

ENAE 483/788D

Fall, 2002

Midterm Exam

This is a take-home examination. You may use any notes or reference material you like. You may not consult other class members or work as a team on this exam! It is due in class on Tuesday, November 12. I estimate that this would be a challenging, but achievable in-class test that should take 75 minutes. You may take as long as you wish, but please time yourself as a calibration point.

1. (25 pts) You are at the International Space Station, in a 500 km altitude circular orbit at 51.2° inclination. An Ariane V has just launched a communications satellite into a GEO transfer orbit, which has a 500 km altitude perigee, an apogee radius of 42,240 km, and a 0° inclination. Some useful numbers: $\mu=398,604 \text{ km}^3/\text{sec}^2$; $r_E=6378 \text{ km}$
 - a. The satellite carries an AKM (“apogee kick motor”) to circularize its orbit at GEO (radius 42,240 km). What ΔV would be required for this maneuver?
 - b. The AKM fails, leaving the spacecraft stranded in its initial parking orbit. You decide to take your experimental spaceplane (based at ISS) on a rescue mission. What ΔV would be required to change orbits from the ISS orbit to the GEO transfer orbit, by performing a single maneuver at the point where the two orbits are in contact? (In other words, what is the ΔV to go from the initial circular orbit to perigee of the GEO transfer orbit with a 51.2° plane change?)
 - c. It turns out that someone else is using the spaceplane, so you give up on rescue and now have to deorbit the satellite to keep it from becoming orbital debris. What apogee ΔV will be required to lower the satellite’s perigee to 100 km so it will enter Earth’s atmosphere and burn up?

2. (10 pts) When Evel Knieval tried to jump the Snake River Canyon, he used a steam-powered rocket. Water was superheated to 1000°F at 500 psi, then expanded to ambient pressure (14.7 psi) to generate thrust. What specific impulse would you expect this rocket engine to have? (Assume a γ of 1.33)
3. (10 pts) A cubical microsat (15 cm on a side) is undergoing testing in a thermal vacuum chamber. Liquid nitrogen shrouds all around the vacuum chamber ensure that the spacecraft is radiating to a temperature of 100°K in all directions. Internal electronics in the microsat are generating 10W of power. **All surfaces of the spacecraft have an absorptivity α of 0.2 and an emissivity ϵ of 0.8.** What is the equilibrium temperature the spacecraft will reach?
4. (10 pts) The first flight of your new launch vehicle has just succeeded. The head of your marketing department wants to go ahead with an advertising campaign claiming a 97% reliability for the vehicle.
 - a. What confidence value would correspond to this 97% reliability claim?
 - b. Unfortunately, the second flight fails. The marketing manager graciously agrees to lower the reliability claim to 95%. What confidence value does this estimate have?
5. (20 pts) A spacecraft on the surface of Mars requires 5000 m/sec ΔV to reach low Martian orbit. It has a payload mass of 20,000 kg and an inert mass of 10,000 kg, *excluding* the propellant tanks, which have a mass equal to 5% of the propellants they contain. **It uses liquid oxygen and methane for propellants, with an I_{sp} of 330 sec.**
 - a. What is the required mass ratio for this spacecraft?
 - b. What are the propellant mass, tank mass, and total initial mass for this spacecraft?
 - c. What is the inert mass fraction δ for this spacecraft?
6. (10 pts) A spacecraft which requires a constant power of 5 kW is in a highly elliptical orbit around the moon. Due to the orientation of the orbit, it receives

- daylight for only 1 hr 15 min of its 6 hour orbital period. Batteries are used to supply power during the dark periods. Size the photovoltaic array (in kW) needed for this spacecraft, assuming perfect efficiency in battery charge/discharge cycles.
7. (10 pts) A human lunar exploration program has been developed with will cost \$1B for the first mission. Five missions will be flown over five years.
 - a. Mission costs are reduced for subsequent flights due to an 80% learning curve. What is the cost for each of the five missions?
 - b. What is the net present value of the total program cost (for all five missions), based on the year of the first mission, **using a discount rate of 10%?**
 8. (5 pts) How long did it take you to complete this exam?