Learning outcomes 2025-26

Contents

0 Introduction

The goal of this document is to list the key concepts of the Space Mision Design & Operations (SMDO) course. This is a concept course, that is it focusses on conceptual aspects with little formal derivations of the results. This allows to cover more topics. Therefore, the content of SMDO can feel wide ranging.

This guide should help you prepare for the exam, but also what you should remember of the course years in the future when you have left university. Of course, it does not imply that the rest is not interesting, but I do not expect the same level of understanding for the different concept categories.

1. **Key concepts:** fundamental aspects of the course. You should understand these in details and be able to describe them without hesitation. *Examples:* the three Kepler laws or the six orbital parameters.
2. **Important concepts:** you should be able to describe important concept clearly, but apply with documentation. They generally are the basis for exercises. *Examples:* Sun-synchronous orbit or Hohmann manoeuvre.
3. **Relevant concepts:** you should be able to explain them and the larger context. They can be discussed in the exam, mostly in the second discussion part. *Examples:* space weather or Lagrange points.
4. **Advanced concepts:** interesting nuggets of information or a preview of a topic not covered in the course. These will *not* be tested in the exam.

The list below is organised by week and by importance of the concept as defined above.

This guide will be distributed with each slide deck before each lecture. The complete guide in one pdf file will be uploaded to Moodle at the end of the course.

Disclaimer: This guide might not cover all concepts nor is it binding – even though I will strive to stick to it. If you spot inconsistencies or missing concepts please reach out so I can improve this list.

1 Week 01

1.1 Key concepts

N/A

1.2 Important concepts

- Newton's laws, inertial frames, energy
- Solar "constant"
- Radiation balance

1.3 Relevant concepts

- Motivations to go to space & applications
- Earth's atmosphere
- Earth's magnetic fields
- South Atlantic Anomaly
- Solar radiation (except solar "constant" → *important concepts*)
- UV radiation
- Earth's radiation budget

1.4 Advanced concepts

N/A

2 Week 02

2.1 Key concepts

- Escape velocity
- Circular velocity
- Kepler's 3 laws
- Conic sections
- Orbital period
- Classical orbital elements

2.2 Important concepts

- Gravitational well
- Gravitational field
- Coordinate systems
- Calendars & solar/sideral days
- Orbital velocity
- Energy of the orbital motion

2.3 Relevant concepts

- Gravitational acceleration profile
- Relative motion in the 2-body problem
- N-body problem
- Flight path angle
- State vector

2.4 Advanced concepts

- Precession of the Earth
- The gravitational constant G and the Cavendish experiment
- Derivation of the shape of the orbits
- Mean and eccentric anomaly

3 Week 03

3.1 Key concepts

- Typical values of v and T in LEO

3.2 Important concepts

- Link between solar activity and atmospheric density
- Definition of LEO, SSO, MEO, GTO, GEO, GSO
- Satellite ground track
- Orbit decay
- Ballistic coefficients
- Nodal regression and SSO condition
- Sun-synchronous orbit

3.3 Relevant concepts

- Sun activity cycle
- Space weather, incl. their impacts (e.g. auroras)
- Protected regions and graveyard orbit
- Effect of climate change on the atmosphere
- Perturbations by other massive bodies
- Lagrange points

3.4 Advanced concepts

- Indicators of space weather
- Molniya orbits
- Beyond GEO
- Perturbations by radiation pressure

4 Week 04

4.1 Key concepts

N/A

4.2 Important concepts

- Single impulse orbital change
- Hohmann transfer
- Hohmann transfer: case of small Δv
- Orbital plane change
- In and out of plane and radial burns
- Strategies to reach GEO (incl. combined manoeuvre)

4.3 Relevant concepts

- One-tangeant burn
- Lambert's problem
- Non-impulsive manoeuvre
- Earth viewed from space
- Apparent motion of satellite
- Orbit determination
- Two-line elements
- LEOP, station-keeping
- Δv budget

4.4 Advanced concepts

- Oberth effect

5 Week 06

5.1 Key concepts

N/A

5.2 Important concepts

- Phase angle
- Catch-up rate
- LVLH frame (general case is an advanced concept)
- Relative motion (including being able to draw them)

