1) One of the launch providers for NASA Commercial Resupply to the International Space Station (ISS) is SpaceX. Their most recent launch was January 10, 2015 from NASA KSC (28.5241° N, 80.6508° W) to the ISS (410 km x 418 km orbit, 51.6 degree inclination). SpaceX hopes to one day re-use the first stage structure of their two-stage rocket. Both stages use liquid oxygen (LOX) and kerosene (RP-1) propellant.

   Useful constants: $\mu = GM \cong 3.986 \times 10^{14}\ m^3\ s^{-2}$, $R_{Earth} = 6371$ km, $g_0 = 9.8\ m\ s^{-2}$

   a. What is the maximum velocity of the ISS orbit?

   b. What is the contribution of the speed of rotation of the Earth at KSC for an eastward launch to the ΔV budget to achieve an ISS orbit?

   c. What factors in addition to the contributions from the two rocket stages must be considered in the ΔV budget? Provide estimates for them.

2) SpaceX uses a two stage rocket with their Merlin engines. It burns LOX/RP-1 with an average I_{sp} at sea level of 282 s and in vacuum 311 s. The first stage has main engine cut off at 80 km at Mach 10 (3.4 km/s). Then the first stage structure is ejected. The second stage has engine cut off reaching an orbit of 310 x 340 km. Let's say the Dragon (ready to be released) has a mass of 6,000 kg and the second stage has a structural mass of 3,000 kg for a total of 9,000 kg.

   a. What is the velocity at perigee for the 310 x 340 km orbit?

   b. What ΔV_1 is needed from the 1st stage?

   c. What ΔV_2 is needed from the 2nd stage?

   d. What is the ratio of the initial to final mass of the **second** stage?

   e. What is the ratio of the initial to final mass of the **first** stage?

   f. What was the initial mass of the rocket?

3) Planet Labs is a nanosatellite startup whose focus is on Earth imaging and utilization of near real-time imagery. Planet Labs are flying a fleet of 3U (10 x 10 x 30 cm) nanosatellites (called Doves). Some of the Doves have been transported to the ISS by the Dragon and deployed by NanoRacks Cubesat Deployers mounted on the ISS robotic arm.

    a. What is the diffraction-limited resolution of the Planet Labs Doves' imager at 500 nm assuming a circularly symmetric optic that must fit within their satellite? What is the answer in degrees?

    b. Assume you can fit a detector that is 5 cm × 5 cm onboard the nanosatellite. What focal length f is needed at the initial ISS orbit altitude h to take an image of an object on the ground with radius R = 10 km? Is this reasonable given the size of their nanosatellite? What about R = 100 km?

    c. What is the angular diameter of the field of view (FOV) for R = 10 km and R = 100 km? Comment on the pointing requirements given your answers.

    d. Describe 3 possible attitude control sensors and 2 possible actuators that might be available to the Planet Labs nanosatellites for use in a low-Earth orbit (deployed from ISS) that could achieve their mission.

    e. Draw a block diagram of a control system for the Planet Labs nanosatellites. Make sure to label everything.

4) Launching CubeSats from the ISS means that there will be additional safety requirements placed on the CubeSats, even though they are stored in closed deployer boxes. The additional requirements are to ensure the safety of the astronauts and the ISS facility.

   Describe (i) a real safety concern/risk for each of the following CubeSat subsystems, and (ii) how that concern can be addressed.

   a. Power
      i. Safety concerns:

      ii. Mitigation strategies:

   b. Propulsion
      i. Safety concerns:

      ii. Mitigation strategies:

   c. Communications.
      i. Safety concerns:

      ii. Mitigation strategies: