AE 5535 **Final Exam** **Assigned: 5/05/2021**
Due: 5/14/2021

Show ALL work – presentation and organization will be a factor in your grade!

Description of Parameters for Ion-Drive Rocket and Required Mission:

An ion-drive system with a specific impulse of 3500 seconds is selected for a space mission. The propellant has charge to mass ratio of 2500 Coulombs per kilogram. The device is to be designed to operate at maximum possible electrical current conditions and has a maximum allowable voltage gradient between anode and cathode of 1.0×10^5 Volts/cm. The power required to ionize the propellant stream prior to introduction into the actual ion drive is 35% of the power required in the ion drive to accelerate the propellant.

For generation of necessary power, this vehicle is to use a nuclear reactor as a heat source coupled with a simple Brayton cycle utilizing molecular nitrogen (N_2) as the working fluid. Nitrogen has a molecular weight of 28 and ratio of specific heats (γ) of 1.4. The highest temperature in the closed cycle occurs at turbine entrance and is 3000 K. Compressor and turbine efficiencies are both equal to 0.90. **This cycle is optimized for minimum radiator area.**

This vehicle is to have a payload mass of 5000 kg (note the payload mass is here defined as the actual payload and the empty rocket structural mass excluding the engine mass, i.e. the overall initial mass of the vehicle = $m_o = m_e + m_L + m_P$.) In addition, due to launch constraints, the overall initial mass of the vehicle is 80,000 kg. Neglect gravity and drag. The mission required of this vehicle is composed of three segments:

a) Acceleration leg from zero initial velocity to a final velocity of 35,000 m/s in direction of target destination.
b) 4000 day 'cold cruise' non-acceleration leg (constant velocity) at 35,000 m/s; systems shut down.
c) Deceleration leg (ΔV = 35,000 m/s) to stabilize with target destination which is at rest with respect to initial position.

The specific power, α', of the engine is 600 Watts/kilogram (very advanced), i.e. for every 600 Watts of net power needed by the accelerator (ion-drive + ionizer), one kilogram of engine mass is required. Remember that the 'engine mass' denotes the sum of all components of the engine/propulsion system for an electrical rocket!

Find (Provide answers on this page and attach neatly-organized work):

The required current in the ion-drive

The required voltage in the ion-drive

The acceleration distance (distance between the anode and cathode in the ion-drive)

The mass flow rate of propellant required for the ion-drive

The thrust provided by the ion-drive

The diameter of the (round) ion beam

The overall (total) electrical power required by the drive (including the ionizer)

The required compressor pressure ratio and the temperature of the nitrogen gas at compressor entrance (radiator exit)

The temperature of the nitrogen gas at exit of compressor and at the exit of the turbine (radiator entrance)

The overall (total) power supplied by the turbine in the Brayton cycle

The power required by the compressor in the Brayton cycle

The heat rate required from the nuclear reactor

The cycle (thermal) efficiency

The radiator area required

The mass flow rate of nitrogen gas required in the Brayton cycle

The accelerator efficiency (exhaust kinetic energy rate/total power needed by ion drive including ionizer)

The total required engine mass

The propellant mass used during the acceleration leg

The propellant mass used during the deceleration leg

The firing times for the ion-drive (acceleration and deceleration legs)

The EXACT distance traveled during this mission from beginning to end (determine and give acceleration distance, cruise distance, deceleration distance, and total distance)!