UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2015/2016 Academic Session

June 2016

ESA 344/2 – Propulsion Systems
[Sistem Dorongan]

Duration : 2 hours
[Masa : 2 jam]

Please ensure that this paper contains **NINE (9)** printed pages and **FOUR (4)** questions before you begin examination.

*Sila pastikan bahawa kertas soalan ini mengandungi **SEMBILAN (9)** mukasurat bercetak dan **EMPAT (4)** soalan sebelum anda memulakan peperiksaan.*

Instruction : Answer **ALL** questions.

Arahan *: 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 question must begin from a new page.

Setiap soalan mestilah dimulakan pada mukasurat yang baru.

In the event of any discrepancies, the English version shall be used.

Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.

1. Given :

T_a =288 K, P_a = 101 kPa
Cold (compressors and heat exchangers) C_p and γ: 1000 J/kg/K and 1.4 respectively
Hot (combustors, turbines and reheat) C_p and γ: 1150 J/kg/K and 1.333 respectively
Turbomachinery efficiencies are isentropic.

The following are the design parameters of a single shaft gas turbine at ISASLS:

Compressor pressure ratio :	16	TET :	1500 K
Compressor and turbine efficiencies :	0.86	FCV :	43 MJ/kg
Combustor pressure loss (% of CDP) :	5	Mass flow :	100 kg/s

[a] Sketch an engine fitted with the above gas generator incorporates a reheat system.

(2 marks)

[b] Draw a T-s diagram of engine 1[a] indicating clearly each component and explain on the process and andvantage of the system.

(5 marks)

[c] Calculate the thrust and SFC of a turbojet fitted with the above gas generator and a convergent nozzle

(15 marks)

[d] What will you recommend to **engine 1[c]** in order to produce more engine thrust. Justify your suggestion.

(3 marks)

2. [a] Smoke is the most obvious pollutant from gas turbine engines because it can be seen with the naked eye. Smoke is generated in any part of the combustion zone where mixing is inadequate. Fuel properties is one of the main controlling factors for soot and smoke formation. The properties of Fuel A and Fuel B are given to you. By comparing their properties, discuss how they can influence the soot formation. Based on your discussion, select which fuel forms less soot and justify your answer.

Fuel A

Viscosity : 8 mm^2/sec
Boiling point : 513.75 K
Aromatics content by volume : 20%

Fuel B

Viscosity : 4.37 mm^2/sec
Boiling point : 623.00 K
Aromatics content : 31.9%

(10 marks)

[b] In gas turbine combustor, large amount of Carbon Monoxide (CO) is formed due to lack of oxygen to complete the combustion. Discuss factors that may cause the above situation and suggest **TWO** approaches that yield to the reduction in CO.

(10 marks)

[c] Nitric oxide can be produced by three different mechanisms namely "Thermal NOx", "Prompt NOx", and "Fuel NOx". Thermal NOx is formed by oxidation of atmospheric nitrogen in the post-flame gases which can be presented by Zeldovich chain mechanism. List down the mechanisms and discuss the correlation between temperature and residence time on Thermal NOx formation.

(5 marks)

3. A propeller-piston engine propulsion system design for an aircraft has the following details:

Aircraft maximum takeoff mass	900 kg (1 N = 0.2248 lb)
Capable of climbing at angle, θ	15 degree
Maximum propeller RPM allowed, $PRpm_{max}$	3000
Propeller efficiency, η	0.89

Assume

- during takeoff aircraft climb at constant velocity, v
- aircraft lift force, $L = 0.2\ v^2$
- aircraft drag force, $D = 0.03\ v^2$

where, L & D in lb
v in knots (1 knot = 1.688 ft/s)

Engine specifications:
4-stroke, 4-cylinder

Indicated Mean effective pressure @ $PRpm_{max}$, P_{mean}	155 psi
Piston bore diameter, b	5.3 in
Piston stroke, s	4.8 in
Engine Mechanical efficiency, η_{mech}	0.85

If propeller shaft is connected directly to engine crankshaft (no gear reduction), does the propulsion system meets the requirements of the maneuver?
Show all calculations.

