Exercise Sheet 2
Thy Physics of Space

Unless specified otherwise, use the following constants throughout this document:

- Gravitational constant $G = 6.67 \times 10^{-11}\,\mathrm{m^3/(kg\,s^2)}$
- Solar mass $M_\odot = 1.988 \times 10^{30}\,\mathrm{kg}$
- Earth mass $M_\oplus = 5.9722 \times 10^{24}\,\mathrm{kg}$
- Speed of light $c = 3 \times 10^{8}\,\mathrm{m/s}$
- Solar radius $R_\odot = 6.957 \times 10^{8}\,\mathrm{m}$
- Earth radius $R_\oplus = 6.37 \times 10^{6}\,\mathrm{m}$

A4 – Propagation and Perturbation

Exercise E2.1
Name the four reasons why an Earth satellite will follow an orbit around the Earth that deviates more than the Kepler orbits observed for the planets.

A5 – Launch and Maneuvers

Exercise E2.2 *(Multiple Choice)*
Check the correct answer(s).

(a) What manoeuvre is most efficient to lower the perigee?

☐ Normal Burn ☐ Anti-Normal Burn ☐ Radial-In Burn ☐ Prograde Burn
☐ Retrograde Burn

(b) What manoeuvre is used to increase the inclination?

☐ Normal Burn ☐ Anti-Normal Burn ☐ Radial-In Burn ☐ Prograde Burn
☐ Retrograde Burn

Exercise E2.3
A geostationary satellite performs a retrograde-burn with a change of 274.6 m/s in velocity. We simplify, for us the change in velocity is immediate. Determine the following:

(a) The velocity and the altitude of the satellite at its periapsis.

(b) The eccentricity e of the resulting orbit.

(c) The Δv required to perform a circularisation burn at the periapsis.

(d) Which manoeuvre did the satellite just perform?

Exercise E2.4
A geostationary satellite was launched into an eccentric elliptical transfer orbit having an orbital plane inclination of 7° and its apogee at the geostationary height. This orbit was then circularised by an appropriate thrust manoeuvre without affecting any change to the inclination. If the velocity of the satellite in the circularised orbit is 3 km/s, determine the velocity thrust required to reach an inclination of 0°. Also sketch the relevant diagram indicating the direction of thrust to be applied.

Exercise E2.5
A certain satellite is moving in a circular orbit with an altitude of 500 km. The orbit altitude is intended to be increased to 800 km. Suggest a suitable manoeuvre to do this and calculate the required changes of velocity. Show the point/s of application of the thrust/s by sketching this scenario. Take $\mu = 39.8 \times 10^{13}\,\mathrm{N\,m^2/kg}$.

A6 – Trajectories Design

Exercise E2.6 *(Newton-Raphson Method)*
Consider the function $f\colon \mathbb{R} \to \mathbb{R}$, $f(x) = x^3 - 7x^2 + 8x - 3$. Use the Newton-Raphson method to determine x_2 for f, starting with $x_0 = 5$.

Exercise E2.7 *(To the Moon (with Astrogator))*
Explore and play around with the features of STK Astrogator. For example, follow the "Moon Mission Using B-Plane Targeting" tutorial (`https://help.agi.com/stk/#training/tx-lunar.htm`) or check out the Astrogator's guild (`https://astrogatorsguild.com/`).

B1 – Satellite Technologies

Exercise E2.8 *(Multiple Choice)*
Check the correct answer. There is only one correct answer per question.

(a) What part of the propulsion system has its optimal size determined by the ambient pressure?

☐ Combustion Chamber ☐ Throat ☐ Nozzle

(b) What part is in a cold gas thruster missing compared to other propulsion systems?

☐ Combustion Chamber ☐ Throat ☐ Nozzle

Exercise E2.9
Consider a case where a spin-stabilised satellite has to generate 22 000 W of electrical power from the solar panels. Assuming that the solar flux falling normal to the solar cells in the worst case is $1250\,\mathrm{W/m^2}$, the area of each solar cell is $4\,\mathrm{cm^2}$ and the conversion efficiency of the solar cells including the losses due to cabling etc. is 15 %.

(a) Determine the number of solar cells needed to generate the desired power.

(b) What would be the number of cells required if the sun rays fell obliquely, at an angle of incidence of 10° to the surface normal.

Exercise E2.10
The propulsion system of a certain satellite uses a propellant with a specific impulse of 250 s. Compute the ejection velocity of the propellant mass.

Exercise E2.11
A satellite has an initial mass of 2950 kg. Calculate the mass of the propellant that would be consumed to produce a thrust of 450 N for a time period of 10 s, given that the propellant used has a specific impulse parameter of 300 s.

Exercise E2.12
A satellite with a mass of 800 kg orbiting Sun at an altitude of 8 Sun radii performs a manoeuvre to decrement its velocity by 25 m/s. Given that 16 kg of propellant were used, determine its specific impulse.