UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For the following qualifications :-

B.Sc. *M.Sci.*

Astronomy 3C37: Solar System Science

COURSE CODE	:	**ASTR3C37**
UNIT VALUE	:	**0.50**
DATE	:	**16-MAY-02**
TIME	:	**14.30**
TIME ALLOWED	:	**2 hours 30 minutes**

02-C0085-3-50

TURN OVER

Answer THREE questions.

The numbers in brackets indicate the provisional allocation of marks for each sub-section of the question.

Stefan-Boltzmann constant σ	$= 5.67 \times 10^{-8}$ W m^{-2} K^{-4}
Boltzmann constant k	$= 1.38 \times 10^{-23}$ J K^{-1}
Proton mass m_p	$= 1.67 \times 10^{-27}$ kg
Permeability of free space μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
Mean Earth-Sun distance (1AU, Astronomical Unit)	$= 150 \times 10^{9}$ m
Sun's radius R_S	$= 6.96 \times 10^{8}$ m
Solar temperature	= 5800 K
Earth's radius R_E	$= 6.37 \times 10^{6}$m
Orbital radius of Venus	= 0.72 AU
Albedo of Venus	= 0.77
Radius of Jupiter R_J	$= 11.2\ R_E$
Density of water	= 1000 kg m^{-3}

1. Explain the mechanism by which the Interplanetary Magnetic Field (IMF) is "frozen-in" to the solar wind plasma. [2]

   Describe briefly, with the aid of simple diagrams, the interaction of the IMF with a planet having (a) no atmosphere and no planetary magnetic field, and (b) an atmosphere and its own planetary magnetic field. Give one example of each in the Solar System. [9]

   Explain what is meant by the "standoff distance". [2]

   Estimate the value of the "standoff distance" for Jupiter using the following information. In the vicinity of Jupiter the particle density of the solar wind is 0.4×10^{6} m^{-3} and the solar wind speed is 330km s^{-1}. Jupiter's radius is $11.2R_E$, and the magnetic field strength at its surface is 4×10^{-4}T (assume a $1/r^3$ fall off of magnetic field strength). [7]

2. Show that, by using a simple heat balance calculation, the general equation for the effective temperature T_p of a planet with albedo A, which is at a distance r_p from the Sun is given by

$$T_p^4 = \frac{(R_s^2\, T_s^4)}{k}\frac{(1-A)}{r_p^2}$$

   where T_s is the solar temperature, R_s is the solar radius, and k is a constant. [9]

   Explain what k is, by showing what value it would have in three simple cases, and give two examples of solar system bodies that have different values of k. [6]

   Calculate the effective temperature of Venus and account for why the surface temperature is much warmer than predicted by this equation. [5]

3. Define what is meant by the Roche Limit and derive an expression for the Roche Limit r_R for a rigid spherical satellite which has a density ρ_s, radius d and is orbiting a spherical primary body of density ρ_c and radius R_p. Explain all assumptions that are made. [10]

A comet has an elliptical path with eccentricity e=0.2, and its perihelion touching Jupiter's orbit. The comet speed at aphelion v_a= 22km/s. Calculate its velocity at perihelion v_p, providing it avoids Jupiter. At one perihelion passage it heads directly for Jupiter, enters its gravitational well and falls towards the planet. Using conservation of energy give the approximate final velocity of the comet before collision. Assuming that the expression for the Roche Limit is the same in this case as derived in the first part of this question, explain whether the comet is affected by the Roche Limit before impact. Why might the Roche Limit be different in this case?

[Mass of Jupiter M_J =1.9×10^{27}kg, Jupiter's orbital radius about Sun=778×10^9m, period of Jupiter's orbit = 4330days, Gravitational constant G=6.67×10^{-11}Nm^{2}kg^{-2}] [10]

4. Show that the equation for the dry adiabatic lapse rate dT/dr is given by

$$dT/dr = mg / C_p$$

State all assumptions that are made, and explain the importance of this rate in determining the stability of an atmosphere. [12]

Calculate the adiabatic lapse rate of Earth at ground level, assuming a chemical composition of 80% molecular nitrogen and 20% molecular oxygen. The actual temperature gradient up to 10km altitude is about 10K/km. What does this say about the stability of Earth's troposphere? (Specific heat capacity at constant pressure C_p = 14.6 J/mol) [3]

Account for why the temperature gradient of the stratosphere is different from the troposphere and how the stability of the stratosphere and the mechanism for heat transfer are affected. [5]

5. Draw a diagram illustrating the internal structure of the Earth and give a brief description for each layer. Explain what is meant by the Primary, Secondary and Tertiary crust and compare the Earth's crust with Venus. [15]

Trace 3 different typical paths of seismic waves, which will include at least one shear and one pressure wave. Explain the difference between shear and pressure waves and hence account for the shape of the wave paths. What evidence is there for the Earth to have a liquid core? [5]

END OF PAPER