PH-3021

UMIST

PHYSICS DEPARTMENT

UNIVERSITY OF MANCHESTER INSTITUTE OF SCIENCE AND TECHNOLOGY

BSc/MPhys Physics

Course Code(s): PH-3021

Course Title(s): Climate and Energy

Date of Exam: Wednesday 26th May 2004 Time: 09.30 - 11.00
Duration of Exam: One and a half hours

Please Read Instructions Carefully

ANSWER TWO QUESTIONS

This paper contains FOUR pages (including front cover)

Department of Mathematics Formula Books may be used

Q1.

a.) What are the blackbody temperatures of the Sun and the Earth, and at which wavelengths do their maximum emissions occur?

[4 marks]

b) Define what is meant by the global planetary albedo. What is its magnitude? Show that the effective blackbody temperature of the Earth-Atmosphere system, T_e, is

$T_e = \left[\frac{(1-A)S}{4\sigma}\right]^{1/4}$. Provide a value for T_e. A is the albedo of the Earth-Atmosphere system, S is the solar constant (1370 W m^{-2}) and σ is the Stefan-Boltzmann constant (5.67 x 10^{-8} J K^{-4} m^{-2} s^{-1}).

[5 marks]

c) Compare your value of T_e with that of the surface of the Earth, what are the main reasons why this difference occurs? Explain qualitatively what processes are occurring and what components in the atmosphere cause it.

[7 marks]

d) In addition to radiative loss, what are the other major loss processes of heat from the Earth's surface? Compare their magnitudes as a fraction of the longwave radiative losses.

[3 marks]

e) The measured effective surface temperatures (T_m) of the Earth and Venus are 250 K and 230 K respectively, while the measured surface temperatures are 280 K and 750 K. calculate the optical thickness of the atmospheres of the Earth and Venus?

Recall that $B(\chi_0) = \frac{F}{2\pi}(\chi_0 + 1)$, and $B(T_S) = B(\chi_0) + \frac{F_s}{2\pi}$, where $B(T_S)$ and $B(\chi_0)$ are the blackbody emission fluxes at the surface (temperature T_s) and in the lowest layer of the atmosphere (with an optical depth χ_0); F is the difference between the upward and downward longwave fluxes and F_s is the incoming shortwave flux.

[6 marks]

Q2.

Describe what is meant by the El Nino Southern Oscillation (ENSO), its main features precipitation patterns, and effects on the Walker circulation and on the wider scale mean weather patterns.

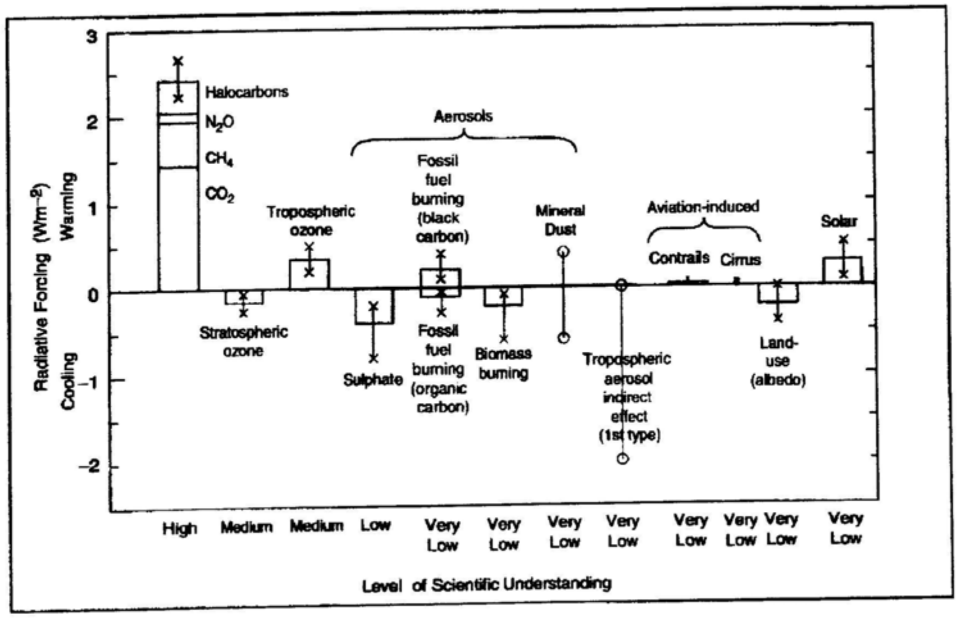
[25 marks]

Q3.

a) Explain what is meant by the *Radiative Forcing* of a parameter in a climate model and why it is used.

[3 marks]

b) Discuss the following plot from the 2001 3rd Assessment Report of the Intergovernmental Panel on Climate Change.



[12 marks]

c) Give some examples of known aerosol-cloud radiation interactions that are also known to affect climate but that are not included in the assessment diagram shown in part (b).

[5 marks]

d) A shallow marine strato-cumulus cloud has a droplet concentration of 10 droplets cm^{-3}. A pollution source raises the number of activated particles to 80 droplets cm^{-3}. Assuming that the microphysics of the cloud remains unchanged and the clouds do not absorb radiation, calculate the fractional increase in the optical depth caused by the pollution source. The optical depth, τ can be approximated by $\tau = 2\pi h r^2 N$, where r is the droplet radius N is the cloud droplet number, and h is the cloud depth.

[5 marks]

Q4.

a) What is meant by "top down" and "bottom up" estimates for alternative energy availability?

[2 marks]

b) The Earth's atmosphere absorbs 19% of the 5.5×10^{24} J of solar radiation incident at the top of the Earth's atmosphere each year, if the Earth's albedo is 0.3, what is the average shortwave energy absorbed by the Earth's surface each year? In addition to the short wave absorption at the surface, the atmosphere re-radiates 5.28×10^{24} J/year of long wave radiation to Earth. In comparison the surface of the Earth loses 1.17 times as much energy via long wave cooling than is incident as solar radiation at the top of the atmosphere. If the global average annual energy loss resulting from dry convection is 3.85×10^{23} J, calculate the annual global latent heat flux.

[5 marks]

c) Using your answer to part (b) and by assessing the energies involved in transferring a unit mass of energy around the hydrological cycle, estimate the global annual energy available for hydroelectric power generation. (latent heat of evaporation 2260 kJ/kg, 6% of global surface area is upland and 18 % is lowland, which are on average 2 km and 500 m above sea level respectively).

[6 marks]

d) Provide an estimate for the average power per unit length of waves delivered to a coastline. Assume a group velocity, $c = \frac{1}{2}\sqrt{\frac{g\lambda}{2\pi}}$, (where λ is the wavelength) and use an expression for the average potential energy of a water wave per unit area of ocean. (density of sea water ~ 1025 kg m^{-3})

[5 marks]

e) Estimate the power input to the North Atlantic Ocean using your result obtained above. What assumptions did you have to make? (assume some simple geometry for the North Atlantic Ocean).

[3 marks]

f) Make an estimate of the total worldwide annual wave energy input to Earth (radius of Earth ~ 6360 km). In the light of your estimate what role can wave power play in the future of world energy?

[4 marks]