UNIVERSITI SAINS MALAYSIA

First Semester Examination
2007/2008 Academic Session
Peperiksaan Semester Pertama
Sidang Akademik 2007/2008

October/November 2007
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ESA 342/3 – Propulsion Systems
Sistem Dorongan

Duration : 3 hours
[Masa : 3 jam]

INSTRUCTION TO CANDIDATES
ARAHAN KEPADA CALON

Please ensure that this paper contains **TWELVE (12)** printed pages and **FIVE (5)** questions before you begin examination.
*Sila pastikan bahawa kertas soalan ini mengandungi **DUA BELAS (12)** mukasurat bercetak dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan.*

Part A: Answer **ALL** questions. Part B: Answer **ALL** questions.
*Bahagian A: Jawab **SEMUA** soalan. Bahagian B: Jawab **SEMUA** soalan.*

Student may answer the questions either in English or Bahasa Malaysia.
Pelajar boleh menjawab soalan dalam Bahasa Inggeris atau Bahasa Malaysia.

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

PART A/*BAHAGIAN A*

1. (a) Explain the mechanism of thrust generated by the following type of aircraft engine : (1) turbojet, (2) turbofan and (3) turboprop.

Terangkan bagaimana caranya daya dorongan dihasilkan pada mesin pesawat terbang tipe: (1) turbojet (2) turbofan dan (3) turboprop.

(6 marks/*markah*)

(b) Explain meaning of the following term:

Terangkan apa yang dimaksudkan dengan istilah berikut:

(i) Specific thrust fuel comsumption STFC and Specific thrust consumption SFC

"Specific thrust fuel comsumption" STFC dan "Specific thrust consumption" SFC

(ii) By pass ratio α

"By pass ratio" α

(iii) Explain why the ramjet engine just can be used for the supersonic airplane?

Terangkan mengapa mesin ramjet hanya digunakan pada pesawat terbang pada halaju supersonik?

(6 marks/*markah*)

(c) With assumption that an ideal condition is valid for the flow past through the turbojet engine components, shows that the fuel air ratio f would be:

Dengan anggapan bahawa kondisi ideal berlaku ketika aliran melalui komponen-komponen mesin pesawat turbojet, tunjukkan bahawa "fuel air ratio" f adalah:

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

(4 marks/*markah*)

and the exit velocity from the Nozzle of turbojet is:

dan halaju aliran keluar dari muncung turbojet adalah:

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

where:

di mana:

Cp : Heat coefficient at constant pressure
Pemalar panas pada tekanan tetap

To : Free stream temperature
Suhu udara aliran bebas

a_0 : Free stream sound speed
Kecepatan suara aliran bebas

h_{pr} : Fuel heating value
Nilai panas bahan bakar

τ_λ : The ratio of the burner exit to the ambient enthalpy
Nisbah entalpi "burner exit" terhadap entalpi persekitaran

τ_c : The temperature ratio of compressor component
Nisbah suhu komponen kompresor

τ_t : The temperature ratio of turbine component
Nisbah suhu komponen turbin

τ_r : The temperature ratio of the free stream
Nisbah suhu aliran bebas

(4 marks/*markah*)

2. (a) The exit velocity for turbo jet engine in term of the temperature compressor ratio τ_c , temperature turbine ratio τ_t and the burner enthalpy ratio τ_λ . is given by:

Halaju udara dari mesin turbo jet dalam besaran nisbah suhu kompresor τ_c, *nisbah suhu turbin* τ_t *dan nisbah entalpi ruang pembakar* τ_λ *diberikan sebagai:*

$$\left(\frac{U_9}{a_0}\right)^2 = \frac{2}{\gamma - 1}\left[\frac{\tau_\lambda}{\tau_r\,\tau_c}\left[\tau_r\,\tau_c\tau_t - 1\right]\right]$$

Using above equation, show that for a constant Mach number M_o [a constant τ_r], the optimum compressor temperature ratio $(\tau_c)_{opt}$ for the maximum thrust would occur at:

Dengan menggunakan persamaan di atas tunjukkan apabila nombor Mach malar [malar τ_r *] , nisbah suhu kompresor optimum* $(\tau_c)_{opt}$ *untuk maksimum daya dorong akan terjadi pada:*

$$(\tau_c)_{opt} = \frac{\sqrt{\tau_t}}{\tau_r}$$

(6 marks/*markah*)

