Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2020/2021

COURSE NAME	:	AIRCRAFT PROPULSION
COURSE CODE	:	BDU 20203
PROGRAMME	:	BDC/ BDM
EXAMINATION DATE	:	JULY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS **ONLY**

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

Q1 (a) A typical theoretical P-V diagram of a spark-ignition piston aerodynamics engine is given in **Figure Q1(a)**. Based on the P-V diagram given, describe the process of 2 to 3, 3 to 4 and 4 to 5. The description given for each of the process should include the name of the process, the movement of the piston, and the change in the pressure, temperature and volume.

(7 marks)

(b) A general aviation aircraft, equipped with a flat 4-piston, four-stroke engine is flying at 2,500 m with a speed of 26 m/s. At this altitude, the ambient temperature and pressure are 282 K and 74.7 kPa respectively. The engine has a propeller with a diameter of 1.75m. The engine data are as follows:

Engine rotational speed	4600 rpm
Swept volume:	2.77×10^{-3} m^3
Clearance volume	3.96×10^{-4} m^3
The fuel heat transfer per unit kg, *q*	2,704 kJ/kg
Mechanical efficiency	80 %
Propulsive efficiency	43 %

If the density of the air at this altitude is 0.927 kg/m^3, examine using the Otto cycle method and evaluate the engine performance in terms of its:

(i) compression ratio
(ii) indicated power
(iii) shaft brake power
(iv) available power
(v) the thrust generated

Take for air, $\gamma = 1.4$, C_P=1.005 kJ/kg and, R = 0.287 kJ/kg.K,

(18 marks)

Q2 (a) The engine of an aircraft is designed to have a thrust of 80,000 N when the engine operates at sea level with an ambient condition of ISA deviation 7 degree. If that aircraft is used at different location where the ambient condition is at an ISA deviation of 20 degree, determine whether the trust produced by the engine will be higher or lower that 80,0000 N and explain your decision.

(4 marks)

(b) Explain how the following factors affect the engine thrust:

Factor 1: Flight speed
Factor 2: Altitude
Factor 3: Ram Air

Support the explanation with suitable figure or equations.

(9 marks)

(c) A turbojet is powering an aircraft flying at 5000 m with a speed of 650 km/h. The ambient conditions at that altitude are 255.65 K and 54 kPa respectively. The inlet and outlet area of the engine are 0.32 m^2 and 0.35 m^2 respectively. The fuel-air ratio (FAR) is 0.015 while the nozzle exit pressure and velocity are 250kPa and 650 m/s respectively. Calculate the following parameters for the engine:

(i) pressure thrust
(ii) momentum drag
(iii) momentum thrust
(iv) gross thrust
(v) net thrust

Take for air, $\gamma = 1.4$, C_P=1.005 kJ/kg and, R = 0.287 kJ/kg.K

(12 marks)

Q3 (a) List 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 Q3(b)** and use the same fuel with Low Heating Value of 45,000 kJ/kg.K. Data from the three engines are given in the Table 1. Analyse the given engine data to obtain the thrust of the engines and make comparison in terms of power produced by the turbine, thrust specific fuel consumption, and propulsive efficiency.

Table 1: Experimental data for the three (3) 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

Take for air, R = 0.287 kJ/kg.K,

(20 marks)

Q4 (a) Provide three (3) assumptions that are applied when performing ideal cycle gas turbine performance analysis.

(6 marks)

(b) A two-spool, mixed nozzle turbofan is used to fly a military jet at a Mach number of 0.7 and with ambient condition 222K and 26.2 kPa. The fan is driven by the low-pressure turbine (LPT) while the compressor is driven by high pressure turbine (HPT). The engine data are as follows:

Mass flow measured at intake	120 kg/s
Bypass ratio	7.9
Fan pressure ratio	2
Overall pressure ratio	16
Turbine entry temperature	1560 K
Fuel low heating value	42,300 kJ/kg

Using the half diagram engine arrangement given in **Figure Q4(b)** as reference, examine the engine using the ideal cycle approach and evaluate the engine performance in terms of its:

(i) compressor pressure ratio
(ii) thrust
(iii) thrust specific fuel consumption

Sketch the *T-s* diagram. Take for air, γ = 1.4, C_P=1.005 kJ/kg and, R = 0.287 kJ/kg.K

(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 *T-s* diagram

(5 marks)

(b) A corporate jet equipped with single-spool turbojet engine is cruising at 7,500 m. At this altitude, the ambient temperature and pressure are 239 K and 38 kPa, respectively. The speed Mach number of the jet is 0.6. The engine configuration is given in **Figure Q5(b)** while the engine data are as follows

Compressor pressure ratio	18
Turbine entry temperature	1500 K

Turbine isentropic efficiency	80%
Afterburner gas temperature	1650K
Mechanical efficiency	95%
Nozzle isentropic efficiency	95%

If the intake mass flow is 95 kg/s and the fuel Low Heating Value is 42,500 kJ/kg, examine the engine using the non-ideal cycle approach and evaluate the engine performance in terms of:

(i) the FAR for burner and afterburner
(ii) the engine thrust
(iii) the engine thrust specific fuel consumption

Sketch the *T-s* diagram. Take for air, $\gamma = 1.4$, $C_P = 1.005$ kJ/kg while for combusted gas air, $\gamma = 1.33$, $C_P = 1.148$ kJ/kg

(20 marks)

Q6 (a) Explain the difference between Design Point and Off Design Point.

(2 marks)

(b) Sketch the component characteristic of a compressor.