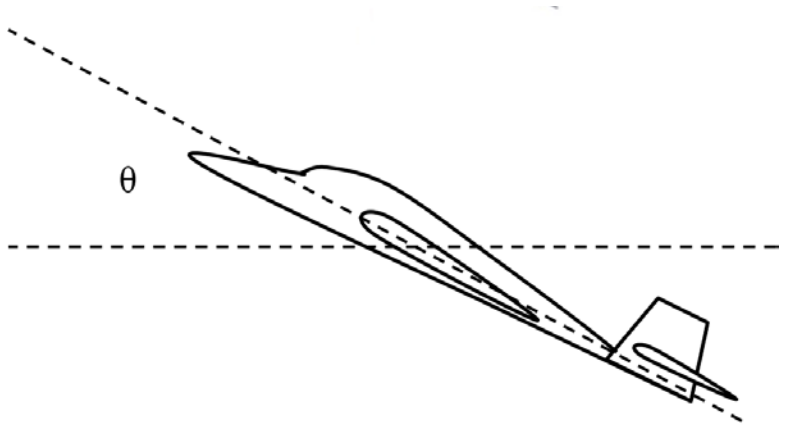


Figure 1

(20 marks)

4. The first stage of a two-stage medium lift launch rocket must accelerate Stage 2 and its payload to a velocity of 1800 m/s. Assume that the first stage follows a vertical trajectory where drag and variations in gravity can be neglected and that the initial mass of the second stage and payload is 180,000 kg. Also assume that the maximum allowable acceleration during this phase of the launch is 5 g's. In addition, use the following data :

Fuel = H_2 (specific gravity=0.08);
Oxidizer = O_2 (specific gravity=1.14);
Fuel-Oxidizer mixture = 3 kg of O_2 per kg of H_2;
I_{sp} = 400 s;
Motor-Pump mass = 3 x 10^{-4} kg per Newton of takeoff thrust;
Stage 1 guidance equipment mass = 180 kg;
Tank mass = 3% of propellant mass;
Propellant tanks L-to-D ratio = 8-to-1;
Mass ratio Λ = 1.811

Considering a constant thrust rocket :

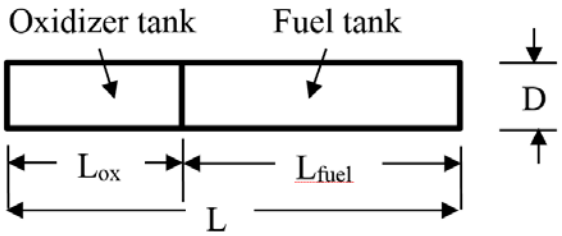
[a] Find mass of :

(i) oxidizer
(ii) fuel
(iii) propellant tanks
(iv) motor-pumps
(v) entire vehicle at liftoff
(vi) takeoff thrust.

(18 marks)

[b] Find lengths (L_{fuel} and L_{ox}) and diameter, D of the fuel and oxidizer tanks (assume both tanks have the same diameters – see figure below).

(8 marks)



[c] Find:

(i) time to burnout
(ii) altitude of rocket at burnout.

(4 marks)

1. *Di beri:*

T_a=288 K, P_a=101 kPa
Sejuk (pemampat dan penukar haba) C_p dan γ masing-masing adalah: 1000 J/kg/K dan 1.4
Panas (pembakar, turbin dan pemanas semula) C_p dan γ masing-masing adalah: 1150 J/kg/K dan 1.333
Kecekapan turbo mesin adalah seentropi.