(b) Show that by assumption of ideal conditions, the velocity exit for turbo jet engine with after burner would be:

Tunjukkan bahawa dengan anggapan kondisi ideal, halaju aliran keluar dari mesin turbo jet dengan "after burner "adalah:

$$\left(\frac{U_9}{a_0}\right)^2 = \frac{2}{\gamma - 1}\tau_{\lambda AB}\left[1 - \frac{\tau_\lambda}{\tau_r\,\tau_c}\frac{1}{\left[\tau_\lambda - \tau_r(\tau_c - 1)\right]}\right]$$

(6 marks/*markah*)

3. (a) Given ram jet engine with engine component data as follows:

Diberikan suatu mesin ram jet dengan data seperti berikut:

Fuel Heating value h_{pr} = 42798.4 kJ/kg
Nisbah panas bahan bakar h_{pr} = 42798.4 kJ/kg

Temperature Turbine limitation T_{t4} = 1800^0 K
Had suhu turbin T_{t4} = 1800^0 K

Flight ambient temperature T_∞ = 262^0 K
Suhu penerbangan sekitar T_∞ = 262^0 K

Flight ambient pressure P_∞ = 61.6 Kpa
Tekanan penerbangan sekitar P_∞ = 61.6 Kpa

Coefficient heat ratio γ = 1.4
Nisbah pemalar panas γ = 1.4

Heat coefficient at constant pressure C_p = 1004 (J/(kg ^{0}K))
Pemalar panas pada tekanan tetap C_p = 1004 (J/(kg ^{0}K))

Flight Mach number M_∞ = 2.0
Nombor Mach terbang M_∞ = 2.0

Rate of mass flow $\overline{\mathbf{m}}$ = **50 kg/saat**
Laju aliran jisim $\overline{\mathbf{m}}$ = **50 kg/saat**

Using an ideal cycle analysis, determine:

Dengan menggunakan analisis putaran ideal, tentukan:

(i) The exit Mach number M_9 and velocity at the nozzle V_9

Nombor Mach M_9 dan Halaju keluar di muncung V_9

(3 marks/*markah*)

(ii) Specific thrust and the thrust

Daya tujah spesifik dan daya tujah

(3 marks/*markah*)

(iii) The fuel air ratio f and the overall efficiency η_o

Nisbah bahan bakar – udara f dan jumlah kecakapan η_o

(4 marks/*markah*)

(b) An airplane flies at altitude of 4000 m above sea level. This airplane uses a turbo jet engine with the engine component data as follows:

Suatu pesawat udara terbang pada ketinggian 4000 m di atas permukaan laut. Pesawat tersebut menggunakan mesin turbo jet dengan data-data sebagai berikut:

Fuel Heating value h_{pr} = 42798.4 kJ/kg
Nisbah panas bahan bakar h_{pr} = *42798.4 kJ/kg*

Temperature Turbine limitation T_{t4} = 1800^0 K
Had suhu turbin T_{t4} = 1800^0 *K*

Flight ambient temperature T_∞ = 262^0 K
Suhu penerbangan sekitar T_∞ = 262^0 *K*

Flight ambient pressure P_∞ = 61.6 Kpa
Tekanan penerbangan sekitar P_∞ = *61.6 Kpa*

Heat coefficient ratio γ = 1.4
Nisbah pemalar panas γ = *1.4*

Heat coefficient at constant pressure C_p = 1004 (J/(kg ^{0}K))
Pemalar panas pada tekanan tetap C_p = *1004 (J/(kg* ^{0}*K))*

Flight Mach number M_∞ = 2.0
Nombor Mach terbang M_∞ = *2.0*

Rate of mass flow $\dot{\mathbf{m}}$ = **50 kg/saat**
Laju aliran jisim $\dot{\mathbf{m}}$ = **50 kg/saat**

Compressor pressure ratio π_c = **12**
Nisbah tekanan kompresor π_c = **12**

4. An airplane flies at altitude of 4000 m above sea level. This airplane uses a turbo fan engine with the engine component data as follows:

Suatu pesawat udara terbang pada ketinggian 4000m di atas permukaan laut. Pesawat tersebut menggunakan mesin turbo fan dengan data-data komponen mesin sebagai berikut:

