Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

COURSE NAME	:	AIRCRAFT PROPULSION
COURSE CODE	:	BDU 20203
PROGRAMME	:	2 BDC/ 2 BDM
EXAMINATION DATE	:	DECEMBER 2016/ JANUARY 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FOUR (4) QUESTIONS** FROM **SIX (6) QUESTIONS** AVAILABLE

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

ANSWER FOUR (4) QUESTIONS FROM SIX (6) QUESTIONS AVAILABLE

Q1 (a) Describe in brief the function of a turbine. Since the turbine blade is exposed to high level of thermal exposure, what would be the function of a blade cooling.

(5 marks)

(b) In a field test, three (3) jet engines which are designed to have a similar thrust are being compared. All three engines have the same engine configuration as shown in Figure **Q1(b)** and use the same fuel with Low Heating Value of 45,000 kJ/kgK. Data from the three engines are given in the Table 1. Based from the given data, calculate the thrust of the engines and make comparison in terms of power produced by the turbine, thrust specific fuel consumption, and propulsive efficiency. Take $\gamma = 1.4$, $C_P = 1.005$ kJ/kg and $R = 0.287$ kJ/kg.K.

Table 1: Experimental data for the three engines

	Engine A	Engine B	Engine C
Ambient temperature (K)	245	245	245
Ambient pressure (kPa)	41.3	41.3	41.3
Mach number	0.5	0.5	0.5
Inlet mass flow (kg/s)	82.376	60	101.182
Turbine entry temperature	1,400	1,975	1,200
Pressure ratio	25	15	30
T01 (K)	257.25	257.25	257.25
P01 (kPa)	48.99	48.99	48.99
Fuel to air ratio	0.017399	0.033114	0.011937
T04 (K)	1,018.579	1,684.204	782.421
P04 (kPa)	402.333	420.824	328.958

(20 marks)

Q2 (a) In gas turbine performance, total property approach is used in the component analysis. Explain briefly why this approach is favourable?

(5 marks)

(b) A two-spool turbojet engine is used to power a military jet. The half diagram of the engine arrangement is given in Figure **Q2(b)**. The military jet is cruising at an altitude with speed reaching Mach 0.8. The inlet static ambient conditions are 250K and 15 kPa respectively. The highest temperature of the engine is 1,700 K. Both low pressure and high pressure compressors has a pressure ratio of 15 respectively. The fuel for this engine is capable in transferring 45,500 kJ heat for each 1 kg/s fuel used. If the inlet mass flow is 85 kg/s, using an ideal cycle approach, analyse the engine performance and provide:

(i) The engine thrust, F_N
(ii) The thrust specific fuel consumption, $TSFC$
(iii) The propulsive efficiency, η_P

Sketch the Ts diagram and take $\gamma = 1.4$, $C_P = 1.005$ kJ/kg and , $R = 0.287$ kJ/kg.K,

(20 marks)

Q3 (a) Most gas turbines use either single of two spools system. What is spool? What is the difference between a single and a two-spool engine?

(5 marks)

(b) A single spool turbofan with mixed nozzle is used to power a military aircraft. The half diagram of the engine arrangement is given in Figure **Q3(b)**. Both fan and compressor are connected to the turbine. The aircraft is with Mach number 0.65 and the ambient temperature and pressure are 205 K and 22 kPa respectively. The engine data recorded are as follows:

Inlet mass flow	:	200 kg/s
By-pass ratio	:	4.948
Fan pressure ratio	:	3
Compressor pressure ratio	:	5
Turbine entry temperature	:	1,750 K
Fuel Low Heating Value	:	42,500 kJ/kg

Using an ideal cycle approach, analyse the engine performance and provide:

(i) The overall pressure ratio of the compression system, $PR_{Overall}$
(ii) The engine thrust, F_N
(iii) The thrust specific fuel consumption, $TSFC$

Sketch the Ts diagram and take $\gamma = 1.4$ and $C_P = 1.005$ kJ/kg

(20 marks)

Q4 (a) Describe the terms given below:
(i) Stroke
(ii) Clearance distance
(iii) Volumetric displacement

(6 marks)

(b) A two-seater aircraft, equipped with a flat six-piston, four-stroke engine is flying at 3,000 m with engine rotational speed of 3,700 rpm. At 3,000 m, the

ambient temperature and pressure are 288 K and 79.5 kPa, respectively. The engine data are as follows:

Piston stroke	14 cm
Piston bore	12 cm
Piston clearance volume	5% of its swept volume
AFR	17:1
Mechanical efficiency, η_m	89%
Propulsive efficiency, η_P	75%

If the fuel Low Heating Value is 44,000 kJ/kg, calculate:

(i) The brake shaft power, $\dot{W}_B$
(ii) The fuel flow if the $BSFC$ is 8.34 x 10^{-5} kg/kWs
(iii) The thermal efficiency, η_{th}

Take $\gamma = 1.4$ and $C_V = 0.718$ kJ/kg

(19 marks)

Q5 (a) Explain the effect of efficiency deterioration and pressure loss on the intake temperatures and pressures when non-ideal cycle approach is considered during the cycle performance calculation. The explanation should be assisted with a Ts diagram.

