ELEC-E4210 Introduction to Space (5 cr) **Exam 15.5.2023**

Answer all four questions. All necessary information is given in the problems. ***IMPORTANT: Always justify your answers.*** *Write down all the assumptions that you make and other details of how you derive your answer.* **List of allowed materials**: Calculator, one sheet of paper (A4) with equations.

1. A satellite is on circular low Earth orbit at altitude h = 600 km from surface and makes an accelerating thruster burn towards velocity vector, with $\Delta v_1 = 60$ m s^{-1}.

a) Calculate the resulting orbit apogeum and perigeum altitudes from the ground. (2p)
b) With the next burn the satellite will be transferred to circular orbit with achieved orbit apogeum altitude. Calculate the Δv which is needed for this orbital transfer. (2p)
c) Calculate how many seconds after the first burn the second burn should be made. (2p)

Useful constants: Radius of Earth = 6370 km; $\mu = 398600$ km^3 s^{-2}

2. You are on an observing shift in Metsähovi (60° 13' 4.1'' N, 24° 23' 35.2'' E) from 9 o'clock Finnish time on September 20th to 9 o'clock Finnish time on September 21st. You come to Metsähovi in a hurry and notice that you accidentally took a source list (Table 1) that you used at another observatory earlier in the year, and now you must quickly work out if you can observe these sources during your shift in Metsähovi. Each quasar observation takes about 30 minutes and a solar map can be made in less than ten minutes. (6p)

a) Which of those four sources, if any, can you observe during your shift?

b) At the same time, your cousin is on an expedition at the North Pole. If he would have a radio telescope similar to the one you are using in Metsähovi, which of the four sources, if any, would he be able to observe?

Carefully document all the steps needed to get to your conclusion.

Table 1.

Source 1. Sun
Source 2. Quasar PKS 0459+060; RA= 05h 02min 15.44s, Dec= +06° 09' 07.49"
Source 3. Quasar B0716+714; RA= 07h 21min 53.45s, Dec= +71° 20' 36.36"
Source 4. Quasar PKS 1424–418; RA= 04h 27min 56.29s, Dec= –42° 06' 19.44"

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3. You land on exoplanet *Alpha* orbiting a red dwarf star (temperature 3 900 K, diameter 10^5 km) in a circular orbit at 0.69 AU distance. Another planet, *Beta* (diameter 10^4 km), orbits almost in the same plane (but the planets or the star do not hide others from the view in any case), 1.38 AU from the star. When the planets are as close to each other as they can get, *Beta*'s apparent magnitude is 0.61.

You want to compare *Beta*'s properties in two extreme cases: when the planets' orbits make *Beta* appear as bright as possible, and as faint as possible, when seen from *Alpha* (cases BRIGHT and FAINT). Stefan-Boltzmann constant is 5.671×10^{-8} W m^{-2} K^{-4}. (Continues on the second page)

a) Sketch the positions of the planets relative to the star and each other in the two extreme cases BRIGHT and FAINT. Mark the distances of the planets to the star (r_α and r_β), and the distances between the planets (d_{Bright} and d_{Faint}). (1 p)

b) How much radiative power *Beta* receives from the star in each case? Answer in watts. (2 p)

c) Seen from *Alpha*, how many times brighter *Beta* is when it is BRIGHT compared to FAINT? (2 p)

d) What is the apparent magnitude of *Beta* when it's FAINT? (1 p)

4. An exoplanet has been found at the distance of 10 R_{SUN} from the centre of its local sun Kepler S, where R_{SUN} is the radius of the Kepler S.

Calculate the interplanetary magnetic field vector **B** =(B_x, B_y, B_z) at points
p_B= (x, y, z) = (0, 0, 10 R_{SUN}) and
p_2= (x, y, z) = (10 R_{SUN}, 0, 0)
by using the "flux conserving" concept and by assuming that:

- the magnetic field near the surface of Kepler S is like in an ideal magnetic dipole whose axis is along the z-axis (c.f. illustrative figure below).
- the magnetic field at the point p_A= (x, y, z) = (0, 0, R_{SUN}) is (0, 0, 200 nT) and at the point p_1= (x, y, z) = (R_{SUN}, 0, 0) it is (0, 0, 100 nT).
- the solar wind flows radially outward starting from the distance of R_{SUN}.
- Kepler S is not rotating.
- the electrical resistivity in the solar wind is zero and the so called ideal Ohm's law is a valid approximation. (6p)

Justify your answer.