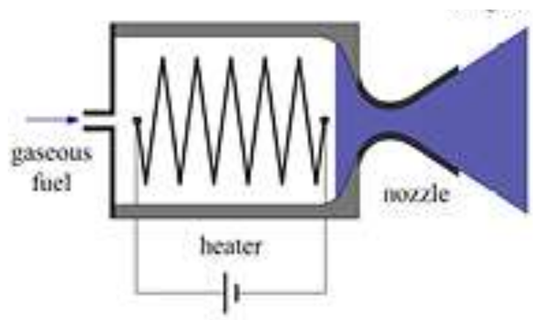
# Problem Set #5: Ideal Rocket Analysis

- Homework solutions should be neat and logically presented, see format requirements at http://seitzman.gatech.edu/classes/ae4451/homeworkformat.html.
- If appropriate, include **a sketch** of the flow/system, and indicate clearly your choice of **control surface**.
- Always indicate any **assumptions** you make. If you use any results or equations from the class notes or text in your solutions, please note and **reference** them (but you better be sure they are applicable to the problem at hand).
- Try to **solve** the problem **algebraically** first. If possible, only use numbers/values in the final steps of each solution.

## Introduction

For this problem set, you have been asked to help with the preliminary design of an electrothermal thruster to be used on a satellite operating in very low Earth orbit (VLEO). An electrothermal thruster uses electrical energy to heat the propellant, which is then expanded through a nozzle (see figure). The satellite here will operate at an altitude where the ambient pressure is 0.00450 atm. The maximum electrical power that can be supplied to the heater is 1.10 kW and the maximum operating temperature of the heating element (i.e., the heater) is 1720 K. Furthermore, your team is considering three propellant choices with the properties given in the table below. Independent of the propellant choice, the propellant storage system can supply the propellant gas (before being heated) at 278. K and 31.4 atm.



*From Mazouffre, Plasma Sources Sci&Technol 25 (2016)*

| *Propellant Gas* | $c_p$ (kJ/kgK) | *Molecular Weight* |
|---|---|---|
| A | 1.773 | 17.03 |
| B | 1.049 | 43.99 |
| C | 5.193 | 4.003 |

1. **Nozzle Design**

   Under the given conditions and constraints, what is the maximum achievable thrust coefficient and the corresponding nozzle expansion ratio (defined to be the ratio of the nozzle exit area to the nozzle throat area) **for each of the three propellant choices**?

2. **Thruster Performance and Design**

   Again using a design that achieves the maximum thrust coefficient, determine the following values **for each of the three propellant choices**:

   a) maximum specific impulse (in seconds)

   b) maximum thrust (in N) at the impulse value found in part a)

   c) nozzle throat diameter (in mm) required to achieve the maximum thrust at the maximum specific impulse