ELEC-E4210 Introduction to Space (5 cr) **Exam 30.1.2023**

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 at Low Earth Orbit (circular) with altitude above the surface at 800 km. The mission however, requires an elliptical orbit with 650 km apogeum and 400 km perigeum. The goal is to achieve the desired orbit with minimal amount of fuel and manoeuvers.

a) What is the most effective orbital transfer sequence to the desired orbit? (1p)
b) How many speed kicks and with what direction are needed to achieve the final orbit? (2p)
c) Calculate the deltaV budget and total deltaV for the transfer. (3p)

Useful constants: Gravitational constant: 6.674×10^{-11} N m^2 kg^{-2}; Mass of Earth: 5.972×10^{24} kg; Radius of Earth : 6371 km; $\mu = M_{Earth} \times G = 3.99\text{x}10^{14}$ m Gy

2. On June 21st from 6 to 18 o'clock you are on observing shift in Metsähovi (latitude: N 60° 13' 4.1", longitude: E 24° 23' 35.2"), and you make radio observations of AGNs and the Sun at 37 GHz. (6p)

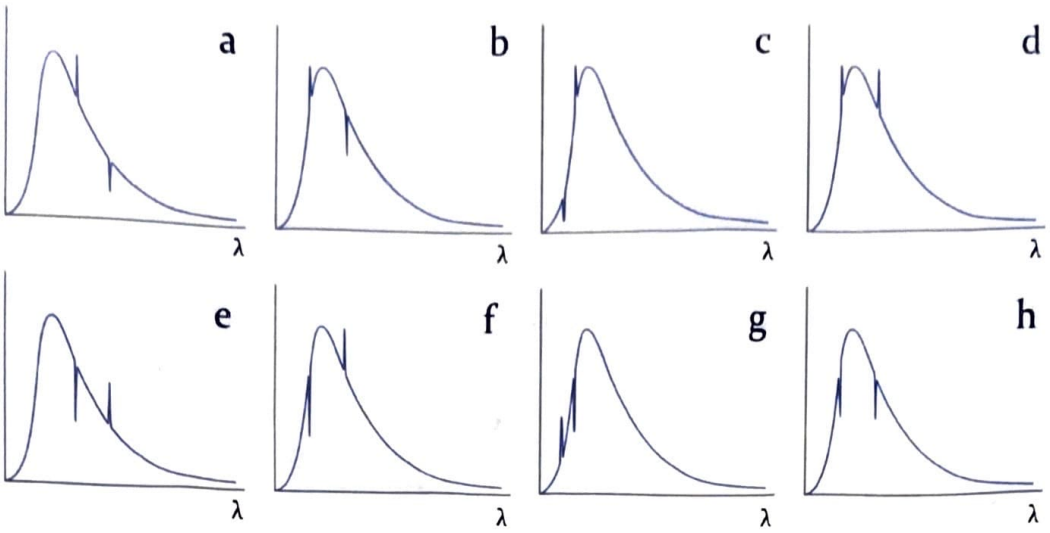
- You are asked to start observing the Sun approximately when it rises to 30°, and then to keep observing it for three hours. At what time (civil time) do you start the solar observations?
- The highest-priority quasar that you must observe on that day is 3C454.3 (J2000 coordinates: RA=22h 53min 53.748s, DEC=+16° 08' 53.56") . One observation takes about 30 minutes. Do you observe it before or after the solar observations?

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

3. When a pulsating Cepheid expands, its radius increases by 20 % while the temperature drops from 6600 K to 6270 K. In addition to the Cepheid's black-body emission, the spectrum shows strong H-alpha emission at 656 nm, and there's also an interstellar cloud between the source and the Earth, where ionised Calcium atoms absorb photons at 393 nm.

a) How much does the brightness of the Cepheid change during expansion, as seen from Earth? You can ignore the effect of the spectral lines. Answer in per-cents. (2p)
b) How much does the visual magnitude change during expansion? You can ignore the effect of the spectral lines. Answer in change in magnitude. (1p)
c) How much does the wavelength of the H-alpha emission line change during expansion? Answer in per-cents. (1p)
d) Which of the images below (top of 2nd page) could represent the observed spectrum of the source? Write the letter of the correct image and justify shortly what features tell you this is the correct one. (2p)

Wien's displacement constant is $2.898\text{x}10^{-3}$ m K.



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.