UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2009/2010

November 2009

ESA 481/3 – Spacecraft Design
Rekabentuk Kapal Angkasa

Duration : 3 hours
[Masa : 3 jam]

INSTRUCTION TO CANDIDATES
ARAHAN KEPADA CALON

Please ensure that this paper contains **TWELVE (12)** printed pages and **TEN (10)** questions before you begin examination.

Sila pastikan bahawa kertas soalan ini mengandungi **DUABELAS (12)** *mukasurat bercetak dan* ***SEPULUH (10)*** *soalan sebelum anda memulakan peperiksaan.*

Part 1 (20%): Answer **ONE (1)** questions
Part 2 (20%): Answer **ONE (1)** questions
Part 3(15%): Answer **FOUR (4)** questions

Bahagian 1(20%): Jawab ***SATU (1)*** *soalan*
Bahagian 2 (20%): Jawab ***SATU (1)*** *soalan*
Bahagian 3 (15%): Jawab ***EMPAT (4)*** *soalan*

Answer the questions in English .
Jawab soalan dalam Bahasa Inggeris.

Each questions 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 kertas soalan, versi Bahasa Inggeris hendaklah digunakan pakai.

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PART 1/*BAHAGIAN*.

Answer ONE (1) questions
Jawab SATU (1) soalan.

1. Present and describe space vehicle design diagram in the structure of space systems. Explain main designing criteria.

Nyatakan dan terangkan gambar rajah reka cipta kapal angkasa di dalam struktur sistem angkasa. Jelaskan kriteria utama dalam perekaciptaan.

(20 marks/*markah*)

2. (a) Describe a jet orientation system (briefly).

Terangkan sistem orientasi jet (secara ringkas.)

(b) Solve a problem below:

Selesaikan masalah di bawah:

A satellite is on the Earth orbit. A jet orientation system (using a cold gas as a working medium) during the most part of the flight provides approximate orientation of the satellite relative to the Sun, Earth and accurate pointing during corrections and scientific experiments. The satellite has the following performances:

Sebuah satelit di orbit Bumi. Sistem orientasi jet (menggunakan gas sejuk sebagai medium kerja) ketika kebanyakan waktu penerbangan menyediakan anggaran orientasi berkadaran dengan matahari, Bumi dan hala yang tepat ketika pembetulan dan eksperimen sains. Satelit tersebut mempunyai prestasi seperti berikut:

I_{Sat} = 40 kg×m^2 – satellite moment of inertia; P_{sp} =70 s - controlled jet nozzles (CJN) specific thrust (the working medium is nitrogen (N_2)); l = 0.2 m - arm of CJN thrust operation; g_0 =9.806 m/s^2 - terrestrial gravity acceleration.
Derive formulas for calculation of the required working medium margin (*m*, kg) and calculate it for the following operations:

I_{sat} = 40 kg x m² - inertia momen satelit; P_{sp} = 70s – tujahan tentu muncung jet terkawal (CJN)(medium kerja ialah Nitrogen (N_2)); l = 0.2 m – operasi lengan tujahan untuk CJN; g_0=9.806 m/s² - pecutan graviti planet.
Dapatkan formula untuk pengiraan margin medium kerja yang diperlukan (m, kg) dan kira operasi seterusnya:

(i) Increase or decrease of satellite angular velocity $\Delta\omega$ ($\Delta\omega$=2 deg/s).

Kenaikan atau penurunan halaju sudut satelit $\Delta\omega$ ($\Delta\omega$=2 deg/s).

(ii) Satellite orientation problem.

Masalah orientasi satelit .

In stabilizing mode (with sensors possessing sensitivity of $\Delta\omega$ =0.1 deg/s – for angular velocity, $\Delta\varphi$=0.5 deg – for an angle) the SV performs vibrating motion with amplitude of $\pm\Delta\varphi$ (equal $2\Delta\varphi$) and angular velocity of $\Delta\omega$. The stabilization process duration τ^* = 50 s.

Dalam mod penstabilan (dengan sensitiviti penderia pada $\Delta\omega$ =0.1 deg/s – untuk halaju sudut, $\Delta\varphi$=0.5 deg – untuk satu sudut) kapal angkasa menunjukkan pergerakan getaran dengan amplitud $\pm\Delta\varphi$ (sama dengan $2\Delta\varphi$) dan halaju sudut $\Delta\omega$. Masa untuk proses penstabilan τ^* = 50 s.

