UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2002/2003
Second Semester Examination
2002/2003 Academic Session

Februari/Mac 2003
February/March 2003

ESA 382/3 – Rekabentuk Sub-Sistem Kapal Angkasa
(Spacecraft Sub-System Design)

Masa : [3 Jam]
Time : [3 hours]

ARAHAN KEPADA CALON :
INSTRUCTION TO CANDIDATES:

1. Sila pastikan bahawa kertas peperiksaan ini mengandungi **(14) TIGA BELAS** mukasurat bercetak **termasuk lampiran** dan **(8) LAPAN** soalan.
   *Please ensure that this paper contains **(14) FOURTEEN** printed pages including attachment and **(8) EIGHT** questions .*

2. Kertas soalan ini mengandungi **4 (EMPAT)** bahagian. Bahagian A,B,C dan D. Anda dikehendaki menjawab **(5) LIMA** soalan
   *This paper contains **4(FOUR)** sections. Section A , B, C and D.*
   *Please answer **(5) FIVE** questions.*

   Jawab **(1) SATU** soalan daripada setiap bahagian
   Pilih **(1) SATU** soalan lagi daripada mana-mana bahagian.
   *Answer **(1) ONE** question from each section and choose **ONE MORE** question from any sections.*

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

4. Agihan markah bagi setiap soalan diberikan di sut sebelah kanan.
   The mark allocated for each question is shown on the right hand side .

5. Mesin kira bukan yang boleh diprogram boleh digunakan.
   Non programmable calculator can be used.

BAHAGIAN A/*PART A*

1. (a) Senaraikan parameter-parameter utama (bersama unit) sel bateri.

List the main characteristic parameters (with unity) of battery cells.

(30 markah/*marks*)

(b) Senaraikan faktor utama yang mempengaruhi prestasi sel bateri.

List the major factors which influence battery cell's performance.

(20 markah/*marks*)

(c) Sistem kuasa sekunder sebuah satelit orbit rendah mengandungi bateri kimia dengan data-data berikut:

The secondary power system of a LEO satellite consists of chemical battery with the following data:

Kuasa beban bayar/*Payload power*	1200 W
Voltan bas/ *Bus voltage*	28 ± 0.5 V
Voltan unit sel / *Voltage of cell unit*	1.25 V
Kedalaman kadar nyahcas maksima/ *Max depth of discharge*	70%
Kuasa tentu/ *Specific power*	35 W-h/kg

(i) Tentukan kapasiti kuasa yang diperlukan apabila satelit itu memasuki tempoh maksimum gerhana.

Calculate the required power capacity when the satellite enters the maximum period of eclipse.

(ii) Tentukan jumlah jisim bateri yang diperlukan.

Calculate the total battery mass required.

(50 markah/*marks*)

2. (a) Senaraikan parameter-parameter utama (bersama unit) sel bahan bakar.

List the main characteristic parameters (with unity) of fuel cells

(20 markah/*marks*)

(b) Senaraikan dan bincangkan tiga jenis bateri bahan bakar.

List and briefly describe three different kinds of fuel cells.

(30 markah/*marks*)

(c) Sebuah kapal angkasa menggunakan sel bahan bakar hidrogen-oxigen untuk misi antara planet.

(i) Terbitkan keseimbangan kimia c ecair h idrogen d an c ecair oxygen.

(ii) Tentukan bilangan elektron yang dipindahkan.

(iii) Apakah voltan sel unggul tersebut pada 25°C?

A spacecraft uses hydrogen-oxygen fuel cells in its interplanetary mission.

(i) Derive the chemical equilibrium of liquid hydrogen and liquid oxygen

(ii) Determine the number of electrons transferred

(iii) What is the voltage of an ideal cell unit at 25 °C?

(50 markah/*marks*)

BAHAGIAN B/*PART B*

3. (a) Terangkan secara umum mengenai kegunaan telemetri, pengesanan dan perintah?

Describe in general the purpose of telemetry, tracking and command?

(30 markah/*marks*)

(b) Apakah keperluan kebiasaan pemerhatian dalam sebuah satelit komunikasi?

What are the typical monitoring requirements of a communication satellite?

(20 markah/*marks*)

(c) Senarai dan terangkan tiga jenis arahan yang umum?

List and describe three basic types of commands?

(30 markah/*marks*)

(d) Lakarkan keseluruhan sistem telemetri dan telearahan secara terperinci.

Draw the overall telemetry and telecommand system detail.

(20 markah/*marks*)

4. (a) Apakah perbezaan antara tentu jarak dan pengesanan?

What the difference between ranging and tracking?

