UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 2006/2007
First Semester Examination
2006/2007 Academic Session

Oktober/November 2006
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ESA 342/3 – Sistem Dorongan
Propulsion Systems

Masa : [3 jam]
Hour : [3 hours]

ARAHAN KEPADA CALON :
INSTRUCTION TO CANDIDATES:

Sila pastikan bahawa kertas soalan ini mengandungi **ENAMBELAS (16)** mukasurat bercetak **termasuk lampiran** dan **ENAM (6)** soalan sebelum anda memulakan peperiksaan.
*Please ensure that this paper contains **SIXTEEN (16)** printed pages **included attachment** and **SIX (6)** questions before you begin examination.*

Bahagian A: Jawab **TIGA (3)** soalan. Bahagian B: Jawab **SEMUA** soalan.
*Part A: Answer **THREE (3)** questions. Part B: Answer **ALL** questions.*

Soalan boleh dijawab dalam Bahasa Malaysia kecuali satu soalan mestilah dijawab dalam Bahasa Inggeris.
The question can be answered in Bahasa Malaysia but one question must be answered in English.

Setiap soalan mestilah dimulakan pada mukasurat yang baru.
Each questions must begin from a new page.

BAHAGIAN A/*PART A*

1. (a) Terangkan bagaimana caranya daya tujahan dihasilkan pada enjin pesawat terbang jenis:

(i) turbojet
(ii) turbofan
(iii) turboprop

Explain how the mechanism of thrust is generated by the following type of aircraft engine:

(i) turbojet
(ii) turbofan
(iii) turboprop

(10 markah/*marks*)

(b) Terangkan apa yang dimaksudkan dengan istilah berikut:

Explain what does it mean for the following term:

(i) Penggunaan bahan api tujah tentu dan penggunaan bahan api tentu.

Specific thrust Fuel comsumption" STFC and "Specific thrust consumption" SFC.

(ii) Enjin "turbofan" dengan campuran aliran ekzos.

Turbo fan engine with mixed exhaust stream.

(iii) Terangkan mengapa enjin ramjet hanya dapat digunakan pada pesawat terbang halaju supersonik?

Explain why the ram jet engine is used for the supersonic airplane?

(10 markah/*marks*)

2. (a) Dengan anggapan bahawa situasi ideal berlaku ketika aliran melalui komponen-komponen enjin pesawat turbo jet, tunjukan bahawa nisbah bahan api udara f adalah:

$$f = \frac{c_p T_0}{h_{pr}} \left[\tau_\lambda - \tau_r \tau_c\right]$$

With assumption that an ideal condition is valid for the flow past through engine components of Ramjet, show that the fuel air ratio f is expressed by:

$$f = \frac{c_p T_0}{h_{pr}} \left[\tau_\lambda - \tau_r \tau_c\right]$$

(10 markah/*marks*)

dan halaju aliran keluar dari muncung turbo jet adalah:

$$\left(\frac{V_9}{a_0}\right)^2 = \frac{2}{\gamma - 1} \frac{\tau_\lambda}{\tau_r \tau_c} \left(\tau_r \tau_c \tau_t - 1\right)$$

and the exit velocity from the Nozzle of turbo jet as :

$$\left(\frac{V_9}{a_0}\right)^2 = \frac{2}{\gamma - 1} \frac{\tau_\lambda}{\tau_r \tau_c} \left(\tau_r \tau_c \tau_t - 1\right)$$

di mana:

where:

a_0 : halaju bunyi
speed of sound

τ_λ : nisbah suhu turbin kepada suhu sekeliling.
the ratio of temperature turbine limitation to the ambient temperature.

τ_c : nisbah suhu kompressor.
the ratio of compressor temperature.

τ_t : nisbah suhu turbin
the ratio of turbin temperature.

τ_r : nisbah suhu aliran bebas.
the ratio of free stream temperature.

h_{pr} : nilai pemanasan bahan api.
fuel heating value.

T_0 : suhu aliran bebas.
free stream temperature.