Berikut merupakan parameter-parameter berkaitan untuk rekabentuk sebuah penjana gas satu kili ketika ISASLS:

Nisbah tekanan pemampat :	*16*	*TET :*	*1500 K*
Kecekapan pemampat dan turbin :	*0.86*	*FCV :*	*43 MJ/kg*
Kehilangan tekanan pembakar (% daripada CDP) :	*5*	*Aliran jisim :*	*100 kg/s*

[a] *Lakarkan sebuah enjin yang dipasang dengan gabungan jentera gas di atas dan pemanas*

(2 markah)

[b] *Lukiskan gambarajah T-s untuk enjin tersebut dan tunjukkan secara jelas setiap komponen dan bincangkan tentang proses dan kebaikan sistem tersebut*

(5 markah)

[c] *Kira daya tujahan dan SFC untuk turbojet yang dipasang dengan jentera gas seperti di atas dan sebuah muncung tumpu.*

(15 markah)

[d] *Cadangkan perkara yang perlu dilakukan untuk **enjin 1[c]** bagi menghasilkan lebih banyak daya tujahan. Berikan justifikasi atas cadangan anda.*

(3 markah)

2. [a] *Jelaga merupakan bahan cemar yang sangat jelas kerana ia dapat dilihat dengan mata kasar. Jelaga terhasil di dalam kebuk pembakar yang mengalami pembakaran yang tidak lengkap. Sifat-sifat minyak merupakan salah satu faktor penyebab penghasilan asap. Sifat-sifat Minyak A dan Minyak B adalah seperti di bawah. Berdasarkan maklumat yang diberi, bincangkan bagaimana sifat-sifat ini mempengaruhi penghasilan jelaga. Berdasarkan hasil perbincangan pilih minyak yang menghasilkan kurang jelaga dan pertahankan jawapan anda*

Fuel A

Kelikatan : 8 mm^2/sec
Takat didih : 513.75 K
Kandungan aromatik : 20%

Fuel B

Kelikatan : 4.37 mm^2/sec
Takat didih : 623.00 K
Kandungan aromatik : 31.9%

(10 markah)

[b] *Kekurangan oksigen dalam proses pembakaran menyebabkan peningkatan penghasilan Karbon Monoksida. Bincangkan faktor-faktor yang menyebabkan kejadian ini dan cadangkan **DUA** pendekatan yang boleh diaplikasikan dalam mengurangkan penghasilan Karbon Monoksida daripada kebuk pembakaran gas turbin.*

(10 markah)

[c] *Nitrik oksida terhasil melalui tiga mekanisma yang berbeza iaitu "Thermal NOx", "Prompt NOx", dan "Fuel NOx". "Thermal NOx" terbentuk melalui pengoksidaan nitrogen atmosfera dalam 'post-flame gases' sepertimana yang ditunjukkan dalam mekanisma Zeldovich. Senaraikan mekanisma Zeldovich dan bincangkan kaitan antara suhu dan masa mastautin terhadap penghasilan "Thermal NOx".*

(5 markah)

3. *Berikut adalah maklumat rekabentuk sistem tujahan kapalterbang yang menggunakan enjin piston-kipas:*

Jisim kapalterbang semasa berlepas	*900 kg (1 N = 0.2248 lb)*
Kebolehan mendaki pada sudut, θ	*15 darjah*
RPM maksimum kipas yang dibenarkan, $PRpm_{max}$	*3000*
Kecekapan kipas, η	*0.89*

Anggapan:

