S-92.3114 Spaceflight Instrumentation

Examination on 17. March 2014, at 16.15-19.00

Four examination exercises give 24 points in maximum and it influences the final grade by 45 %. Final grade is not registered before the laboratory work is done.

Grading

1 = 11 p – 12 p, 2 = 13 p – 15 p, 3 = 16 p – 18 p, 4 = 19 p – 21 p, 5 = 22 p – 24 p.

Some constants:

Earth radius = 6371 km

Gravitational constant $\mu_e = 3.986 \times 10^{14}$ $m^3 s^{-2}$

Stefan-Boltzman constant = 5.67×10^{-8} $Wm^{-2}K^{-4}$

Solar constant at 1 AU = 1350 Wm^{-2}

Some equations:

$$P = \eta I_s A \cos\theta$$

$$P = \eta I_s A \cos\theta \qquad E_p = -GMm/r$$

$$\tau = 2\pi\sqrt{\frac{a^3}{\mu}}$$

$$\varepsilon_s A_s \sigma T_s^4 = Q_{sun} + Q_{Et} + Q_{Er} + Q_i ,$$

$$Q_{sun} = \alpha_s \pi R^2 I_{sun}, \; Q_{Et} = \varepsilon_s A_s F_{Et} \sigma T^4_E$$

$$F_{Et} = \frac{1}{2}\left[1 - \frac{\sqrt{H^2 + 2H}}{1 + H}\right] \text{ where } \quad H = \frac{h}{R_E}$$

$$\Delta v = V_e^* \ln\left(\frac{m_0}{m_b}\right)$$

$$F = \dot{m} V_e + A_e (p_e - p_a)$$

$$V_e' = V_e + \frac{A_e (p_e - p_a)}{\dot{m}} \qquad E_e = -GMm/2a$$

$$1/2\, v^2 - \mu/r = -\mu/2a$$

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1. Please explain (1 point each)

a) Give definition to common acronyms in space business: PDR, TRL, EM.

b) Can Hohmann transfer orbit be used with ion engine? Explain.

c) Which has typically lower specific impulse, chemical propulsion or electrical propulsion?

d) How changes the satellite contact time window when you increase the satellite speed with chemical rocket booster?

e) In what direction delta V should be applied in order to change orbit inclination?

f) What is RAAN?

2. Please answer (2 point each)

a) Write Kepler laws (with words). How well these laws describe movement of satellites? Explain.

b) Compare solid fuel and liquid fuel propulsion. Illustrate functioning concept with diagrams. What are the main problems and benefits of those technologies?

c) Compare protoflight and flight models and their test programs. What are the main differences

3. (6 points) A satellite with mass m=240 kg is inserted to circular orbit at 390 km altitude from the Space Shuttle. Inclination of the orbit is 22°. Calculate the needed delta V budget in order to transfer the satellite to geostationary orbit.

4. (6 points) A rocket has following parameters: mass 14000 kg, propellant mass flow rate 165 kg/s, exhaust velocity 2500 m/s, burning time 75 s, exhaust plane area 0.35 m2, pressure at the nozzle exit 34000 N/m2, ambient pressure (atmosphere at sea level) 101300 N/m2. Calculate: thrust force, effective exhaust speed, thrust per initial weight ratio, vertical acceleration and mass ratio of the rocket.