Human Uses of Energy

Examination Questions 2000

Examiner: Hugh Coe

1

a) One method of harnessing incoming solar radiation is to use it to warm a fluid and so drive a conventional heat engine. Describe the main design features of such a system that maximise the temperature of the fluid.

(7 marks)

b) Derive an expression that relates T, the temperature of the heated fluid to the temperature of the Sun, T_0 in terms of the radius of the Sun, R_0, the radius of the earth's orbit around the Sun, R, the absorptivity a and the emissivity e of the collector, X the optical concentration of radiation at the collector and the efficiency, γ_s. γ_s is defined as the ratio of the power collected by the working fluid to the incident power on the collector surface.

(6 marks)

c) A long parabolic reflector of width 0.75 m concentrates sunlight onto a pipe of diameter 2 cm. The heated fluid in the pipe is used to drive a heat engine and generate electricity. Estimate the overall efficiency of the installation assuming that the temperature of the Sun is 6000 K, the radius of the Sun is 7×10^5 km and the radius of the Earth's orbit around the Sun is 1.5×10^8 km. Make reasonable estimates of other necessary information.

(6 marks)

d) A solar collector of the type described above is to be used as a power generation system for a city of 1 million people. If the average solar flux onto the city is 150 W m^{-2}, estimate the size of the installation required? Comment on your result and highlight any other infrastructure that may be required by this facility.

(6 marks)

2.

a) In what sense can the energy in water waves be thought of as integrating wind power over the ocean?

(2 marks)

b) Provide a "top-down" estimate of the world's potential wave power resource.

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

(5 marks)

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

(3 marks)

d) 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

(3 marks)

e) The energy demand of a small town is 125 MW and is to be supplied by a wind farm sited on top of a range of nearby hills, 500 m above the town. The average wind speed on top of the hills is around 10 m s^{-1}. The wind turbines have a radius of 10 m and the density of air = 1.3 kg m^{-3}. Estimate the area taken up by the wind farm?

(8 marks)

f) Why is some form of energy storage required for the wind farm scheme? This energy storage is to be met by pumping water to high level reservoir in the hills above the town and generating electricity from hydroelectric turbines. Estimate the surface area of the reservoir if it is to fill a 60 m deep V shaped valley and store 2 weeks of energy supply to the town. (density of water = 10^3 kg m^{-3})

(4 marks)