- *kapalterbang mendaki pada laju seragam, v*
- *daya angkat kapalterbang,* $L = 0.2\ v^2$
- *daya seret kapalterbang,* $D = 0.03\ v^2$

  di mana, L & D dalam lb

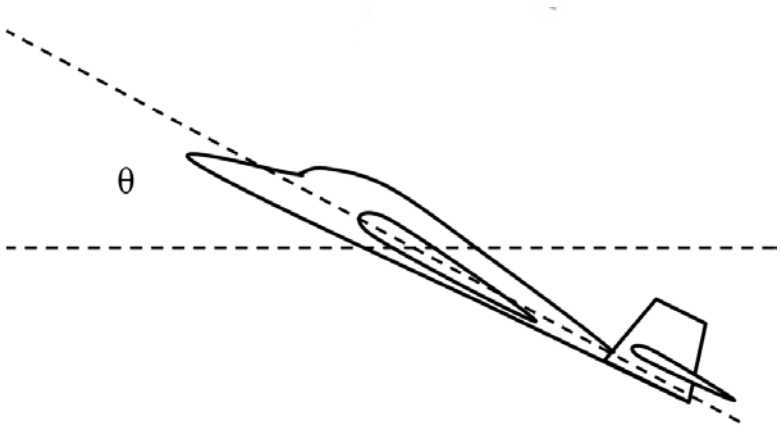
  v dalam knots (1 knot = 1.688 ft/s)

Spesifikasi enjin :

4-lejang, 4-silinder

Tekanan tunjukkan purata berkesan @ 3000 rpm, P_{mean}	*155 psi*
Garispusat lubang omboh, d	*5.3 in*
Strok piston, s	*4.8 in*
Kecekapan mekanikal enjin, η_{mech}	*0.85*

Jika aci kipas disambung terus ke aci-engkol enjin (tiada pengurangan gear), adakah sistem tujahan memenuhi keperluan misi pesawat?
Tunjukkan semua pengiraan.



Rajah 1

(20 markah)

4. *Fasa pertama daripada dua fasa sebuah roket daya tujah sederhana harus memecut fasa 2 dan muatan kepada halaju 1800 m/s. Anggap fasa pertama mempunyai pergerakan menegak dan abaikan daya rintangan dan graviti serta anggap jisim asal fasa kedua dan muatannya adalah 180,000 kg. Juga anggap kadar pecutan maksima yang dibenarkan semasa fasa pelancaran adalah 5 g serta menggunakan data-data berikut :*

Bahan api = H_2 (gravity tentu=0.08);
Pengoksida = O_2 (gravity tentu =1.14);
Campuran Bahan api-Pengoksida = 3 kg O_2 per kg H_2;
I_{sp} = 400 s;
Jisim motor-pam = 3 x 10^{-4} kg per Newton tujahan berlepas;
Jisim alatan panduan peringkat 1 = 180 kg;
Jisim tangki= 3% dari jisim bahan-dorongan;
Nisbah tangki bahan-dorongan L-*kepada*-D = *8-kepada-1;*
Nisbah jisim Λ = 1.811

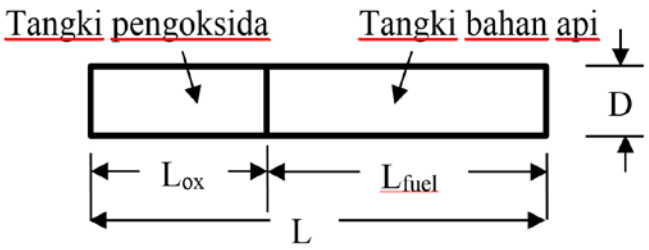
Andainya roket menghasilkan daya tujah yang seragam:

[a] *Kira jisim:*
- *(i)* *pengoksida*
- *(ii)* *bahan api*
- *(iii)* *tangki bahan dorongan*
- *(iv)* *motor-pam*
- *(v)* *keseluruhan kenderaan semasa pelancaran*
- *(vi)* *daya tujah semasa pelancaran.*

(18 markah)

[b] *Kira panjang (*L_{fuel} *dan* L_{ox}*) dan diameter,* D *tangki bahan api dan pengoksida (anggap kedua-dua tangki berdiameter sama - lihat gambar di bawah).*

(8 markah)



[c] *Kira:*
- *(i)* *masa untuk melengkapkan pembakaran*
- *(ii)* *ketinggian roket ketika pembakaran lengkap.*

(4 markah)

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