AR}$$

Where AR is the aspect ratio and e is the Oswald's efficiency. If the weight of an aircraft is given as W and its span is b, show that at load factor 1, its induced drag can be written as:

$$D_i = \frac{2}{\rho \pi e}\left(\frac{W}{bV}\right)^2$$

(5 marks)

(b) An aeroplane of 1,750 kg mass makes a co-ordinated level turn at a bank angle of 25° from a straight and level flight.

(i) Explain why the aeroplane will experience increasing drag during the turn

(2 marks)

(ii) Explain why at the beginning of the turn, adverse yaw occurs if the aeroplane is not equipped with necessary devices or the pilot not applying adequate rudder force

(2 marks)

(c) Determine the ground run distance and the required time for ground run for a jet airplane having a weight of 301,022 N. The wing area of airplane is 90 m^2 and has a tricycle type landing gear. Its C_{LMAX} with flaps is 2.9 and other data is given as follows:

Lift-off speed	: $V_{LOF} = 1.16V_s$
Transition speed	: $V_2 = 1.086V_{LOF}$
Lift coefficient during ground run	: C_L=1.15
Drag polar with landing gear and flaps	: $C_D = 0.012 + 0.03C_L^2$
Thrust variation during take-off	: $T = 100510 - 0.0654V^2$

Take-off takes place from a level and dry concrete runway (μ=0.02).

(11 marks)

Q4 (a) A wing is tested in a subsonic wind tunnel produced 0.52 lift coefficient at 5° angle of attack. The zero-lift angle of attack is found at -1.5°. Meanwhile, the moment coefficient about the centre of gravity at 1.0° and 7.88° are -0.01 and 0.05, respectively. If the centre of gravity is located at 0.35c, analyse:

(i) the location of the aerodynamic centre and moment coefficient about the aerodynamic centre.

(10 marks)

(ii) the longitudinal static stability and dynamic stability status of the wing.

(4 marks)

(b) Explain why turbojet engine is less efficient compared to the propeller driven engine at low-speed flight.

(2 marks)

(c) An aircraft powered by two gas turbines is flying at 600 knots. If the jet velocity is 440 m/s, and the mass flow is 66 kg/s for each engine, calculate the total thrust being developed.

(4 marks)

PART B: ANSWER **ONE** QUESTION **ONLY**

Q5 Two commercial twin jet engine aeroplanes, namely Aircraft A and Aircraft B, have the same empty weight $W = 80$ kN and use identical jet engines that can provide thrust $T = 8$ kN per engine. Their differences are in term of drag polar and wing area are as follow:

Aircraft A

Reference wing area, S (m^2)	:	20
Drag polar coefficient	:	$C_D = 0.02 + 0.06\,C_L^2$

Aircraft B

Reference wing area, S (m^2)	:	30
Drag polar coefficient	:	$C_D = 0.016 + 0.054\,C_L^2$

A buyer wants to buy one of them based on three criteria; (1) high maximum speed, (2) low minimum power required and (3) high flight speed at maximum climb angle.

As a consultant, which aircraft will you advise the buyer to buy? Support your advice by providing data based on the required criteria.

(20 marks)

Q6 A jet airplane having a weight of 441450 N and wing area of 110 m^2 has a tricycle type landing gear. Its C_{Lmax} with flaps is 2.7 and other data are given as follows:

The take-off speed $V_1 = 1.16\ V_s$

The transition speed $V_2 = 1.086\ V_1$

The lift coefficient C_{Lg} during ground run is 1.15

The drag polar with landing gear and flaps is $C_{Dg} = 0.044 + 0.05 C_{Lg}^2$

Thrust variation during take-off, $T = 128{,}500 - 0.0929\ V^2$

where, V is in the km/hour unit and gravitational acceleration g is 9.81 m/s^2

If an airport has a 900 m dry concrete runway (μ=0.02), Evaluate whether the runway length is sufficient for this aircraft to take-off.

(20 marks)

– END OF QUESTIONS –

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List of Equations

1 m/s = 1.94 knots

Density ratio, $\frac{T}{T_0} = \left(1 - \frac{\lambda}{T_0}h\right)$

Pressure ratio, $\frac{p}{p_0} = \left(1 - \frac{\lambda}{T_0}h\right)^{5.256}$

Density ratio, $\frac{\rho}{\rho_0} = \left(1 - \frac{\lambda}{T_0}h\right)^{4.256}$

Temperature Lapse Rate in Troposphere,

λ = 6.5°C/ 1000 m

Lift Curve, $C_L = C_{L\alpha}(\alpha - \alpha_0)$

Total drag, $D = D_0 + D_i$

Drag polar, $C_D = C_{D0} + KC_L^2$

Induced Drag, $C_{Di} = \frac{C_L^2}{\pi e A_r}$

Power available, $P_{ave} = \eta BHP$

Power required, $P_{req} = DV = \sqrt{\frac{2W^3}{\rho S}}\left(\frac{C_D}{C_L^{3/2}}\right)$

Climb angle, $\sin\gamma = \frac{V_C}{V}$

Glide Range = Height x (L/D)

Rate of Turn, ROT = TAS/R

Rate 1 turn = 180° turn/ minute

Distance for ground run phase:

$S = \frac{W}{2gB}\ln\left(\frac{A}{A-BV_1^2}\right)$

Distance for transition phase: $S = \frac{W}{2g}\left(\frac{V_2^2-V_1^2}{T-D}\right)$

Distance for climb phase: $S = \frac{Screen\ height}{\tan\gamma}$

Steady descent equation,

$T - D + W\sin\gamma = 0$

$L - W\cos\gamma = 0$

Moment coefficient about a CG of wing

$C_{M,cg} = C_{M,ac} + a\alpha_w(h - h_{ac})$

where a is the lift slope of the wing, $a = \frac{dC_L}{d\alpha}$