(20 marks/*markah*)

PART 2/*BAHAGIAN 2*

Answer ONE (1) questions
Jawab SATU (1) soalan.

3. (a) Describe space vehicle general requirements and space vehicle design general requirements of the following:

Perihalkan keperluan am untuk kapal angkasa dan keperluan am untuk reka bentuk kapal angkasa seperti berikut:

(i) Reliability requirements.
Keperluan kebolehharapan.

(ii) Operational specifications.
Spesifikasi operasi

(iii) Economic requirements.
Keperluan ekonomi.

(iv) Least mass and volume requirements.
Keperluan jisim dan isipadu yang minima

(v) Strength requirements.
Keperluan kekuatan

(vi) Stiffness requirements.
Keperluan kekakuan

(vii) Pressurization requirements.
Keperluan tekanan

(viii) Requirements on minimum energy demand.
Keperluan pada permintaan tenaga yang minima

(ix) Requirements on industrial-technological complex.
Keperluan kepada teknologi industri yang kompleks

(15 marks/*markah*)

(b) Present and explain the decision on in-flight complex configuration with independent reliability. Determine the total probability of faultless operation (P_Σ). (P_1=0.55 - probability of faultless operation of a single SV, N = 3 - number of satellite).

Tunjukkan dan terangkan keputusan konfigurasi kompleks ketika penerbangan dengan keboleh harapan bebas. Tentukan jumlah kemungkinan operasi tanpa gagal (P_Σ). (P_1=0.55 – kemungkinan untuk operasi tanpa gagal untuk sebuah kapal angkasa, N=3 – bilangan satelit).

(5 marks/*markah*)

4. Explain Korolev's formula below.

Terangkan mengenai formula Korolev seperti di bawah.

Korolev's formula.

$$\underbrace{V_f = -gP_{sp.thr.v.} \ln \mu_f}_{\text{Tsiolkovsk i's formula}} - \underbrace{\frac{P_{sp.thr.0}}{n_0} \int_{\mu_f}^{1} g \sin\theta \frac{d\mu}{\mu}}_{\Delta V_{grav}} - \underbrace{\frac{P_{sp.thr.0}}{n_0} \frac{g}{P_m} \int_{\mu_f}^{1} qc_x \frac{d\mu}{\mu}}_{\Delta V_{aer}} - \underbrace{\Delta P_{sp.thr.} g \int_{\mu_f}^{1} \frac{P(H)}{P(0)} \frac{d\mu}{\mu}}_{\Delta V_{e.u.}}$$

(20 marks/*markah*)

5. (a) Describe and explain a **Solar probe thermal protection system** which is nonstandard thermal protection system design as depicted in the sketch below (refer to **Figure 1** and **Figure 2**).

*Perihalkan dan terangkan Sistem Perlindungan haba untuk kuar suria di mana ianya adalah sistem reka cipta untuk perlindungan haba tanpa piawaian seperti yang dilakarkan dalam lakaran di bawah (rujuk **Rajah 1** dan **Rajah 2**).*