(20 markah/*marks*)

(b) Senarai dan terangkan dua ketegori umum data telemetri.

List and describe two basic categories of telemetry data.

(20 markah/*marks*)

(c) Terangkan secara terperinci mengenai telemetri paket dan teleperintah paket.

Describe in detail about packet telemetry and packet telecommand.

(30 markah/*marks*)

(d) Senarai dan terangkan lima fungsi utama 'Pengendalian Data' di Pesawat.

List and describe five main function of Onboard Data Handling.

(30 markah/*marks*)

BAHAGIAN C/*PART C*

5. (a) Terangkan dengan terperinci

(i) jenis-jenis utama sistem dorongan kapal angkasa,

(ii) misi yang berkaitan dengan jenis-jenis sistem dorongan kapal angkasa serta

(iii) lukiskan gambarajah skematik enjin untuk sistem dorongan kimia (sistem dorongan termodinamik).

Explain in detail

(i) types of spacecraft propulsion,

(15 markah/*marks*)

(ii) their mission and

(15 markah/*marks*)

(iii) draw the schematic diagram of the chemical propulsion engines (thermodynamic propulsion system).

(20 markah/*marks*)

(b) (i) Terbitkan persamaan Tsiolkovsky (persamaan roket yang ideal) dan

(ii) Terangkan hubungkait keupayaan roket (sistem dorongan) dengan persamaan tersebut **SECARA TERPERINCI**

(i) Derive the Tsiolkovsky's equation (the ideal rocket equation) and

(30 markah/*marks*)

(ii) Explain the relationships of the rocket (propulsion) performance with the equation in ***DETAILS.***

(20 markah/*marks*)

6. (a) Terangkan dengan jelas keperluan sistem dorongan untuk sebuah kapal angkasa bermisi GEO orbit (dari bumi).

Explain in detail based on propulsion requirement of a spacecraft to GEO orbit (from ground) (propulsion requirement)

(40 markah/*marks*)

(b) Sebuah ruang (chamber) roket beroperasi pada permukaan laut (p_2 = 1 atm atau 0.1013 MN/m^2) dengan menggunakan bahan bakar di mana produk pembakaran mempunyai nisbah spesifik haba 1.30.

An ideal rocket chamber ~~is to~~ operate at sea level (p_2 = 1 atm or 0.1013 MN/m^2) using propellants whose combustion products have a specific heat ration of 1.30.

(i) Kirakan ketentuan ruang tekanan dan muncung keluar di antara tekak dan bahagian keluar sekiranya nombor Mach di bahagian muncung keluar adalah 2.40. (Andaikan: nombor Mach di bahagian muncung masuk adalah 0).

Determine the required chamber pressure and nozzle exit ratio between throat and exit if the nozzle exit Mach number is 2.40. (Assumptions: The nozzle inlet Mach number is considered to be zero).

(15 markah/*marks*)

(c) Rekakan satu muncung untuk roket yang ideal di mana beroperasi pada ketinggian 25 km dan menghasilkan daya dorong 5000 N pada ruang tekanan 2.068 MN/m^2 (MPa) dan ruang suhu 2800 K. Andaikan K = 1.30 dan R = 355.4 J/kg-K, Tentukan

(i) keluasan tekak,

(ii) keluasan bahagian keluar,

(iii) halaju bahagian tekak dan

(iv) suhu bahagian keluar.

(v) Dengan pengiraan tersebut, terangkan tekak pada kelompok mana muncung itu berada dan lukiskan gambarajah muncung.

...9/

Design 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 MN/m^2 (MPa) and a chamber temperature of 2800 K. Assuming K = 1.30 and R = 355.4 J/kg-K, determine

(i) *the throat area,*

(10 markah/*marks*)

(ii) *exit area,*

(10 markah/*marks*)

(iii) *throat velocity and*

(10 markah/*marks*)

(iv) *exit temperature.*

(10 markah/*marks*)

(v) *With the calculated answers, explain where the nozzle type belongs and draw the nozzle.*

(5 markah/*marks*)

BAHAGIAN D/*PART D*

7. (a) Nyatakan dan bincangkan tiga mod perpindahan haba.

State and describe the three modes of heat transfer.

(30 markah/*marks*)

(b) Senaraikan faedah menggunakan penebat terma pada kapal angkasa.

List the advantages of using thermal insulators on spacecraft.

(30 markah/*marks*)

(c) Terangkan konsep penggunaan paip haba sebagai sistem kawalan terma secara aktif.

Describe the working concept of heat pipes as an active thermal control system.

(40 markah/*marks*)

8. (a) Bincangkan teknik kawalan terma secara pasif.

Briefly describe passive thermal control techniques.

