Tutorial Sheet 2
Maneuvers

Hint: These exercises were created by the tutors for the tutorials. They are neither relevant nor irrelevant for the exam. The evaluation of the difficulty corresponds to the assessment of the tutors.

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

- Gravitational constant $G = 6.67 \times 10^{-11}\,\mathrm{m}^3/(\mathrm{kg\,s}^2)$
- Solar mass $M_\odot = 1.988 \times 10^{30}\,\mathrm{kg}$
- Speed of light $c = 3 \times 10^8\,\mathrm{m/s}$

Exercise T2.1 *(Prograde)*

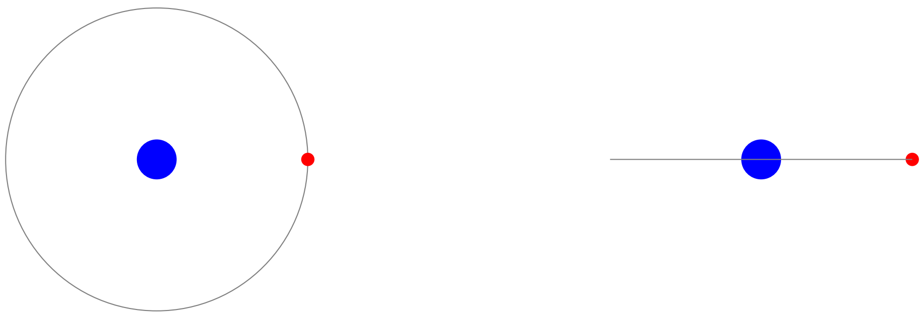

Figure 1: Satellite in a circular orbit. Left: ‘top down‘ view; Right: ‘Side’ view.

A satellite is in a circular orbit. In reference to the top-left figure, it is moving clockwise. Assume the satellite would burn **prograde** at its current position.

(a) Sketch the resulting orbit, indicate the direction in which the rocket nozzle was pointing and the direction of the Δv vector. Assume that the velocity change was instantaneous.

(b) How does this burn impact the orbital period, eccentricity and orbital energy?

Exercise T2.2 *(Retrograde)*

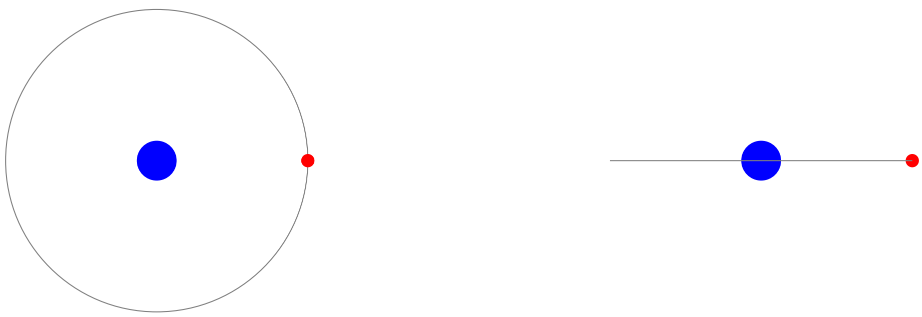

Figure 2: Satellite in a circular orbit. Left: ‘top down‘ view; Right: ‘Side’ view.

A satellite is in a circular orbit. In reference to the top-left figure, it is moving clockwise. Assume the satellite would burn **retrograde** at its current position.

(a) Sketch the resulting orbit, indicate the direction in which the rocket nozzle was pointing and the direction of the Δv vector. Assume that the velocity change was instantaneous.

(b) How does this burn impact the orbital period, eccentricity and orbital energy?