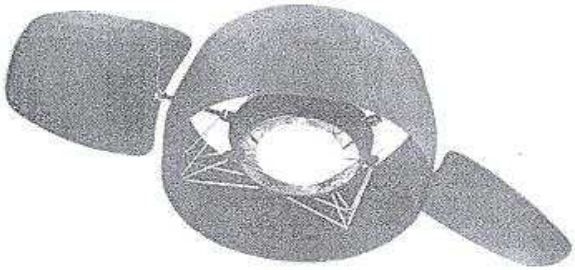

Figure 1/*Rajah 1*

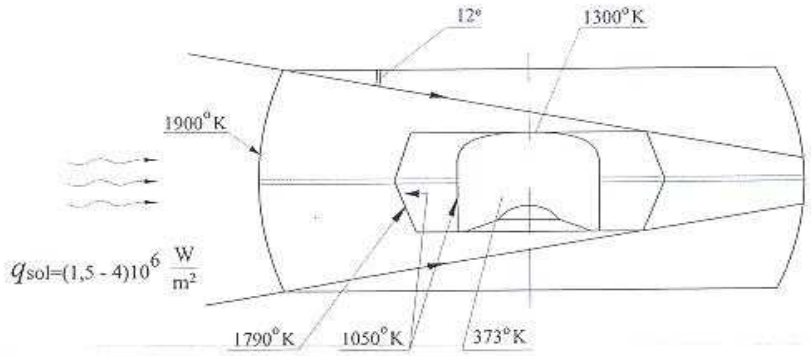

Figure 2/*Rajah 2*

(15 marks/*markah*)

(b) Present and explain the decision on in-flight complex configuration with independent reliability. Calculate a number of satellites to provide the total probability of a faultless operation $P_{\Sigma} = 0.9$, if the probability of a faultless operation of a single satellite is $P_1=0.5$.

Tunjukkan dan terangkan keputusan konfigurasi kompleks ketika penerbangan dengan keboleh harapan bebas. Kirakan bilangan satelit untuk membekalkan jumlah kemungkinan pada operasi tanpa gagal $P_{\Sigma} = 0.9$, *jika kemungkinan pada operasi tanpa gagal untuk sebuah satelit ialah* $P_1=0.5$.

(5 marks/*markah*)

PART 3/*BAHAGIAN 3.*

Answer **FOUR (4)** questions.
*Jawab **EMPAT(4)** soalan.*

6. (a) Present and explain a transfer between two coplanar circular orbits (Hohmann transfer).

Tunjukkan dan terangkan pemindahan dua orbit bulat koplanar (Pemindahan Hohmann)

(b) Present and explain a non-coplanar transfer between two non-coplanar circular orbits (refer to **Figure 3**).

*Tunjukkan dan terangkan pemindahan bukan koplanar di antara dua orbit bulat bukan koplanar (rujuk **Rajah 3**)*

(c) Solve a problem below:

Selesaikan masalah berikut:

A satellite is on the Earth circular orbit (support orbit, r_{so} =6571km). Calculate the total velocity needed for coplanar orbit transfer to working circular orbit (r_{wo} =6871km). Gravitational constant to Earth's mass product $\mu = 398600\ km^3/s^2$.

Sebuah satelit di orbit bulat Bumi (orbit penyokong, r_{so} =6571km). Kira jumlah kelajuan yang diperlukan untuk pemindahan orbit koplanar kepada orbit kerja bulat (r_{wo} =6871km). Pemalar graviti kepada produk jisim Bumi $\mu = 398600\ km^3/s^2$.

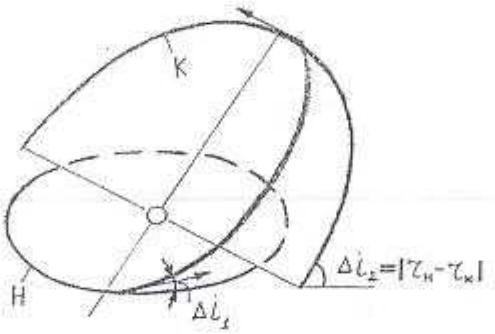

Figure 3/*Rajah 3*

(15 marks/*markah*)

7. Describe the forces exerted against a spacecraft in orbital flight and spacecraft center-of-mass motion equation. (The spacecraft motion is in the gravitational field of Earth which is assumed to be a perfect sphere). Describe orbital elements (refer to **Figure 4**).

*Terangkan daya yang digunakan terhadap kapal angkasa di orbit penerbangan dan persamaan gerakan pusat jisim untuk satelit. (Pergerakan kapal angkasa adalah di dalam medan tarikan graviti Bumi di mana dianggap sebagai bulatan yang sempurna). Terangkan elemen-elemen untuk orbit (rujuk **Rajah 4**).*

$$\frac{d^2\bar{r}}{dt^2} = \bar{u}_G + \bar{u}_{at} + \bar{u}_m + \bar{u}_s + \bar{u}_c$$

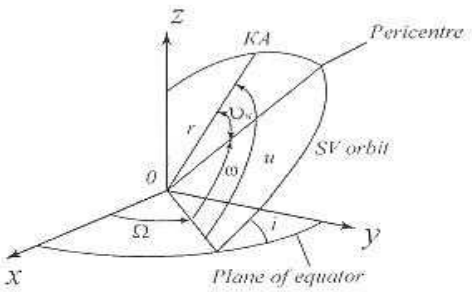

Figure 4/*Rajah 4*

(15 marks/markah)

8. Tanks' configuration. Present and explain the decision upon the number of spherical tanks.

Tatarajah tangki. Perihalkan dan terangkan keputusan terhadap bilangan tangki bulat.

