UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2014/2015 Academic Session

June 2015

ESA 344/2 – Propulsion Systems
[Sistem Dorongan]

Duration : 2 hours
[Masa : 2 jam]

Please ensure that this paper contains **EIGHT (8)** printed pages and **FOUR (4)** questions before you begin examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **LAPAN (8)** 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. All symbols have their usual meaning, unless specified otherwise:
T_a=288K, P_a=101kPa
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
Unless specified otherwise, 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] Calculate the power and thermal efficiency of the gas turbine engine. The exhaust system causes a pressure loss of 2 percent

(12 marks)

[b] Make a sketch of the engine if an intercooler is incorporated into the gas generator. Draw also a T-s diagram of the engine indicating clearly each component

(4 marks)

[c] Calculate the power output and thermal efficiency of 1b if at the point, the pressure of compressor has risen to 404 kPa and the gas is cooled to 300K. Consider no losses for the intercooler.

(12 marks)

[d] Comment on the above results. Include a comparison of **1[c] and 1[a]**

(2 marks)

2. [a] Discuss the influence of each of the following parameters upon the level of soot formation.

[i] Fuel properties

[ii] Pressure

[iii] Combustor temperature

[iv] Fuel to air ratio

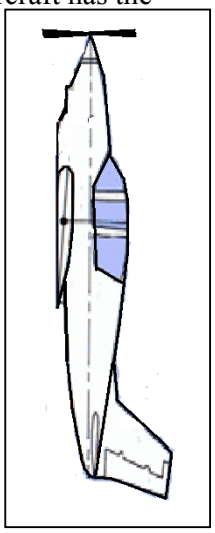
[v] Fuel drop size

(10 marks)

[b] Discuss the mechanisms involved with the production of nitrogen oxides (NO_x), and explain how **lean primary zone** and **reducing residence time** can contribute to the reduction of NO_x.

(10 marks)

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



Aircraft maximum takeoff mass	1400 kg
Capability to climb vertically at steady speed	9 knots
Maximum propeller RPM allowed	3000
Propeller efficiency, η	0.87

Engine specifications:
4-stroke, 4-cylinder

Indicated Mean effective pressure @ 3000 rpm, P_{mean}	170 psi
Piston bore diameter, d	5.40 in
Piston stroke, s	5.45 in
Engine Mechanical efficiency, η_{mech}	0.86

1 lb = 4.448 N

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. Consider drag to be negligible for the entire aircraft.

(15 marks)

4. The first stage of a two-stage medium lift launch rocket must accelerate Stage 2 and its payload to a velocity of 2450 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 250,000 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 = 250 kg;
Tank mass = 3% of propellant mass;
Propellant tanks L-to-D ratio = 8-to-1;
Mass ratio Λ = 2.3306

Considering a constant thrust rocket, calculate the following:

[a] Mass of oxidizer, fuel and propellant tanks.

(15 marks)

[b] Mass of motor-pumps and the entire vehicle at liftoff, and takeoff thrust.

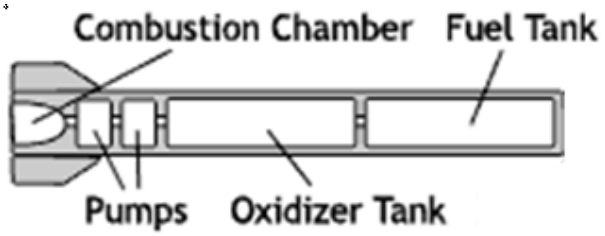
(5 marks)

[c] Length and diameter of the fuel and oxidizer tanks (assume both tanks have the same diameters).

(10 marks)

[d] Time to burnout and altitude of rocket at burnout.

(5 marks)



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1. *Setiap simbol mempunyai makna yang biasa. Melainkankan jika dinyatakan sebaliknya:*
T_a=288K, P_a=101kPa
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
Melainkan jika dinyatakan sebaliknya, kecekapan turbo mesin adalah seentropi

Berikut merupakan parameter-parameter berkaitan untuk rekabentuk sebuah penjana gas dua aci 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] Kira kuasa dan kecekapan terma untuk enjin gas turbin. Sistem ekzos menyebabkan kehilangan tekanan sebanyak 2 peratus

(12 markah)

[b] Lukiskan lakaran enjin berpenyejuk. Lukiskan juga gambarajah T-s untuk enjin tersebut dan tunjukkan secara jelas setiap komponen.

