P607 Climate and Energy Examination Questions 2002

Question 1

a) What is meant by the global mean planetary albedo and give an estimate of its magnitude for the Earth?

(2 marks)

b) Calculate the equilibrium temperature of the surface of the Earth assuming that the atmosphere is transparent to both incoming shortwave and outgoing longwave radiation. The solar flux at the top of the Earth's atmosphere is 1370 W m^{-2}. (The Stefan-Boltzmann constant is 5.67×10^{-8} W m^{-2} K^{-4}).

(4 marks)

c) Describe the transfer of short and long wave radiation through the atmosphere as a function of altitude and explain how this transfer can account for both the stratospheric temperature profile and the increase in the temperature of the lower atmosphere above that calculated in part (b).

(19 marks)

Question 2

a) Sketch the average short and long wave radiation budgets at the surface of the Earth as a function of latitude. What implications does your sketch have for the heat budget of the Earth-Atmosphere system and how is the energy transferred?

(7 marks)

b) Describe and explain the main features of the thermohaline circulation in the oceans.

(12 marks)

c) How may the thermohaline circulation be modified by climate change?

(6 marks)

Question 3

a) Suppose a tidal barrier across the mouth of the estuary of the river Humber is planned as an 'alternative' energy supply for the city of Hull. The tidal range is around 10 m and the tidal estuary is approximately 1 km wide and 40 km long, estimate the power and the annual energy delivered by such a system.
(density of sea water = 1025 kg m^{-3}, length of lunar day=24 hours 48.8 minutes)

(8 marks)

b) Another plan is to supply the same city with electricity delivered from wind powered generators mounted 20 m above the ground and sited offshore, where the average wind speed is typically 10 m/s. Estimate the area of the North Sea that is required for this scheme to provide the same amount of electricity as the tidal barrier scheme. Density of air = 1.3 kg/m^3. Use $\langle u^3 \rangle = 2\langle u \rangle^3$ and a separation distance between the generators of 10 times the rotor diameter.

(8 marks)

c) Estimate the contribution of such systems to the energy supply of Hull, which has a population of around 220000 people? Comment on the extent to which tidal and wind power generation can meet the total UK energy demand. Use a figure of 5 kW as a typical value of the total power consumed per person in the UK.

(4 marks)

d) Why is some form of energy storage generally required for wind farm schemes? Estimate the surface area of a reservoir that would be capable of acting as a hydroelectric power source if it were sited at a height of 300 m in a 60 m deep valley and were to be designed to deliver 110 MW continuously for two weeks. (density of water = 10^3 kg m^{-3})

(5 marks)

Question 4

a) It is estimated that the world population will reach a steady value of approximately 10 billion people by 2080. A corresponding steady state power consumption of 5 x 10^{21} J $year^{-1}$ (5 Q $year^{-1}$) can be calculated by this time by extrapolating the current energy burden. Briefly outline the energy resources at our disposal by 2080 and comment on their likely contribution to the projected demand.

(10 marks)

b) Discuss the impact that these changing resources have on the way energy is delivered to the point of use and the effect utilising different resources has on our total energy requirement.

(8 marks)

c) Estimate the extra increase in world energy demand in 2080 above the 5 Q/year quoted in (a) if in the future all energy is delivered with an efficiency of 40% with the exception of transport which is 16% efficient. Use the following data from the US economy: In 1970 the household and commercial sectors required 12.9 mQ and the industrial sector required 18.4 mQ of energy in the form of fuel burnt at the point of use. The transport sector required 16.3 mQ of energy in the form of fuel and 17 mQ of energy was generated for electrical energy use. Use efficiencies of 75% for fuel burnt at the point of use, 40% for electricity generation and 25% for gasoline engines. Comment on your answer given the annual input of solar energy to the Earth is 3000 Q.

(7 marks)