S-92.3114 Spaceflight Instrumentation

Examination on 16. Dec. 2010, at 13.00-16.00, S4

You can leave out 1 assignment which will be compensated with the final grade of your homework. If you answer to all questions, the best answered questions will be accounted for the final grade automatically. So it is possible to achieve maximal result if all examination assignments are answered perfectly.

Here are some constants and equations you may need.

Constants:

Earth radius = 6371 km

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

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

Solar radiation power near earth = 1350 Wm^{-2}

Some equations:

$$\frac{1}{2}v^2 - \frac{\mu}{r} = -\frac{\mu}{2a}$$

$$L = \left(\frac{4\pi \cdot f}{c} d\right)^2$$

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

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

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

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

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

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

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

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

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1. Please explain (1 point each)
   a) What kind of orbit is a Molnya orbit? How it is useful?
   b) Keplers second law?
   c) What is specific impulse?
   d) What is the difference between three axis stabilization and spin stabilization?
   e) What is right ascension of ascending node?
   f) What are trapped electrons? Where are they?

2. Please answer (2 point each)
   a) Describe project phases of a satellite project (ESA).
   b) Name and describe most important types of instrument models built in most satellite projects
   c) Describe most important tests performed to these models.

3. (6 points) A rocket has following parameters: mass m_0=11000 kg, propellant mass flow rate $\dot{m}$=160 kg/s, exhaust velocity V_e=2100 m/s, burning time t_b=60 s, exhaust plane area A_e=0.25 m^2 , pressure at the nozzle exit p_e=34500 N/m^2, ambient pressure (atmosphere at sea level) p_a=101300 N/m^2. Calculate: thrust force, effective exhaust speed, thrust per initial mass ratio, vertical acceleration and mass ratio of the rocket.

4. Answer
   a) A satellite is in polar Earth orbit at altitude 680 km. The satellite is three axis stabilized so that the solar panel points to the sun always when possible and sun is on the satellite's orbital plane. The solar panel area is 2 m^2 and surface efficiency is 98%. In the shadow satellite consumes 200Wh of energy and it needs to recharge in sunlight. Calculate the maximal power which the satellite can use in sunlight in addition to battery charging when we know that solar panel efficiency is approximately 21% and battery charging efficiency is 92%. (4 points)
   b) What are RTGs and in what kind of missions are they usually used? (2 points)

5. (6 points) A nanosatellite with mass m=3 kg is dropped to circular orbit at 300 km altitude from the Space Shuttle. Inclination of the orbit is 24°. Calculate needed Δv in order to transfer the satellite to geostationary orbit.