AE6450 Fall 2003
Things You Should Know By Now or Find Out Right Away
Version 1: Midterm

A space launch vehicle is traveling at Mach 2, and its trajectory at the instant being considered is at an angle of 45 degrees with respect to the tangent to the surface of Earth. Its thrust vector is aligned along the vehicle axis, but the vehicle is at 8 degrees angle of attack. It has an aerodynamic lift-to-drag ratio of 8 at this angle of attack. Draw a force-balance diagram, and write down the expressions for all components of acceleration of the vehicle.

Find the delta-v corresponding to the Earth's rotation at a launch site in Tibet, within 100 miles of Lhasa. (check out the elevation there..). How is this different from the following sites:

Cape Kennedy, Courou (French Guyana), Baikonur Cosmodrome, (former Soviet Union – I believe it is now in Kazakhstan.)

What is the delta-v for escape from Mars? How do you find it from Newton's Law of Gravitation?

Calculate the delta-v needed to go from GEO to the Hohman transfer Orbit down to LEO at an altitude of 500 miles above the Earth's Equator.

* The mean molecular weight of a gas mixture is 53.75
(a) What is the gas constant for this mixture?
(b) The mixture is heated so that one of the compounds present starts dissociating. Will the gas constant increase or decrease?
(c) The ratio of specific heats for the mixture in part (a) is 1.37. What are the values of the specific heats at constant pressure and volume?
(d) Why is the specific heat at constant pressure greater than that at constant volume? (Physical reasoning, not "because R is positive"!)
* Does the specific heat of air at constant pressure increase or decrease as the temperature is decreased? Why?
* Fifty Joules of work is done on an adiabatic system. What is the change in internal energy of the system?
* What is an exothermic reaction? Give an example.
* Given that a mixture of perfect gases contains 8 possible species, and that the only elements present are oxygen, hydrogen, and nitrogen, how many independent equilibrium constants do you need to solve for the final composition? Assume that the final temperature and pressure are known. How would you do this, if the final temperature is not known?

* The stagnation pressure in a chamber is 5 atmospheres, and the stagnation temperature is 1000K. The mass flow rate through the nozzle throat is 100Kg/sec, and it is choked. Find the max. mass flow rate when the stagnation pressure is 3 atmospheres, and the stagnation temperature is 800K.
* Why are diffusion flames thin?
* Given a mixture containing 1.5 moles of oxygen, 2 moles of hydrogen, 2.1 moles of nitrogen, 1 mole of carbon dioxide, and 0.3 moles of carbon monoxide at a pressure of 2 atmospheres and a temperature of 500K, determine:
(a) the molecular weight of the mixture
(b) the total enthalpy of the mixture
(c) the enthalpy per unit mass of the mixture
(d) the enthaply per mole of the mixture
(e) the internal energy per mole of the mixture.
Assume that the enthalpy per mole at 300K is h0 and the internal energy per mole at 300K is e0.

* The rate of a certain chemical reaction can be described by the Arrhenius rate expression. It activation energy is 25Kcal/mole. If the temperature increases by 10%, what is the percentage increase in reaction rate?

* The stagnation pressure upstream of a nozzle is 3 atmospheres, and the stagnation temperature is 2000K. The exit Mach number is 1.5. The nozzle efficiency is 0.98.
Find:
(a) the exit velocity
(b) the stagnation pressure at the exit
(c) the static temperature at the exit
(d) the static pressure at the exit.

- The stagnation pressure at the exit of a turbine is 5 atmospheres, and the stagnation temperature is 1000K. The mass flow rate through the turbine is 100Kg/sec, and the last stage of the turbine is choked. Find the max. mass flow rate when the stagnation pressure is 3 atmospheres, and the stagnation temperature is 800K.
- How the angle of attack requirement for a gravity turn different from, say, that for a tangent-steering approach for the ascent to low-earth orbit of a rocket with no aerodynamic lift?
- If you operate a monopropellant cold gas thruster with no pressure regulator, how will the total impulse, and the thrust profile, differ from a case with a pressure requlator? Try a sketch based on simplified analytical expressions
- For a single-stage rocket with a propellant specific impulse of 200 seconds, what is the mass ratio to reach a burnout velocity of 500 m/s, going straight up? Neglect drag.
- What value of structure mass fraction is needed to reach circular orbit at 500km above the Earth's surface, with a single stage, and no aerodynamic lift or airbreathing propulsion? Assume specific impulse is limited to 410 seconds. The payload (excluding structure) is to be no less than 2% of initial mass.
- What is a typical value of thrust coefficient for a large first-stage rocket?
- What is a typical value of nozzle expansion ratio for a large first-stage rocket?
- What is a typical delta-v requirement to overcome air drag in the process of reaching low-earth orbit?
- Why is it not more efficient to shoot straight up to the desired orbital height in an elliptic ballistic trajectory, then do a burn to transfer to a circular orbit?
- How is a Hohman transfer different from a one-tangent burn or a spiral transfer?
- Is it more efficient to do plane-change maneuvers at launch, or at the final insertion into orbit? Why?
- Is the heat of formation of a given species at 500K necessarily greater or less than the heat of formation at 298K? Why?
- How is "heat of reaction" different from "heat of formation"?
- How do you convert data on equilibrium constant for a given reaction from a value based on mass fractions to one based on partial pressures? On mole fractions?
- Why does the Gibbs Free energy method give the same results as the method based on equilibrium constants?
- How do you do a computation using the "STANJAN" code? (i.e., try the actual process, including preparation of the data files).
- If we neglect the formation of OH in the hydrogen-oxygen combustion reaction reaching 4000K and 15 atm, starting with a fuel-lean mixture, how will that affect the accuracy of the final composition? The final Isp prediction?
- How will the shape of the h-s diagram for a given nozzle differ from the T-s diagram? (this relates to the shape of the various constant-property lines, and to the perfect gas law..)

- Heat is removed from the throat section and immediately downstream of it, by recirculating fuel. Represent this on a h-s or T-s diagram.
- Why do underexpansion or overexpansion result in lower performance? How and by how much for typical values?
- Do you believe that the above issue is completely absent in the case of an “aerospike” nozzle? Why?
- How do you design the contour an optimum Bell nozzle, give a specification of “80% Bell”
- Plot the qualitative comparison between the performance of an ideal conical vs. ideal Bell vs. isentropic spike vs. truncated conical spike vs. aerospike nozzles.
- A new missile system developed by someone is discovered to have a bell nozzle with area ratio of 15 and a specific impulse of 70 s. using cold monopropellant hydrogen peroxide. Estimate the gas generator pressure needed to run this system.