(10 markah/*marks*)

3. Data sebuah enjin turbo jet adalah seperti berikut:

Given turbo jet engine with engine component data as follows:

Nisbah kompressor $\pi_c = 12$

Batas suhu turbin $T_{t4} = 1800\ ^0K$

Nilai pemanasan bahan api $H_{pr} = 42800\ \dfrac{Kj}{kg^0K}$

Pemalar haba pada tekanan tetap $Cp = 1004\ \dfrac{j}{kg^0K}$

Nisbah pemalar haba $\gamma = 1.4$

Suhu sekitar penerbangan $T_\infty = 217\ ^0K$

Nombor penerbangan Mach $M = 1.5$

Compressor ratio $\pi_c = 12$

Turbine limitation $T_{t4} = 1800\ ^0K$

Fuel heating value $H_{pr} = 42800\ \dfrac{Kj}{kg^0K}$

Heat coefficient at constant pressure $Cp = 1004\ \dfrac{j}{kg^0K}$

Coefficient heat ratio $\gamma = 1.4$

Ambient temperature flight $T_\infty = 217\ ^0K$

Flight Mach Number $M = 1.5$

Dengan menggunakan analisa siklus ideal tentukan:

Using an ideal cycle analysis find:

(i) jumlah nisbah suhu kompressor τ_c

the total temperature compressor ratio τ_c

(2 markah/*marks*)

(ii) jumlah nisbah suhu turbin τ_t

the total temperature turbine ratio τ_t

(2 markah/*marks*)

(iii) halaju keluar di muncung

the exit velocity at the nozzle

(2 markah/*marks*)

(vi) tujahan tentu

specific thrust

(2 markah/*marks*)

(v) nisbah bahan api udara

fuel air ratio

(2 markah/*marks*)

(vi) penggunaan tentu daya tujah-bahan api

specific thrust fuel consumption

(2 markah/*marks*)

(vii) kecekapan suhu

thermal efficiency

(2 markah/*marks*)

(viii) kecekapan keseluruhan

overall efficiency

(2 markah/*marks*)

(ix) nisbah optimum suhu kompressor $(\tau_c)_{opt}$

the optimum compressor temperature ratio $(\tau_c)_{opt}$

(2 markah/*marks*)

(x) daya tujah pada nisbah optimum suhu kompressor

the thrust at optimum compressor temperature ratio

(2 markah/*marks*)

4. Data sebuah enjin turbo fan dengan sistem ekzos terpisah adalah seperti berikut:

- Nombor penerbangan Mach $\mathbf{M_\infty = 0.75}$
- Suhu ambien $\mathbf{T_\infty = 216.7^0 K}$
- Nisbah suhu untuk aliran udara sejuk $\gamma_c = 1.4$
- Pemalar haba untuk aliran udara sejuk $\mathbf{C_{pc} = 1.004 \frac{K\,J}{kg\ ^0K}}$
- Nisbah haba untuk aliran udara panas $\boldsymbol{\gamma_t = 1.35}$
- Pemalar haba untuk aliran udara panas $\mathbf{C_{pt} = 1.096 \frac{K\,J}{kg\ ^0K}}$
- Kecekapan peresap ram $\boldsymbol{\pi_{dmax} = 0.98}$
- Nisbah jumlah tekanan ruang bakar $\pi_b = \mathbf{0.98}$
- Nisbah tekanan jumlah muncung $\pi_N = \mathbf{0.98}$
- Nisbah jumlah tekanan muncung kedua $\pi_{FN} = \mathbf{0.98}$
- Kecekapan pembakaran $\eta_b = \mathbf{0.99}$
- Kecekapan tranmisi mekanik $\eta_m = \mathbf{0.98}$
- Kecekapan politropik kompresor $e_c = \mathbf{0.90}$
- Kecekapan politropik turbin $e_t = \mathbf{0.90}$
- Kecekapan politropik kipas $e_f = \mathbf{0.90}$
- Nilai haba bahan bakar $\mathbf{h_{pr} = 42\,800 \frac{KJ}{kg}}$
- Had suhu turbin $T_{T4} = 1800\ ^0K$
- Nisbah tekanan kompresor $\boldsymbol{\pi_c = 20}$
- Nisbah tekanan kipas $\boldsymbol{\pi_f = 2}$

Given a data turbo fan engine with separated exhaust system as follows:

- *Flight Mach number* $\mathbf{M_{\infty} = 0.75}$
- *Temperature ambient* $\mathbf{T_{\infty} = 216.7^{0}K}$
- *Heat ratio for air cold stream* $\gamma_c = 1.4$
- *Heat coefficient for cold stream* $\mathbf{C_{pc} = 1.004 \dfrac{K\,J}{kg\ ^{0}K}}$
- *Heat ratio air hot stream* $\gamma_t = \mathbf{1.35}$
- *Coefficient for hot stream* $\mathbf{C_{pt} = 1.096 \dfrac{K\,J}{kg\ ^{0}K}}$
- *Ram efficiency diffuser* $\pi_{dmax} = \mathbf{0.98}$
- *Total pressure ratio – burner* $\pi_b = \mathbf{0.98}$
- *Total pressure ratio - nozzle* $\pi_N = \mathbf{0.98}$
- *Total pressure ratio secondary nozzle* $\pi_{FN} = \mathbf{0.98}$
- *Burner efficiency* $\eta_b = \mathbf{0.99}$
- *Mechanical efficiency transmission* $\eta_m = \mathbf{0.98}$
- *Polytropic efficiency compressor* $e_c = \mathbf{0.90}$
- *Polytropic efficiency turbine* $e_t = \mathbf{0.90}$
- *Polytropic efficiency fan* $e_f = \mathbf{0.90}$
- *Fuel heating value* $\mathbf{h_{pr} = 42\,800 \dfrac{KJ}{kg}}$
- *Temperature turbine limitation* $T_{T4} = 1800\ ^{0}K$
- *Total pressure compressor ratio* $\pi_c = \mathbf{20}$
- *Total pressure fan ratio* $\pi_f = \mathbf{2}$

...9/-

Muncung primer dan sekunder menghasilkan pengembangan gas aliran jet tekanan ambien,

$$\frac{P_9}{P_\infty} = 1 \text{ and } \frac{P_{19}}{P_\infty} = 1$$

Both primary and secondary nozzle expanded the jet flow to the pressure ambient,

$$\frac{P_9}{P_\infty} = 1 \text{ and } \frac{P_{19}}{P_\infty} = 1$$

Tentukan:

Find:

(i) nisbah jumlah suhu kompressor τ_c

total temperature ratio compressor τ_c

(3 markah/*marks*)

(ii) kecekapan kompressor τ_c

compressor efficiency η_c

(3 markah/*marks*)

(iii) nisbah bahan api-udara f

fuel air ratio f

(3 markah/*marks*)

(iv) jumlah nisbah suhu turbin sekiranya nisbah pirau $\alpha = 2$

total temperature turbine ratio τ_t *if by pass ratio* $\alpha = 2$

(3 markah/*marks*)

BAHAGIAN B/*PART B*

5. Sebuah muncung untuk roket unggul beroperasi pada ketinggian 25 km dan menghasilkan daya tujahan 5000 N pada tekanan kebuk 2.068 MN/m^2 dan suhu kebuk 2800 K. Andaikan k = 1.30 dan R = 355.4 J/kg-K, tentukan:

A nozzle for an ideal rocket that has to operate at a 25 km altitude and give a 5000 N thrust at a chamber pressure of 2.068 MPa (or MN/m2) and a chamber temperature of 2800 K. Assuming that k = 1.30 and R = 355.4 J/kg-K, determine:

(i) Luas tekak

The throat area

(4 markah/*marks*)

(ii) Luas keluar

Exit area

(4 markah/*marks*)

(iii) Halaju tekak

Throat velocity

(4 markah/*marks*)

(iv) Suhu keluar

Exit temperature

(4 markah/marks)

Berapakah peratusan perubahan di dalam daya tujahan pada aras laut dan ketinggian 25 km untuk sebuah roket yang menghasilkan tekanan kebuk 20 atmosfera dan nisbah luas pengembangan sebanyak 6.0? (Gunakan k = 1.30)

What is the percentage variation in thrust between sea level and 25 km for a rocket having a chamber pressure of 20 atmospheres and an expansion area ratio of 6.0? (use k = 1.30)

(4 markah/*marks*)

6. (a) Bandingkan jenis-jenis muncung subbunyi, bunyi, dan superbunyi. (Perbandingan hendaklah di tentukan dari segi (1) halaju tekak (2) halaju keluar (3) Nombor Mach (4) Nisbah tekanan (5) Bentuk Muncung

Compare the nozzle types between subsonic, sonic and supersonic nozzles (Comparison in terms of (1) throat velocity (2) exit velocity (3) Mach Number (4) Pressure ratio (5) Nozzle Shape)