(15 marks/markah)

9. Describe the low orbit satellite configuration. Explain the influence of aerodynamic and solar pressure on low orbit satellite. (refer to **Figure 5** and **Figure 6**).

*Terangkan tatarajah orbit rendah untuk satelit. Terangkan kesan dari segi aerodinamik dan tekanan suria pada orbit rendah untuk satelit.(rujuk **Rajah 5** dan **Rajah 6**)*

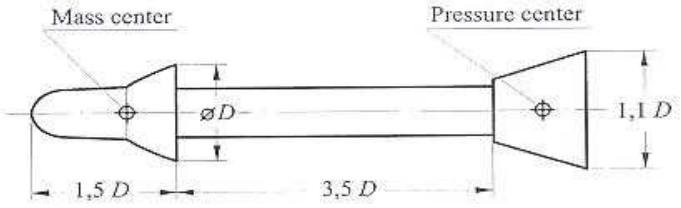

Figure 5/*Rajah 5*

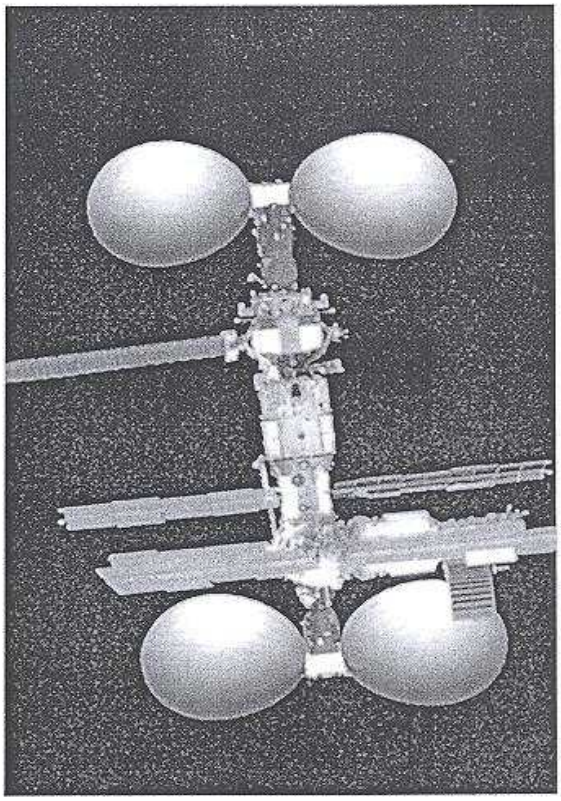

Figure 6/*Rajah 6*

(15 marks/*markah*)

10. Describe the spacecraft (SC) configuration in gravitational field. Explain the conditions of the stable position of a SC in gravitational field (refer to **Figure 7**).

*Terangkan tatarajah kapal angkasa di dalam medan tarikan graviti. Terangkan keadaan pada posisi stabil sebuah kapal angkasa di dalam medan tarikan graviti (rujuk **Rajah 7**)*

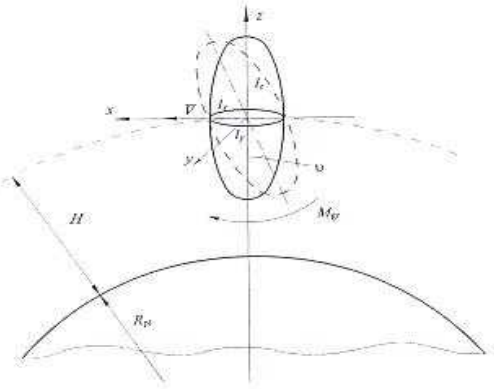

Figure 7/*Rajah 7*

(15 marks/*markah*)

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