PRIFYSGOL ABERYSTWYTH UNIVERSITY

SEMESTER ONE 2025-2026

COMPUTER SCIENCE

CS36510 : SPACE ROBOTICS

Time allowed: **2 HOURS**

Answer all **THREE** questions

All questions carry equal marks.

YOU MAY BRING THE FOLLOWING INTO THE EXAMINATION:
UP TO 3 SHEETS OF NOTES ON A4 PAPER (WHICH MAY BE DOUBLE-SIDED). THERE ARE NO ADDITIONAL RESTRICTIONS ON CONTENT OR FORMATTING OF THESE NOTES.
NO ELECTRONIC DEVICES.

CALCULATORS ARE PERMITTED (CASIO FX83 OR FX85 MODELS ONLY) Addendum: or CASIO FX991

STUDENTS MAY SUBMIT ANSWERS TO THIS PAPER IN EITHER WELSH OR ENGLISH

Once seated, students may complete the front cover of the answer book(s) and the attendance slip ONLY.

DO NOT TURN THE EXAMINATION QUESTION PAPER OVER UNTIL INSTRUCTED TO DO SO.

19/11/25

1. This question is about a selection of Space Robotics topics that have been discussed during the module.

a) Wheeled rovers have long been a popular and practical choice for planetary exploration, and some aerobots have been used on missions as well. However, there are other interesting environments for which neither of these types of probe are suitable.

Describe the design of **three** mobility systems (**not** including wheeled rovers or aerobots) that are being developed for possible future missions. For each system, you need to state the environments or possible destinations they are intended to work in. Discuss the problems of (1) electrical power and (2) communications that would arise for each system, and how these might be overcome. [12 marks]

b) There have been a number of static landers and rover missions successfully landed on the planet Mars to date, using a variety of entry, descent and landing (EDL) systems. Describe and compare **three** different EDL options available for landing a mission on Mars. Which systems would be suitable for (1) a small static lander or (2) a large, heavy rover? Give reasons for your choices. [12 marks]

c) The Beagle 2 probe was expected to land on Mars in December 2003. After release from its parent craft it was never heard from again. Eleven years later it was identified on the surface in images taken from orbit. Briefly explain what is believed to have happened to Beagle 2, and why it never sent back a signal. [4 marks]

d) In 2016 the ExoMars landing system demonstrator, Schiaparelli, crashed into the surface of Mars and was destroyed. Briefly explain why the craft failed. What was the lesson learned from Beagle 2 that enabled engineers to work out exactly what had gone wrong with Schiaparelli? [5 marks]

2. This question is about planetary rover navigation

a) When considering navigation of a ground-based rover on a remote planet, one can consider multiple autonomy levels. Describe what these levels can be and discuss their advantages and disadvantages. [10 marks]

b) In order to be able to navigate, a planetary rover such as the one used for ExoMars needs to build maps of its environment. In the proposed system studied in lectures, multiple maps are created, all representing different aspects of the landscape, using 2D grids.

(i) Briefly describe **two** different types of information that are stored in the different maps. [4 marks]

(ii) What are the advantages and disadvantages of such a data structure (2D grid) to represent spatial information? Make sure you address points specific to planetary exploration. [8 marks]

c) Creating a map for navigation requires localisation.

(i) Explain what localisation is and why localisation is needed in order to be able to build a map. [4 marks]

(ii) Localisation on a planet such as Mars is difficult because there is no Global Navigation Satellite System (GNSS). The proposed ExoMars system uses *absolute localisation* and *relative localisation*. Explain what is meant by these two types of localisation and justify why the two types of localisation are needed. [7 marks]

3. This question is about the use of a tethered balloon as part of a Mars mission.

You have been asked to help with the design of a future Mars weather station, which consists of a large static lander equipped with instruments to measure atmospheric conditions and radiation levels at the surface. To complement the ground-based instruments, it is proposed that a tethered balloon be included as part of the mission. This will carry additional instruments and will be able to take readings at a maximum height of 50m above the surface. Power and data connections for the floating instruments will be provided through the tether.

The balloon will be deployed after landing using hydrogen from a compressed gas bottle and a winch mechanism, both of which remain part of the lander. The gas bottle contains sufficient hydrogen to completely inflate the balloon on Mars, plus an additional 10% to allow for any leakage during the deployment process.

Use your knowledge of the neutral buoyancy aerostatic equation and the engineering data in Table 1 to answer the following questions about the proposed mission. Make sure you show your equations and working throughout.

a) Calculate the total mass that the balloon and its deployment system will add to the mission launch mass. [18 marks]

b) Calculate the maximum possible mass of scientific instruments that the balloon could carry with the tether fully extended. [10 marks]

c) Any space mission involves risks and potential problems. Using your knowledge of weather and conditions on Mars, comment briefly on the problems they might cause for this particular mission. [5 marks]

Some useful equations:

$$\text{Volume of a sphere of radius } r = \frac{4}{3}\pi r^3$$

$$\text{Surface area of a sphere of radius } r = 4\pi r^2$$

Table 1: Mars tethered balloon engineering data

Density of hydrogen at landing site	5.33×10^{-4} kg/m^3
Density of Martian atmosphere at landing site	1.15×10^{-2} kg/m^3
Diameter of balloon	12 m
Density of balloon envelope	930 kg/m^3
Thickness of balloon envelope	8×10^{-6} m
Linear density of tether	50.6 kg/km
Mass of empty gas bottle	2.25 kg
Mass of winch mechanism	1.75 kg

END OF PAPER