MECA2830 Flight dynamics

HW1 : Space dynamics

Hand-out : Oct 23rd , 2025 Hand-in : Nov 15th , 2025

Guidelines

- Submission: Submit on the Moodle platform a written or typed report with your answers and graphics. Follow the guidelines on the platform for submission
- Code submission : Submit your source code on the Moodle platform, the code should be executable and should give the numerical/graphical answer asked.
- Use the following parameters :

Variable	Symbol	Values
gravity	g_0	9.81 m/s^2
Air density (sea level)	ρ_0	1.225 kg/m^3
Earth radius	R_e	6371 km

The Vostok spacecraft was a single crew spacecraft onboard of which Youri Gagarine made his first flight in Space in 1961. It is composed of a service module to operate in Space and the reentry capsule that should keep the cosmonaut safe during atmospheric entry (see Figure 1 and Table 1).

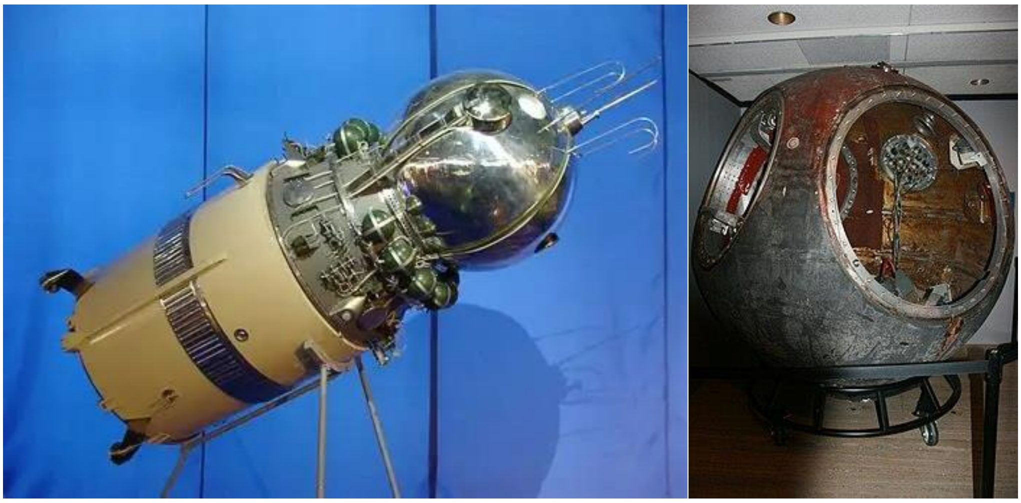

Figure 1 Vostok spacecraft (service module and re-entry module on the left, and reentry module post flight on the right)

Parameters	Values
C_D of the reentry module	2.0
Mass of the reentry module	2460 kg
Mass of the total spacecraft	4730 kg
Trust of the total spacecraft	15.83 kN
Isp of the total spacecraft	266 s
Diameter of the reentry module	2.3 m

1. Space maneuver (service + reentry modules)
    a. Draw the Hohmann transfer indicating clearly the direction of the burns to go from 200 to 300km altitude.
    b. Characterize the orbit (eccentricity, time to transfer, radius of perigee and apogee)
    c. Compute the Delta v for each maneuver.
    d. Compute the propellant mass required for the transfer.
    e. How long should Vostok wait on the 200km orbit if the transfer is a rendez-vous with another spacecraft orbiting at 300 km, 60 degrees ahead of Vostok.
    f. Compute the impulse time and comment.
2. Deorbit maneuver (service + reentry modules)
    a. Compute the propellant required to do a deorbit maneuver at 300km using a Hohmann transfer with a perigee at 10km.
    b. Compute the velocity and flight path angle of the capsule at re-entry assuming a re-entry point at 122km.
    c. Draw the deorbit maneuver on top of graph 1.a
3. Flight path entry (reentry module only)
    a. Derive from ground to 86km altitude the density of the atmosphere (your code should show the integration, use the table provided in the introduction slides). Compare with a model assuming $\rho = \rho_0 \exp{(-0.1378h)}$.
    b. Assuming a ballistic entry with the evolution of density in 3.a, and using the initial conditions from question 2.b, plot the velocity from reentry point with respect to altitude up to h=40km and the deceleration (g loads) faced by the pilot. Mention in the report values for 80, 60 and 40 km.
    c. Compute the heat flux versus altitude comment on peak heat flux and integrated heat flux.