The University Of Sheffield.

DEPARTMENT OF PHYSICS AND ASTRONOMY

Spring Semester 2006-2007

THE SOLAR SYSTEM **2 HOURS**

Answer THREE questions.

A formula sheet and table of physical constants is attached to this paper.

All questions are marked out of ten. The breakdown on the right-hand side of the paper is meant as a guide to the marks that can be obtained from each part.

1. Considering the nebular disc that condensed to form the Sun and the planets, explain how the composition of this nebula can be divided into 'earthy', 'icy' and 'gaseous' components. What are the relative masses of these components? Estimate their condensation temperatures. Explain why the compositions of Earth, Moon, Jupiter and Pluto are so different. [4]

Explain why

(a) the solar system is nearly flat;

(b) each planet is, on average, about 74 % further away from the Sun than its neighbour on the smaller orbit;

(c) there are no planets inside the orbit of Mercury or beyond the orbit of Neptune;

(d) a planet did not form in the Asteroid Belt;

(e) Jupiter is just over three times more massive than Saturn;

(f) Jupiter spins about three times faster than Earth. [6]

2. The gas in the Earth's atmosphere obeys the hydrostatic equation and the ideal gas law. Quote these, taking care to define the parameters that they contain. Then use these two equations to derive the expression $P = P_0 e^{-\frac{h}{H}}$, where P_0 is the ground level pressure, P is the pressure at a height h and H is the scale height. Define the scale height in terms of Boltzmann's constant, the absolute temperature, the mean mass of a molecule and the acceleration of gravity. [6]

Calculate the scale height of the Earth's atmosphere, justifying the values of the parameters that you have used. [1]

Given that the sea-level atmospheric density is 1.293 kg m^{-3}, calculate the mass of the Earth's atmosphere. [1]

Where has the Earth's atmosphere come from and how has its composition varied as a function of time? [2]

3. (a) Explain the crater formation process that occurs after a 10 km asteroid hits a continental landmass on Earth, paying special attention to the ways in which the kinetic energy of the incident body is utilised.

Obtain an approximate relationship between the diameter of the resultant crater and the size of the incident body. [4]

The number, N, of craters bigger than diameter D on a planetary surface is given by an equation of the form

$$\log N = a - 2.00 \log D \text{ (km)},$$

where a is a constant.

If the tenth biggest crater on the Moon is 316 km in diameter, how many craters on the Moon will be bigger than 20 km across? [2]

(b) Suggest a possible mechanism of generating a planetary magnetic field. Why do different planets have different magnetic field strengths and orientations? [4]

4. Show that the relationship between the average temperature, T, of a planetary surface and the average distance, r, between the planet and the Sun is of the form

$$T \propto \frac{1}{\sqrt{r}}.$$ [2]

Define the terms *albedo*, *emissivity*, *greenhouse effect*, *orbital eccentricity*, *spin axis orientation* and *spin period*. How do these affect the surface temperature of a planet and the way in which the temperature varies both over a planetary surface and with time? [6]

How does the surface temperature affect the ability of a solar system body (planet or satellite) to retain an atmosphere? [2]

5. (a) Compare and contrast the surface features of Mercury, Venus, Earth and Mars. [5]

(b) Compare and contrast the atmospheres of Mars, Jupiter, Neptune and Pluto. [5]

6. Describe in detail THREE of the following:

(a) the rings of Saturn;
(b) Jupiter's Red Spot;
(c) the Voyager spacecraft missions;
(d) the physical characteristics of an active comet;
(e) the asteroid belt. [3 $\frac{1}{3}$ each]

END OF QUESTION PAPER