Candidates are admitted to the examination room ten minutes before the start of the examination. On admission to the examination room, you are permitted to acquaint yourself with the instructions below and to read the question paper.

Do not write anything until the invigilator informs you that you may start the examination. You will be given five minutes at the end of the examination to complete the front of any answer books used.

April 2011

Answer Book
General Data Sheet
Any bilingual English language dictionary permitted
Only Casio-fx83 calculators are permitted

THE UNIVERSITY OF READING

MSc Examination for Courses in Sciences

Climate Change

MTMG16

2 hours

Answer **ANY TWO** questions

The marks for the individual components of each question are given in [ ] brackets. The total mark for the paper is 100.

1.

(a) Sketch a simple energy balance model that contains a surface with no heat capacity of temperature T_s and 1 atmospheric level of temperature T_a. Assume $(S/4)(1-\alpha)$ of absorbed solar radiation at the surface. Longwave radiation is emitted by the surface at the rate σT_s^4, a fraction ε_a of this emission being absorbed by the atmosphere. The atmosphere emits $\varepsilon_a \sigma T_a^4$ both upward and downward. What do α, $S/4$ and ε represent?

[12 marks]

(b) Solve the energy balance at the surface and in the atmosphere and determine an expression for surface temperature that relates to S, α and ε_a.

[4 marks]

(c) Using the following values, $\alpha=0.3$, $S=1364$ Wm^{-2}, $\sigma=5.67\times10^{-8}$ Wm^{-2} K^{-4} and $\varepsilon_a=0.85$, calculate T_s. How does this compare to current planetary temperature? How could the model parameters be altered to produce a more realistic present day global mean temperature?

[6 marks]

(d) A simple equation for transient climate change is:
$C_s d\Delta T(t)/dt = \Delta F(t) - Y\ \Delta T(t)$,
where $\Delta F(t)$ is the radiative forcing, $\Delta T(t)$ is the global average surface temperature difference from equilibrium (both as a function of time, t) and Y is the climate feedback parameter. Assume at t=0 a volcanic eruption introduces a radiative forcing $\Delta F(t=0)=-1.9$ Wm^{-2} and that $\Delta T(t=0)=0$ K. Solve this equation using a forward finite difference technique that may be used in a spreadsheet, where the year 1 temperature $\Delta T(t=1)$ depends upon the previous years temperature, $\Delta T(t=0)$, and radiative forcing, $\Delta F(t)=\Delta F(t=0)$. Assume that $Y=2$ $Wm^{-2}K^{-1}$ and $C_s=4.2\times10^8$ $JK^{-1}m^{-2}$. Find the solution after 1 year (t=1) using a time step of 1 year.

[8 marks]

(e) Calculate the subsequent year $\Delta T(t=2)$ assuming that the radiative forcing remains constant.

[4 marks]

Question 1 continues overleaf

Question 1 continued

(f) A simple expression for the time (t) dependent global-mean surface temperature change due to a time dependent radiative forcing is given by:

$$\Delta T(t) = e^{-Yt/C_s} \int_0^t \frac{\Delta F(t)}{C_s} e^{Yt'/C_s}\, dt'$$

where $\Delta T(t)$ is the global-mean temperature change, $\Delta F(t)$ is the radiative forcing, C_s the effective heat capacity of the climate system and Y the climate feedback parameter. Assuming a constant ΔF as above, integrate this expression and calculate the ΔT at t=1 year and t=2 years. What are the relative merits of using the finite difference and analytical techniques?

[12 marks]

(g) Briefly explain which method is the most similar to that used in a climate model and why.

[4 marks]

2.

(a) The top of atmosphere energy imbalance has recently been estimated to be around 0.9 Wm^{-2}. If two thirds of this energy flux is absorbed by the upper 700m of the ocean, what is the rate of warming per decade? (Assume a volumetric heat capacity of $4.1x10^{6}$ J m^{-3} K^{-1}.) [4 marks]

(b) How much will sea level rise (to nearest mm/decade) due to thermal expansion of this ocean layer (mm/decade), given a volumetric thermal expansivity $0.2x10^{-3}$ K^{-1}? [2 marks]

(c) The actual rate of sea level rise is closer to 25-30 mm/decade. Explain why this may differ from the calculation.

[6 marks]

(d) Why was global average sea level at the last glacial maximum about 120 m lower than at present?

[4 marks]

(e) Around 13000 years ago, warming from the last glacial period was interrupted and the region surrounding the north Atlantic cooled markedly. A mechanism for this cooling is thought to involve ocean circulation. Briefly describe the mechanism and what evidence this is based upon.

[6 marks]

(f) How is the North Atlantic overturning ocean circulation expected to change in the future? Explain why and what the implications are for climate change. [8 marks]

(g) Dangerous climate change may involve the possibility of triggering rapid or irreversible climate change. Choose two examples of this type of dangerous climate change event and discuss the controlling mechanisms and the likely impact of the event. [8 marks]

(h) Several geo engineering solutions have been suggested which might reduce the magnitude of future climate change and its impacts. Describe briefly two such methods and highlight their advantages and disadvantages. [12 marks]

3.

You are an advisor to the new Science Minister. There have been a number of articles in the press arguing that the climate has changed in the past and so current warming is nothing to be alarmed about. The Science Minister needs to be briefed on the causes of climate change in the past, present and future. She has a scientific background. Write an essay that covers the key topics below.

a) The climate has always been changing. Explain why there have been glacial cycles over the past few million years.

[10 marks]

b) We cannot predict the year to year climate variability. Explain to the minister what are the causes and characteristics of internal climate variability.

[10 marks]

c) Explain what mechanisms have caused externally forced climate change over the course of the 20th century, highlighting key uncertainties.

[10 marks]

d) Explain what are the uncertainties involved in projections of dangerous climate change in the 21st century.

[10 marks]

10 marks will be allocated to the logical structure and clarity of the presentation.

(End of Question Paper)