(5 marks)

(b) A single spool turbojet engine used to power a military aircraft. The component arrangement is similar to those in Figure **Q5(b)**. The aircraft is cruising at 9,000 m at a speed reaching Mach number 0.75. At an altitude of 9,000 m, the ambient temperature and pressure are 260 K and 30 kPa, respectively. The characteristics of the engine components are as follows:

Inlet mass flow	:	75
Compressor pressure ratio	:	15
Compressor isentropic efficiency	:	87%
Turbine entry temperature	:	1,450 K
Fuel Low Heating Value	:	41,400 kJ/kg
Afterburner temperature	:	1,400 K
Nozzle isentropic efficiency	:	95%

Synthesis the information obtained from the engine components to determine whether the nozzle is chocked or un-choked and provide:

(i) The engine thrust, F_N
(ii) The specific thrust, F_s
(iii) The thrust specific fuel consumption, $TSFC$

Sketch the Ts diagram. Take for air, $\gamma = 1.4$ and $C_P = 1.005$ kJ/kg while for combusted gas, $\gamma = 1.34$ and $C_P = 1.148$ kJ/kg

(20 marks)

Q6 (a) Based on the value given below, synthesize the valuable information that can be obtained:

(i) Thermal efficiency : 40%
(ii) Mechanical efficiency: 90%

(4 marks)

(b) A two-spool turbofan with mixed nozzle, used to power a military aircraft. The aircraft is flying at Mach number 0.8 and altitude 10,000 m. The half diagram of the engine arrangement is given in Figure **Q6(b)**. The ambient temperature and pressure are 200 K and 26 kPa respectively. The inlet mass flow is 85 kg/s. The fan is driven by the low-pressure turbine (LPT) while the compressor is driven by high pressure turbine (HPT). The component characteristics of the engine are as follows:

Fan pressure ratio	:	3
Compressor pressure ratio	:	6
Turbine entry temperature	:	1,350 K
Fan isentropic efficiency	:	85%
Compressor isentropic efficiency	:	85%
Fuel LHV	:	42,800 kJ/kg

Synthesis the information obtained from the engine components to determine whether the nozzle is chocked or un-choked and provide:

(i) The engine by pass ratio, β
(ii) The engine thrust, F_N
(iii) The thrust specific fuel consumption, $TSFC$

Sketch the Ts diagram. Take for air, $\gamma = 1.4$ and $C_P = 1.005$ kJ/kg while for combusted gas, $\gamma = 1.33$ and $C_P = 1.148$ kJ/kg

(21 marks)

- END OF QUESTION -

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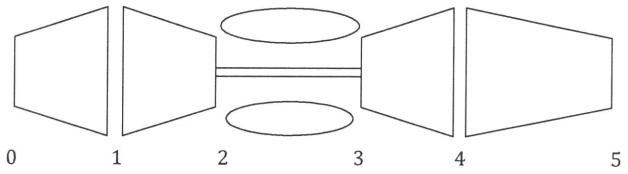

FIGURE Q1(b)

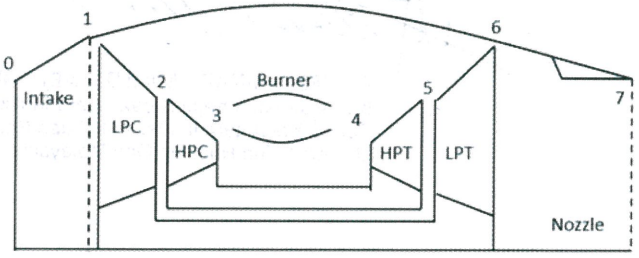

FIGURE Q2(b)

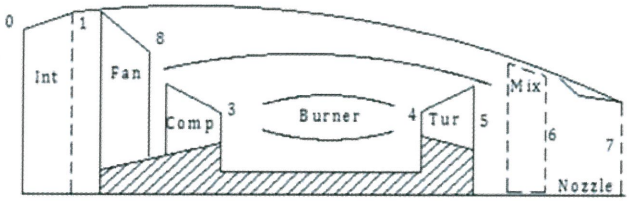

FIGURE Q3(b)

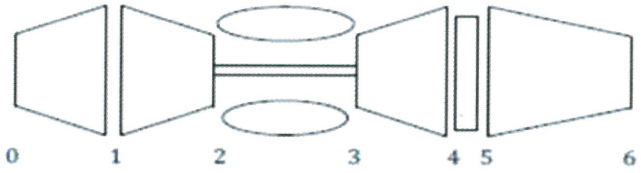

FIGURE Q5(b)

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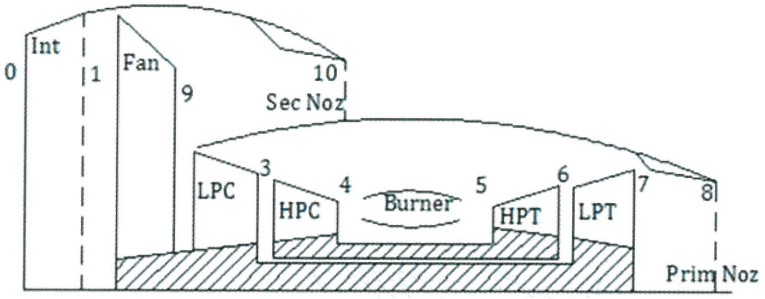

FIGURE Q6(b)