5.3 Relevant concepts

- Rendezvous problem
- Phasing manoeuvres
- Motivations for RPOD
- Trends in satellite population (no details needed)
- Debris problem, incl mitigations and disposal guidelines and graveyard orbit

5.4 Advanced concepts

- Derivation of the catch-up rate
- Navigation for RPO
- RPO profiles for ATV, Crew Dragon, Adras-J
- Docking
- Orbital debris flux

6 Week 08

6.1 Key concepts

N/A

6.2 Important concepts

- Astronomical unit
- Interplanetary trajectory – Strategy (i.e. patched-conic approximations)
- Convention (uppercase/lower case variables)
- Sphere of influence (derivation is an advanced concept)
- Departure from a planet (v_d, v_d^∞)
- Heliocentric velocity right after crossing the SOI
- Arrival to a planet (v_p, v_a^∞)

6.3 Relevant concepts

- The deep space environment, NEO/NEA
- Velocity on an hyperbola
- Aerobraking manoeuvres (Aero-capture, -braking, -entry)
- Phasing angles, waiting time
- Lambert problem for interplanetary flight

6.4 Advanced concepts

- Derivation of the sphere of influence
- Locus of possible departure and inclination
- Sensitivity analysis
- B-Plane
- Porkchop plots

7 Week 09

7.1 Key concepts

- Tsiolkovsky equation
- Specific Impulse I_{sp}

7.2 Important concepts

- Gravity assist
- Simple Moon trajectories
- Patched-conic approximation to go to the Moon, incl Moon phase trajectory
- Final velocity VS Mass ratio
- Mass of propellant needed (m_p, dry mass, wet mass)

7.3 Relevant concepts

- The Earth-Moon system (but not details on Earth-Moon system)
- Details of the patched-conic approximation to go to the Moon
- Free return trajectories
- Orders of magnitude of I_{sp}
- Types of propulsion systems

7.4 Advanced concepts

- Gravitational assist: computation of δ, β, how Δ v depends on δ
- Lunar libration
- Independant parameters to go & come back from the Moon
- Orbits around the Moon
- Errors made using the patched-conic approximation
- Allowable touchdown cones

8 Week 11

8.1 Key concepts

N/A

8.2 Important concepts

- ADCS description
- Thruster-based attitude control
- Reaction Wheel
- Minimum orbit inclination and launch site latitude

8.3 Relevant concepts

- Coordinate systems for ADCS
- Euler sequence
- Spacecraft attitude control methods including the different methods
- Attitude control loop
- Three axis stabilisation
- Control Moment Gyroscopes
- Electrical power system (solar panels, batteries, fuel cells, RTG)
- Ascent to space (Δv losses, case for orbit insertion
- Earth's rotation speed
- Launch site restriction and launch azimuths
- Vehicle staging
- Effect of launch on payloads
- Re-entry corridor

8.4 Advanced concepts

- Main events during re-entry
- Re-entry predictions and statistics
- Consequences on the atmosphere
- Re-entry examples

9 Week 12

9.1 Key concepts

N/A

9.2 Important concepts

- Tehthers in space (Δvs)

9.3 Relevant concepts

- Tethers in space (as generator and motor)
- Newspace vs old space
- Trends in operations
- In-orbit servicing
- Satellite constellation (incl design factors)
- Outer Space Treaty
- Agencies and operators (only the largest ones: NASA, ESA, SpaceX)
- Kessler syndrom, probability of collision
- Major mission tasks (only the most important points)
- Trends in mission operations

9.4 Advanced concepts

- Intersatellite links
- Details of the constellation design
- Space activities in the world
- Collision screenings, CDM analysis, COLA
- Mission lifetime cycle
- CHEOPS case study

10 Week 13

10.1 Key concepts

N/A

10.2 Important concepts

N/A

10.3 Relevant concepts

- Why human spaceflight
- Human rating of the Space Shuttle
- Physiological effects in different mission phases

10.4 Advanced concepts

- The first steps
- The Space Shuttle
- Claude Nicollier spaceflight experience
- ISS and the Tiangong Space Stations, and visiting vehicles
- The human body and mind in the space environment
- Manual vs. automatic control of a spacecraft
- Extravehicular activity or EVA
- Space robotics
- The “New” Human Spaceflight