(8 markah/*marks*)

(b) Dengan menggunakan nilai yang ditentukan pada soalan (5), lukiskan,

Using the value in Question (5), draw the,

(i) gambarajah skema muncung kon

schematic diagram of a conical nozzle

(4 markah/*marks*)

(ii) gambarajah skema muncung "bell"

schematic diagram of a bell nozzle

(4 markah/*marks*)

(Gunakan $\alpha = 15^o$, f = 80% of a 15^o kon, $R_1 = 1.5\ R_t$, and $R_2 = 0.382\ R_t$)
(Hint: Use $\alpha = 15^o$, f = 80% of a 15^o cone, $R_1 = 1.5\ R_t$, and $R_2 = 0.382\ R_t$)

(c) Bandingkan jawapan b(i) dan b(ii)

Compare your result in (b)(i) and (b)(ii).

(4 markah/*marks*)

20. $$v_2 = \sqrt{\frac{2\gamma}{\gamma - 1} RT_1 \left[1 - \left(\frac{p_2}{p_1} \right)^{\frac{\gamma-1}{\gamma}} + v_1^2 \right]}$$

21. $$v_2 = \sqrt{\frac{2\gamma}{\gamma - 1} RT_1 \left[1 - \left(\frac{p_2}{p_1} \right)^{\frac{\gamma-1}{\gamma}} \right]} = \sqrt{\frac{2\gamma}{\gamma - 1} RT_0 \left[1 - \left(\frac{p_2}{p_0} \right)^{\frac{\gamma-1}{\gamma}} \right]}$$

Nozzle

22.

$$\lambda = \frac{1}{2}(1 + Cos\alpha)$$

$$98.3\% @ \alpha \approx 15^0$$

23.

$$X_N = R_1 Sin\alpha$$

$$YN = .R_t + R_1(1 - Cos\alpha)$$

24.

$$L_N = \lambda \left[\frac{R_t\left(\sqrt{\varepsilon} - 1\right) + R_1\left[\frac{1}{cos\,\alpha} - 1\right]}{tan\,\alpha} \right]$$

25. R1 = 1.5Rt
R2 = 0.382Rt

26.

$$L_N = f \times \lambda \left[\frac{R_t\left(\sqrt{\varepsilon} - 1\right) + R_2\left[\frac{1}{cos\,\alpha} - 1\right]}{tan\,\alpha} \right]$$

Table 1. Nozzle Angle Correction Factor

Nozzle Cone Divergence Half Angle, α (deg)	Correction Factor, λ
0	1.0000
2	0.9997
4	0.9988
6	0.9972
8	0.9951
10	0.9924
12	0.9890
14	0.9851
16	0.9806
18	0.9755
20	0.9698
22	0.9636
24	0.9567

Table 2. Conversion psia → MN/m^2.

psia	MN/m^2
100	0.6895
200	1.378
300	2.068
400	2.758
500	3.4475
600	4.137

Table 3. Properties of the Atmosphere

Altitude (m)	Temperature (K)	Pressure Ratio	Density (kg/m^3)
0 (sea level)	288.150	1.0000	1.2250
1,000	281.651	8.8700×10^{-1}	1.1117
3,000	268.650	6.6919×10^{-1}	9.0912×10^{-1}
5,000	255.650	5.3313×10^{-1}	7.6312×10^{-1}
10,000	223.252	2.6151×10^{-1}	4.1351×10^{-1}
25,000	221.552	2.5158×10^{-2}	4.0084×10^{-2}
50,000	270.650	7.8735×10^{-4}	1.0269×10^{-3}
75,000	206.650	2.0408×10^{-5}	3.4861×10^{-5}
100,000	195.08	3.1593×10^{-7}	5.604×10^{-7}
130,000	469.27	1.2341×10^{-8}	8.152×10^{-9}
160,000	696.29	2.9997×10^{-9}	1.233×10^{-9}
200,000	845.56	8.3628×10^{-10}	2.541×10^{-10}
300,000	976.01	8.6557×10^{-11}	1.916×10^{-11}
400,000	995.83	1.4328×10^{-11}	2.803×10^{-12}
600,000	999.85	8.1056×10^{-13}	2.137×10^{-13}
1,000,000	1000.00	7.4155×10^{-14}	3.561×10^{-15}

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