(30 markah/*marks*)

(b) Ungkapkan keseimbangan haba untuk sebuah satelit yang ditempatkan pada orbit 35900 km dan perolehkan suhu yang berkaitan.

Formulate the heat balance for a satellite deployed at 35900 km orbit and derive the corresponding temperature.

(30 markah/*marks*)

(c) Andaikan sebuah satelit-hexagon-berputar menyerap dan memancar fluks suria pada masing-masing 0.75 dan 0.82. Keterikan fluks suria adalah 1330 W/m^2. Satelit itu mengeluarkan haba sebanyak 240W daripada transponder. Setiap permukaan mempunyai dimensi 100mm x 500mm keluasan. Kirakan suhu keseimbangan:

Assuming that a hexagon shaped spinning satellite absorbs and emits solar flux at 0.75 and 0.82 respectively. The solar flux intensity is 1330 W/m^2. The satellite is dissipating heat from its transponders at 240W. Each face has a dimension of 100mm x 500mm in area. Calculate the equilibrium temperature of:
(Stefan-Boltzmann constant = 5.67×10^{-8} $W/(m^2K^4)$)

(i) Satelit pasif berkeadaan mantap

A steady-state passive satellite.

(ii) Satelit aktif berkeadaan mantap

A steady-state active satellite.

(40 markah/*marks*)

LAMPIRAN

$$C = \frac{P \cdot t}{DOD \cdot n \cdot V_1}$$

C = battery capacity
P = payload power
t = eclipse period
DOD = max depth of discharge
n = number of cells
V_1 = voltage of cell unit

$$V_r = \frac{-\Delta G}{n \cdot F}$$

V_r = reaction voltage
ΔG = charge of Gibbs free energy (-237.2 kJ/mol for water at 25°)
n = number of electrons
F = Faraday constant (9.65×10^4 C/mol)

LAMPIRAN

Parameter	Equations
Average exhaust velocity, v_2 (assume that $v_1 = 0$) (m/s)	$v_2 = \sqrt{\left[\frac{2k}{(k-1)}\right] RT_1 \left[1 - \left(\frac{p_2}{p_1}\right)^{\left(\frac{k-1}{k}\right)}\right]}$
Effective exhaust velocity, c (m/s)	$c = \frac{I_{sp}}{g_0}$
Characteristic exhaust velocity, c*	$c^* = \frac{\sqrt{kRT_1}}{k\sqrt{\left[\frac{2}{k+1}\right]^{\frac{k+1}{k-1}}}}$
Mass flow rate, $\dot{m}$, (kg/sec)	$\dot{m} = \frac{A_t v_t}{V_t} = A_t p_1 \frac{k\sqrt{\left[\frac{2}{k+1}\right]^{\frac{k+1}{k-1}}}}{\sqrt{kRT_1}}$
Specific Impulse (sec)	$I_{SP} = \frac{c}{g_0}$
Mach Number, M	$M = \frac{v}{a} = \frac{v}{\sqrt{kRT}}$
Nozzle exit	$\alpha = \frac{A_2}{A_1} = \frac{1}{M_2}\left[\frac{1 + \frac{k-1}{2} M_2^2}{1 + \frac{k-1}{2}}\right]^{\frac{k+1}{k-1}}$
Isentropic relationships for stagnation and free-stream conditions	$\frac{T_0}{T} = \left(\frac{p_0}{p}\right)^{\frac{k-1}{k}} = \left(\frac{V}{V_0}\right)^{k-1}$ $\frac{T_x}{T_y} = \left(\frac{p_x}{p_y}\right)^{\frac{k-1}{k}} = \left(\frac{V_y}{V_x}\right)^{k-1}$

LAMPIRAN

Nozzle Expansion Ratio	$\alpha = A_2/A_t$
Throat Pressure for a maximum flow in an isentropic expansion nozzle (Critical Pressure)	$\frac{p_t}{p_1} = \left[\frac{2}{(k+1)}\right]^{\frac{k}{k-1}}$
Volume and Temperature at critical pressure	$V_t = V_1\left[\frac{(k+1)}{2}\right]^{\frac{1}{k-1}}$ $T_t = \frac{2T_1}{k+1}$
Throat velocity	$v_t = \sqrt{\frac{2k}{k+1}RT_1} = \sqrt{kRT_t}$

STANDARD ATMOSPHERE

Properties of Atmosphere

Altitude (m)	Temperature (K)	Pressure (MPa)	Density (kg/m^3)
0	288.15	0.10135	1.225
10,000	223.25	0.026504	0.41351
25,000	221.55	0.002549	0.040084
50,000	270.65	0.00007979	0.0010269

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