SESA2024 Astronautics

Chapter 7: Propulsion – Exercises

Use $g_0 = 9.81\,\mathrm{m/s^2}$ throughout.

1. Starting with the definition of total impulse,

$$I = \int_0^t T dt \qquad \text{(N sec)}$$

show that the specific impulse $I_{sp} = V_{ex} / g_0$ (sec). Explain why specific impulse is such an important performance indicator for propulsion systems.

2. Explain how a monopropellant hydrazine thruster works.

3. What are the two sources of thrust from a rocket motor?

4. What is meant by hypergolic fuel?

5. Give three functions of the propulsion subsystem on a spacecraft.

6. List two advantages and two disadvantages for the following propulsion systems or fuels:

- Liquid monopropellant
- Liquid bipropellant
- Solid
- Cold gas
- Ion
- Nuclear

7. Which of the systems or fuels listed in the previous question has the highest I_{sp}?

8. Which of the systems or fuels listed in Question 6 could be used to launch payloads into low-Earth orbit?

9. Why are solid rocket motors generally not used on attitude control systems? State one exception.

10. Estimate the electrical power requirement to produce a 50 mN thrust level for each of the types of electrical propulsion in Table 1. What are the system implications of operating these thrusters onboard a spacecraft?

Table 1. Characteristics of electric thrusters

Thruster type	**Specific Impulse I_{sp}** (sec)	**Efficiency η**
Resistojet	700	0.9
Arcjet	1500	0.3
Ion	5000	0.75

11. Tabulate values of $\Delta V / V_c$ for values of V_{ex} / V_c from 0.01 to 10, using equation (7.15) of notes for values of M_p / M_0 = 0.1 and 0.5. Plot these values on a linear-log scale to reproduce the diagram shown in the notes. Explain why the curves have a maximum value, leading to a requirement to optimise the electrical propulsion system for the mission considered.

12. To place a spacecraft in orbit around Pluto requires a ΔV of around 17 km/sec. To produce this magnitude of velocity change, the use of an electrical propulsion system is proposed (why is the use of a chemical propulsion system not feasible?). The spacecraft has a payload fraction of $M_p / M_0 = 0.1$, where the definition of payload is as given in chapter 7 of the notes. If the required burn-time of the engine is 2 years, the initial spacecraft mass is 3000 kg, and we assume that the engine efficiency η = 1, then use the equations in the notes to estimate the characteristics of the electrical propulsion system and the spacecraft. In particular obtain estimates of the specific impulse I_{sp}, thrust T and fuel flow rate σ of the engine (what type of electrical propulsion would be appropriate?), the specific power β and total power W of the electrical power plant (what type of power source would be appropriate?), and the mass break-down of the vehicle in terms of M_p, M_e and M_w.