(4 markah)

[c] Kira kuasa dan kecekapan terma untuk enjin 1b sekiranya tekanan pemampat meningkat kepada 404 kPa dan gas disejukkan hingga suhu 300K. Tiada kehilangan untuk penyejuk.

(12 markah)

[d] Banding dan komen keputusan yang diperolehi pada ***1[c] dan 1[a].***

(2 markah)

2. [a] *Bincangkan kesan parameter-parameter di bawah terhadap kadar penghasilan jelaga*

[i] Ciri-ciri minyak

[ii] Tekanan

[iii] Suhu kebuk pembakar

[iv] Nisbah minyak terhadap udara

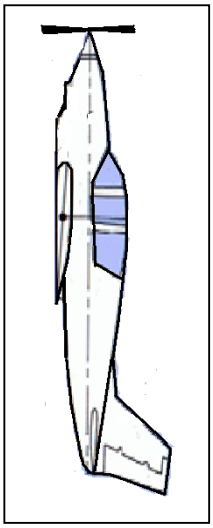
[v] Saiz minyak

(10 markah)

[b] *Bincangkan mekanisma yang terlibat dalam penghasilan nitrogen oksida, dan terangkan bagaimana* ***campuran kurang pada zon utama kebuk pembakaran*** *dan* ***pengurangan agihan masa*** *dapat membantu mengurangkan penghasilan NOx.*

(10 markah)

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



Jisim kapalterbang semasa berlepas	*1400 kg*
Kebolehan mendaki menegak pada laju seragam	*9 knots*
RPM maksimum kipas yang dibenarkan	*3000*
Kecekapan kipas, η	*0.87*
Spesifikasi enjin:	
4-lejang, 4-silinder	
Tekanan tunjukan purata berkesan @ 3000 rpm, P_{mean}	*170 psi*
Garispusat lubang omboh, d	*5.40 in*
Strok piston, s	*5.45 in*
Kecekapan mekanikal enjin, η_{mech}	*0.86*

1 lb = 4.448 N

Jika aci kipas disambung terus ke aci-engkol enjin (tiada pengurangan gear), adakah sistem tujahan memenuhi keperluan pergerakan pesawat?
Tunjukkan semua pengiraan.Abaikan daya seret untuk keseluruhan pesawat.

(15 markah)

4. *Fasa pertama daripada dua fasa sebuah roket daya tujah sederhana harus memecut fasa kedua dan muatan kepada halaju 2450 m/s. Anggap fasa pertama mempunyai pergerakan menegak dan abaikan daya rintangan dan graviti serta anggap jisim asal fasa kedua dan muatannya adalah 250,000 kg. Juga anggap kadar pecutan maksima yang dibenarkan adalah 5 g serta menggunakan data-data berikut:*

Bahanapi = H_2 (gravity tentu=0.08);
Pengoksida = O_2 (gravity tentu =1.14);
Campuran Bahanapi-Pengoksida = 3 kg O_2 per kg H_2;
I_{sp} = 260 s;
Jisim motor-pam = 3 x 10^{-4} kg per Newton tujahan berlepas;
Jisim alatan panduan peringkat 1 = 250 kg;
Jisim tangki= 3% dari jisim bahan-dorongan;
Nisbah tangki bahan-dorongan L-kepada-D = 8-kepada-1;
Nisbah jisim Λ = 2.3306

Andainya roket menghasilkan daya tujah yang tetap, kira perkara-perkara berikut:

[a] Jisim pengoksida, bahanapi dan jisim tangki bahan dorongan.

(*15 markah*)

[b] Jisim motor-pam dan keseluruhan kenderaan semasa pelancaran dan daya tujah semasa pelancaran.

(5 *markah*)

[c] Panjang dan diameter tangki minyak dan tangki bahan api (anggap kedua-duanya mempunyai diameter yang sama)

(*10 markah*)

[d] Masa untuk pembakaran lengkap dan ketinggian roket ketika itu.

(*5 markah*)

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