Exercise T2.3 *(Radial Out)*

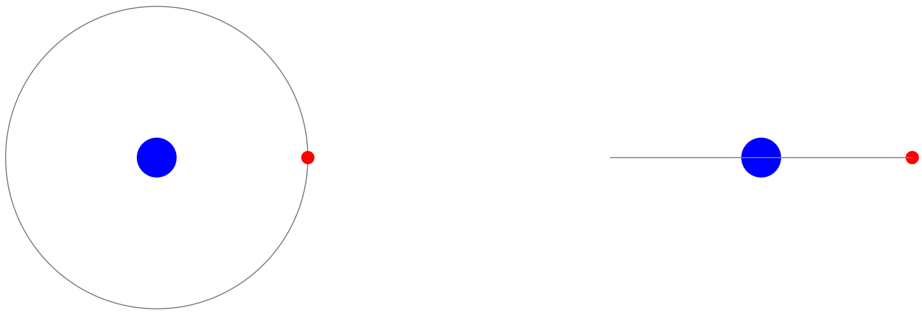

Figure 3: Satellite in a circular orbit. Left: 'top down' view; Right: 'Side' view.

A satellite is in a circular orbit. In reference to the top-left figure, it is moving clockwise. Assume the satellite would burn **radial-out** at its current position.

(a) Sketch the resulting orbit, indicate the direction in which the rocket nozzle was pointing and the direction of the Δv vector. Assume that the velocity change was instantaneous.

(b) How does this burn impact the orbital period, eccentricity and orbital energy?

Exercise T2.4 *(Normal)*

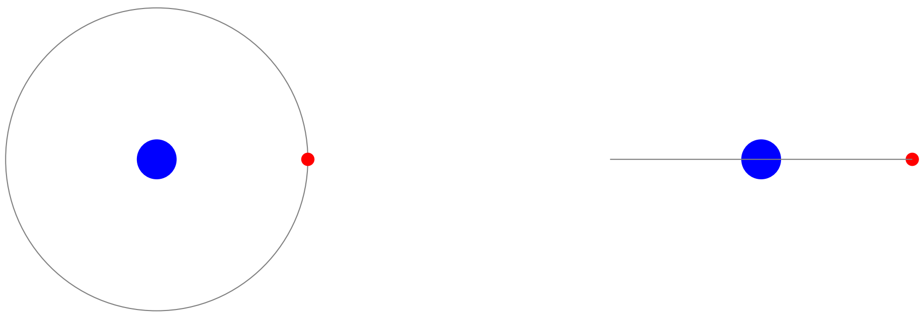

Figure 4: Satellite in a circular orbit. Left: 'top down' view; Right: 'Side' view.

A satellite is in a circular orbit. In reference to the top-left figure, it is moving clockwise. Assume the satellite would burn **normal** at its current position.

(a) Sketch the resulting orbit, indicate the direction in which the rocket nozzle was pointing and the direction of the Δv vector. Assume that the velocity change was instantaneous.

(b) How does this burn impact the orbital period, eccentricity and orbital energy?

Exercise T2.5 *(Getting Down to Earth)*
Consider the previous exercises, which of these maneuvers can be used to de-orbit the satellite? Which of them is best to minimize reentry heating?

Exercise T2.6 *(Orbit Transfer)*

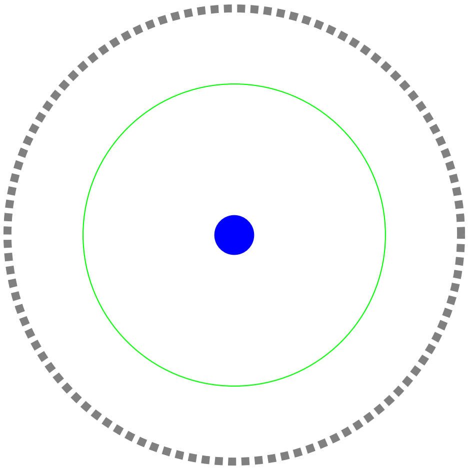

Figure 5: Starting orbit(green). Target Orbit(dotted gray).

Consider the sketch above. Assume that the satellite is moving clockwise and that the thrust changes are instantaneous.

(a) Which sequence of maneuvers could you perform to get most efficiently from your starting orbit to the target orbit? Indicate for each maneuver the direction of its Δv vector and sketch the transfer orbit(s).

(b) Can you name the sequence of maneuvers you have used?

(c) How would you derive the magnitude of Δv for each maneuver? Summarize the computation steps and formula.

