SEMESTER 2 EXAMINATION 2013-2014

ENERGIES IN THE ENVIRONMENT

Duration: 120 MINS (2 hours)

This paper contains 8 questions.

Answer **all** questions in **Section A** and **only two** questions in **Section B**.

Section A carries 1/3 of the total marks for the exam paper and you should aim to spend about 40 mins on it.

Section B carries 2/3 of the total marks for the exam paper and you should aim to spend about 80 mins on it.

An outline marking scheme is shown in brackets to the right of each question.

A Sheet of Physical Constants is provided with this examination paper.

Only university approved calculators may be used.

A foreign language translation dictionary (paper version) is permitted provided it contains no notes, additions or annotations.

Section A

A1. A car with an efficiency of 12.5 km/l is driven 50 km per day. Estimate the mass of CO_2 the car emits in a year and show your working. [6]

A2. Give the definition of the term "doubling time". Assuming a constant CO_2 growth rate of 0.5%, what is the CO_2 doubling time? By how much will the CO_2 concentration increase in 100 years, compared to the preindustrial level? [4]

A3. A common argument against the proposed effect of anthropogenic CO_2 emission on Earth's climate states that "other CO_2 flows in and out of the atmosphere are much larger than the additional flow produced by humans, and thus should not have an effect". In no more than 2-3 sentences, argue why this statement is invalid. [4]

A4. List, in no more than one to two sentences each, the physical sources of geothermal energy. [3]

A5. List three types of power production using water, and give an example for each type. [3]

Section B

B1. (a) Name and briefly explain, in no more than one sentence each, the two mechanisms through which buildings lose heat. [4]

(b) Consider a building with 9 m^2 floor and 9 m^2 flat roof, the walls are 2 m high, and include a 2 m^2 door and in total 4 m^2 of windows. The thermal transmittance, or U-values, of the parts are as follows: $U_{floor} = U_{wall} = 0.4$, $U_{window} = U_{ceiling} = 0.2$, and $U_{door} = 0.3$ W m^{-2} K^{-1}. The air outside the building is around 10°C on average, and the building should always be heated to 20°C. You may further assume two air exchanges per hour, and a volumetric heat capacity of air of 1.2 kJ m^{-3} K^{-1}. How much heat does the building lose in total? [5]

(c) In one to two sentences, describe/suggest how heatloss from a specific building with fixed wall/floor/roof areas can be reduced. [3]

(d) For the building discussed in section a) and b), derive the power consumption that is needed to heat the building, assuming an electric space heater with an efficiency of 50% is used. [2]

(e) Give the definition of the efficiency of a heat engine and a heat pump and briefly, in just one to two sentences each, explain their basic mechanism/working/principle, and state typical values for the efficiencies. [6]

TURN OVER

B2. (a) (i) The solar constant $S_\odot$ is defined as the solar power per unit area received at the top of the atmosphere when the Sun is directly overhead. What is the relationship between $S_\odot$ and the total radiative power produced by the Sun, $P_\odot$?

(ii) Show that the average solar power per unit area that reaches Earth's surface is $\frac{S_\odot(1-A)}{4}$ where A denotes the albedo. [4]

(b) Draw a simple sketch of Earth's surface and atmosphere on which a simple climate model can be based. Allow for direct reflection of sunlight, and include a single atmospheric layer. Label all layers in your sketch as well as all incoming and outgoing fluxes. [5]

(c) Based on your sketch in question (b), write down the equilibrium equations for all layers in your model [3]
and show that the surface temperature can be expressed as [3]

$$T_S = \sqrt[4]{\frac{(1-A)S_\odot}{4\sigma(1-\epsilon/2)}}$$

where A denotes the albedo, ϵ the atmospheric emissivity, and σ the Stefan-Boltzman constant. [6]

(d) Assuming the Stefan-Boltzman constant as $\sigma = 5.7 \times 10^{-8}$ W m^{-2} K^{-4}, an albedo of 30%, a solar constant of $S_\odot = 1360$ W/m^2, and an atmospheric emissivity of $\epsilon = 0.8$ for our simple climate model, work out Earth's surface temperature in $^\circ$ Celsius. What would the surface temperature be if Earth did not have an atmosphere, and if Earth had no atmosphere and no albedo? [3]

(e) Venus, another planet in our solar system, and often called a twin to Earth as both planets are of similar size, however does differ greatly in it's surface temperature of $T_S \approx 460^\circ$C. Venus' albedo is ≈70% and thus considerably larger than Earth's. Can you think of any reasons why Venus temperature is so high, despite it's larger albedo? (Hint: the total solar power is $P_\odot = 4 \times 10^{26}$ W, and the distance Venus - Sun is $R_{S-V} \approx 1.1 \times 10^{11}$ m.) [2]

B3. (a) Show that the power that can be generated by a windmill with diameter d and efficiency ϵ is described by

$$P = \frac{\pi \epsilon d^2 \rho v^3}{8}$$

where v is the wind velocity, and ρ the air density.

[6]

(b) Based on the previous expression for the power that can be generated by a windmill, show that the power per unit land area of a wind park is given by

$$p_{windpark} = \frac{\epsilon \pi \rho v^3}{200}$$

Which rule of thumb is used to derive this expression?

[4]

(c) Assume a wind speed of 6 m/s, air density of 1.3 kg/m^3, and an efficiency of 50%, and 60 million people living in the UK. We further assume that the total area that can be covered by windmills is 24,000 km^2. Work out the total power that can be generated by wind parks in kWh/d/p (kWh per day per person). [3]

(d) List the main advantages and disadvantages of onshore and offshore wind parks, compared to each other. [4]

(e) According to official estimates, about 150 kWh/d/p of offshore wind power is available, however, only a small fraction of ≈ 5 kWh/d/p can be realised. In just 5-10 words each, give three reasons to explain this difference (or rephrased: give three reasons that restrict the available area and hence the exploitable offshore wind power). [3]

END OF PAPER