Temperature Turbine limitation $T_{t4} = 1800^0$ K
Batasan suhu turbin $T_{t4} = 1800^0$ K

Fuel Heating value $h_{pr} = 42798.4$ kJ/kg
Nisbah panas bahan bakar $h_{pr} = 42798.4$ kJ/kg

Heat coefficient ratio of cold air $\gamma_c = 1.4$
Nisbah haba untuk udara sejuk $\gamma_c = 1.4$

Heat Coefficient ratio of hot air $\gamma_t = 1.30$
Nisbah haba untuk udara panas $\gamma_t = 1.30$

Heat coefficient at constant pressure of cold air $C_{pc} = 1004$ (J/(kg ^{0}K))
Pemalar haba pada tekanan tetap udara sejuk $C_{pc} = 1004$ (J/(kg ^{0}K))

Heat coefficient at constant pressure of cold air $C_{pt} = 1239$ (J/(kg ^{0}K))
Pemalar haba pada tekanan tetap udara panas $C_{pt} = 1239$ (J/(kg ^{0}K))

Ram diffuser efficiency $\pi_{d\,max} = \mathbf{0.95}$
Kecakapan ram diffuser $\pi_{d\,max} = \mathbf{0.95}$

Burner pressure ratio $\pi_b = 0.96$
Nisbah tekanan kebuk pembakaran $\pi_b = 0.96$

Nozzle pressure ratio $\pi_N = 0.98$
Nisbah tekanan muncung $\pi_N = 0.98$

Nozzle's Fan pressure ratio $\pi_{FN} = 0.98$
Nisbah tekanan muncung kipas $\pi_{FN} = 0.98$

Polytropic efficiency compressor $e_c = 0.9$
Kecekapan politropik kompresor $e_c = 0.9$

Polytropic efficiency turbine r $e_t = 0.9$
Kecekapan politropik turbin r $e_t = 0.9$

Polytropic efficiency fan $e_f = 0.9$
Kecekapan politropik kipas $e_f = 0.9$

Mechanical efficiency transmission $\eta_m = 0.99$
Kecekapan tranmisi mekanik $\eta_m = 0.99$

Low pressure compressor ratio $\pi_{Lpc} = \mathbf{5.0}$
Nisbah kompresor tekanan rendah $\pi_{Lpc} = \mathbf{5.0}$

High pressure compressor ratio $\pi_{Hpc} = \mathbf{4.0}$
Nisbah kompresor tekanan tinggi $\pi_{Hpc} = \mathbf{4.0}$

Pressure fan ratio $\pi_F = \mathbf{2.0}$
Nisbah tekanan kipas $\pi_F = \mathbf{2.0}$

Pressure compressor ratio $\pi_C = \pi_{Lpc} \times \pi_{Hpc} = \mathbf{20}$
Nisbah tekanan kompresor $\pi_C = \pi_{Lpc} \times \pi_{Hpc} = \mathbf{20}$

by pass ratio " $\alpha = 5.0$
Nisbah "by pass" $\alpha = 5.0$

Flight Mach number $M_\infty = 0.85$
Nombor Mach terbang $M_\infty = 0.85$

Rate of mass flow $\dot{\mathbf{m}}$ = **50 kg/saat**
Laju aliran jisim $\dot{\mathbf{m}}$ = **50 kg/saat**

Flight ambient temperature $T_\infty = 262^0$ K
Suhu terbang sekitar $T_\infty = 262^0$ *K*

Flight ambient pressure $P_\infty = 61.6$ Kpa
Tekanan terbang sekitar $P_\infty = 61.6$ *Kpa*

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

Kedua muncung baik untuk yang pertama mahupun yang kedua menghasilkan pengembangan gas dengan tekanan menuju ke tekanan sekitar.

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

Find:

Tentukan:

PART B/*BAHAGIAN B*

5. (a) 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)

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

(8 marks/*markah*)

(b) Using the value in Questions 5(a), draw the

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

(i) Schematic diagram of a conical nozzle

Gambarajah skema muncung kon

(4 marks/*markah*)

(ii) Schematic diagram of a bell nozzle

Gambarajah skema muncung "bell"

(4 marks/*markah*)

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

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

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

(4 marks/*markah*)

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