Answer THREE Questions

The numbers in square brackets on the right hand side indicate the provisional allocation of maximum marks per sub-section of a question.

1.1. Show that the variation of pressure, p, with altitude, z, under the assumption of hydrostatic equilibrium is given by

$$p = p_0 \exp\left[-\int_{z_0}^{z} \frac{dz}{H} \right]$$

where p_0 is the pressure at the reference altitude z_0, and H is the scale height, and thereby obtain an expression for the scale height. **[10]**

Why is the thermosphere the one layer in the atmosphere where it ought to be possible to integrate this expression directly? What is it about the molecular motion in the thermosphere which complicates the situation? **[2]**

If the partial pressures of ^{14}N and ^{15}N are equal at an altitude of 200 km on Mars, calculate the ratio of the partial pressures p_{14}/p_{15} at an altitude of 400 km where the solar wind is deflected by the ionopause? [Assume that the thermospheric temperature is 200K, that the gas constant is 8314 Joules kg-mole^{-1} K^{-1}, and that the acceleration due to gravity on Mars is 3.7 m s^{-2}]. **[6]**

What is the significance of this result to our understanding of the evolution of the Martian atmosphere? **[2]**

2. What are the four main mechanisms by which planets gain the volatile materials in their atmospheres? **[8]**

Contrast the relative importance of these mechanisms in the terrestrial planets and Jupiter giving reasons for your evaluation.
[8]

There has recently been a controversial discovery of small comets striking the upper atmosphere of Earth. What questions does this raise about the current composition of the atmosphere of Earth and Mars?
[4]

3. Sketch the spectrum of the radiation from the Sun incident on the Earth and the spectrum of the radiation emitted by the Earth and comment on the relation between them. The expression

$$B_g = \frac{\phi}{2\pi}\left[\chi_0^* + 2\right]$$

relates the black body function for radiation from the ground B_g to the net upward flux of radiation ϕ and the optical depth of the surface χ_0^*. Define optical depth and explain the greenhouse effect with the help of this equation and your sketch. **[10]**

Explain how positive feedback related to water leads to different situations at Venus, Earth and Mars.
[5]

In the light of these results, and what we know of their surface structure, discuss the probable history of surface water on the three terrestrial planets. **[3]**

What effect has the presence, or absence, of surface water had on the atmospheric composition of the three planets?
[2]

4. Calculations show that the global production rate of ozone at the equinox, is 4.86×10^{31} molecules/sec. The calculated loss rate of odd oxygen due to the main Chapman loss process

$$O + O_3 \Rightarrow 2O_2$$

is only 0.89×10^{31} molecules/sec. What are the implications of this result? **[6]**

Explain the latest observations from satellites which show that, in the Antarctic spring, there is a peak in the concentration of Chlorine Monoxide, ClO, centered approximately over the Antarctic continent, which matches a depression in the total ozone content. **[10]**

Could the chlorine have originated in volcanoes or come from sea water? **[2]**

If the destruction of ozone continued at the rate shown by the satellite observations, what are likely to be the consequences for life on Earth? **[2]**

5. The equation of motion for air in an atmosphere may be expressed as follows;

$$\frac{V^2}{r} = -2\,\Omega\,V \sin\lambda - \frac{1}{\rho}\frac{\partial P}{\partial n}$$

where the coordinate n is directed normal to the wind direction, positive to the left. The other quantities are V the velocity of the flow, ρ the atmospheric density, P the pressure, Ω the angular velocity of the rotation of the planet, λ the latitude and r the radius of curvature of the atmospheric wind motion. The radius of curvature is measured towards the centre of rotation and is positive when parallel to n. Explain the physical significance of each of the terms in the equation and derive the cyclostrophic approximation. Indicate in a sketch the relation between the direction of the pressure gradient and the circulation. **[10]**

Explain how the zonal winds on Venus are part of a cyclostrophic system. **[3]**

At a point in a hurricane at a latitude of 20°N the measured wind speed is 50m s^{-1}. Assuming the circulation proceeds with a constant angular velocity about the eye what is the pressure difference between the point at which the wind speed is measured and the eye? In which direction, clockwise or anticlockwise, will the air be circulating? [Assume that R/m_r, the gas constant per unit mass, is 287 J kg^{-1} K^{-1}, the temperature is 300K and that the pressure where the speed is measured is 100kPa] **[7]**