(3 marks)

(c) A two-spool turbofan with unmixed nozzle is flying at Mach number 0.5. The atmospheric conditions are 243 K and 33 kPa respectively. The engine configuration is given in **Figure Q6(c)**. The engine data and the gas path values for the cold section are as follows:

Engine data:

Fan pressure ratio	2
Fan isentropic efficiency	90%
Compressor pressure ratio	13
Compressor isentropic efficiency	87%
Burner efficiency	98%
Turbine entry temperature	1750 K
High pressure turbine isentropic efficiency	90%
Low pressure turbine isentropic efficiency	90%
Nozzle isentropic efficiency	95%

Gas path values at gas turbine cold section:

$\bar{V}_i = 156.23$ K	$m_{core} = 50$ kg/s	$m_{BP} = 250$ kg/s
$T_{01} = 255.15$ K	$P_{01} = 39.14$ kPa	$P_{08} = 78.28$ kPa
$T_{08}' = 317.24$ K	$P_{03} = 1017.64$ kPa	$T_{03}' = 711.41$ K

If the engine mass flow is 300 kg/s and the fuel Low Heating Value is 43,200 kJ/kg, examine the engine using non-ideal cycle approach and evaluate the engine performance in terms of :

(i) the engine remaining gas path values
(ii) the FAR for the burner
(iii) the engine thrust
(iv) the engine thrust specific fuel consumption

Sketch the *T-s* diagram. Take for air, $\gamma = 1.4$, C_P=1.005 kJ/kg while for combusted gas air, $\gamma = 1.33$, C_P=1.148 kJ/kg

(20 marks)

- END OF QUESTION -

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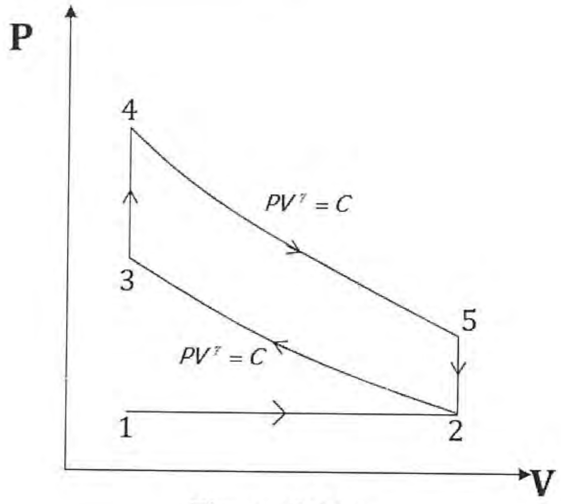

Figure Q1(a)

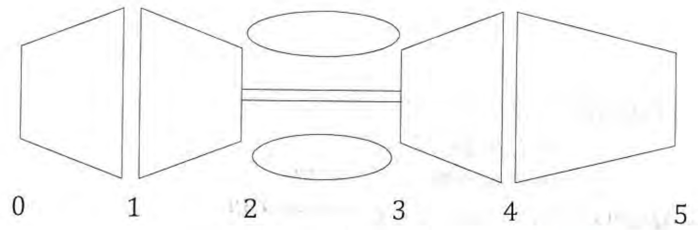

Figure Q3(b)

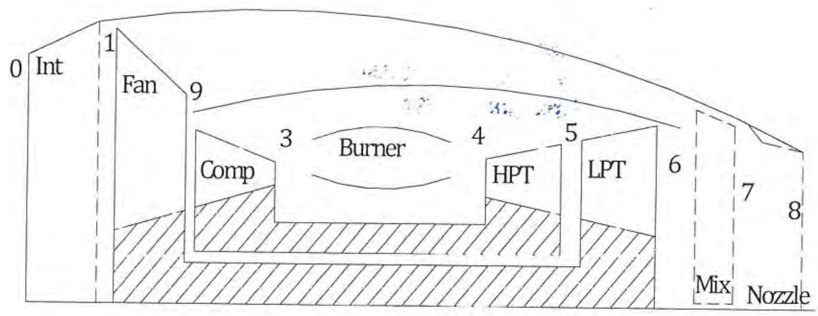

Figure Q4(b)

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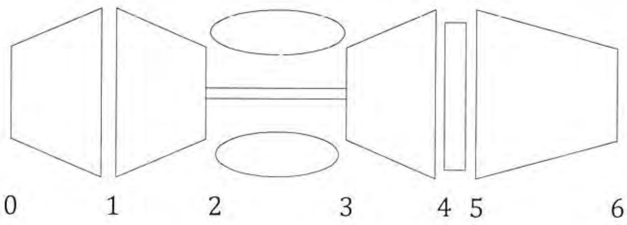

Figure Q5(b)

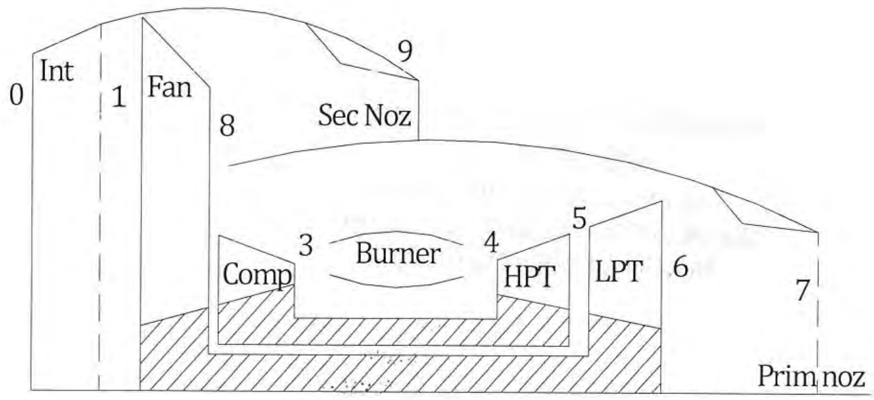

Figure Q6(c)