Exercise T2.7 *(Orbit Transfer 2)*

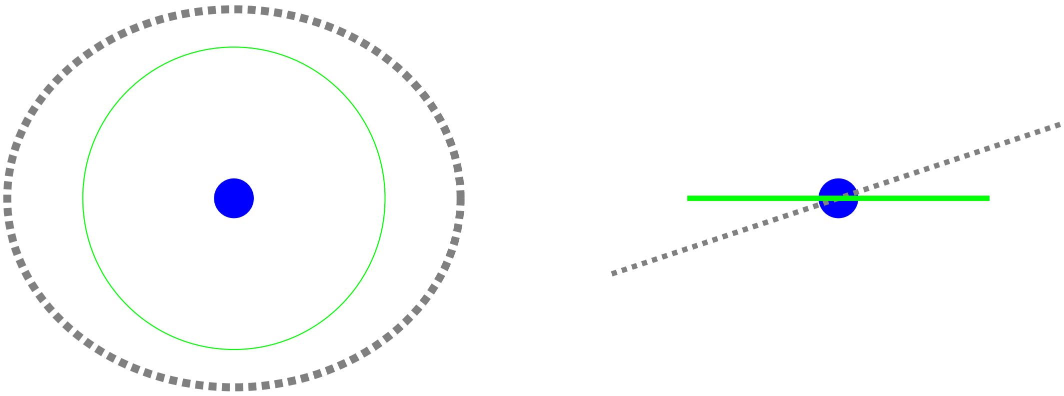

Figure 6: Starting orbit(green). Target Orbit(dotted gray). Left: Top-Down view. Right: Side view

Consider the sketch above. This exercise builds upon the previous exercise, but the target orbit is inclined by 10°. Thus, his radius remains unchanged, and it is still circular.

Assume that the satellite is moving clockwise and that the thrust changes are instantaneous.

(a) What is the most efficient sequence of maneuvers to get to the target orbit? Consider your maneuvers from the previous exercise. What maneuver(s) do you have to add or modify to get to the new target orbit? Indicate for each added maneuver the direction of its Δv vector and for each modified maneuver the added Δv vector and sketch the transfer orbit(s).

(b) For the modified or added maneuver(s): How would you derive the magnitude of the required Δv? Summarize the computation steps and formula.

Exercise T2.8 *(Propulsion Systems)*

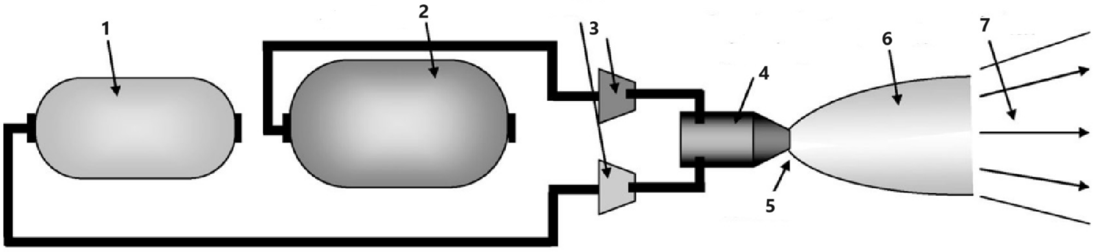

Figure 7: Propulsion schematic

(a) Name the components in the figure above and explain which role each component plays.

(b) What type of Propulsion System is this?

(c) Name and explain the advanteges and disadvanteges of this propulsion type.

Exercise T2.9 *(Schwarzschild radius)*
For a given celestial body, the Schwarzschild radius describes the orbital radius of the event horizon of a black hole of equal mass. In other words, nothing orbiting below this threshold can escape the gravitational field.

Calculate the Schwarzschild radius of the Sun.

Hint: Think about the meaning of *nothing* and *escape*.

Exercise T2.10
Let $54° : 18/3/1$ be a Walker-Delta Constellation.

(a) How many satellites does this constellation contain?

(b) How many orbital planes does this constellation contain?

(c) How many satellites does this constellation contain per plane?

(d) Which is the angle between two satellites in the same plane?

(e) What is the inclination of the orbital planes?

(f) What is the (angular) spacing between satellites in adjacent planes?