SEMESTER 2 EXAMINATION 2012-2013

INTRODUCTION TO ENERGY IN THE ENVIRONMENT

Duration: 120 MINS (2 hours)

This paper contains 9 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.

Copyright 2013 © University of Southampton

Section A

A1. Give three reasons why it is important to think about moving away from power production using fossil fuels and towards other sources like sustainable energies. [3]

A2. Define the term "doubling time" and give the relation between doubling time, time constant and growth rate. [3]

A3. The current annual growth rate of the world population is 1.1 %. In how many years will the world population have doubled? By how much will the world population have been increased in 200 years if the growth rate stays constant throughout that time? [3]

A4. List three modes of solar energy production. [3]

A5. The "Shockleigh-Queisser limit" is an important limit in solar/photovoltaic power production. Briefly explain (in 3 to 5 sentences, or around 100 words) how photovoltaic cells work and why the "Shockleigh-Queisser" limit is important. [4]

A6. Briefly explain (in around 100 words) the two types of nuclear reaction that (in theory) can be used to generate power and give examples of reactor types. Where does the energy that is produced come from? [4]

Copyright 2013 © University of Southampton

Section B

B1. (a) Draw a simple sketch of Earth's surface and atmosphere. Label incoming and outgoing fluxes. Allow for direct reflection of sunlight, and include a single atmospheric layer. Label the different layers in your sketch. [5]

(b) Based on your figure, show that Earth's surface temperature depends on

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

Explain which physical key concept is used in order to derive this formula. [5]

(c) Measurements of air trapped in ice-core samples give a good record of historic CO_2 concentrations in the atmosphere. In the past ≈ 200 years, CO_2 concentrations have been rising steeply. In no more than four sentences, give an explanation for this observation. Your reasoning should not only include where the additional CO_2 is coming from, but also list two effects that can be used to prove this. [6]

(d) The surface temperature change due to an additional radiative forcing ΔF can be described as

$$\Delta T_S = \lambda \Delta F$$

where $\lambda = (4\sigma {T_S}^3(1 - \frac{\epsilon}{2}))^{-1}$ is the climate sensitivity. The radiative forcing equivalent to CO_2 doubling is 3.6 W m^{-2}. Calculate the temperature change for CO_2 doubling based on our simple climate toy model, assuming an average surface temperature of $T_S = 15^\circ$ Celsius, an atmospheric emissivity/absorptivity of $\epsilon = 0.77$, and the Stefan-Boltzmann constant as $\sigma = 5.67 \times 10^{-8}$ W/(m^2 K^4). Explain why your answer does not agree with suggested temperature changes. [4]

TURN OVER

Copyright 2013 © University of Southampton

B2. (a) A moving car consumes power to maintain its motion. The power consumption of a car can be described as

$$P = \frac{1}{\epsilon}\left(\frac{m_{car}\, v^3}{2d} + \frac{c_d\, \rho_{air}\, A_{car}\, v^3}{2} + C_{rr}\, m_{car}\, g\, v\right)$$

Describe the various sources of energy loss. (In other words: where does this energy go to?) [2]

(b) Consider a car with the following parameters: $m_{car} = 1000$ kg the mass of the car, v the car's speed, $c_d = 0.35$ the drag coefficient, $A_{car} = 3$ m^2 is the cross section of the car, and $C_{rr} = 0.01$ the coefficient of rolling resistance. Furthermore, you may assume $\rho_{air} = 1.3$ kg m^{-3} as the density of air, $g = 9.8$ m s^{-2} as the gravitational acceleration on Earth.

With the parameters given above, under which conditions does air resistance dominate the power consumption of the car? What kind of driving does this correspond to? [7]

(c) The total power consumption of a plane can be described as

$$P = \frac{1}{\epsilon}\left(\frac{(m_{plane}\, g)^2}{2\,\rho_{air}\, A_{air}\, v} + \frac{\rho_{air}\, A_{plane}\, c_d\, v^3}{2}\right)$$

Explain what each part of the power equation describes. Give a definition of the plane-based energy cost and, with the aid of a suitable graph, explain why the energy cost is lowest at an optimised speed. [7]

(d) For a jet with a wingspan of $w = 70$ m, a mass of 4×10^5 kg, a drag coefficient of $c_d = 0.03$, an engine efficiency of $\epsilon = 0.3$ and a filling factor $f_A = \frac{A_{plane}}{A_{air}} = 0.03$, work out the optimum speed that implies the lowest power consumption. [4]

Copyright 2013 © University of Southampton

B3. (a) List the three main types of hydroelectric power production devices. In one or two sentences, explain the basic physical principle behind all of these power generators. [3]

(b) In one or two sentences, explain how waves are created. Assuming a wave power of 40 kW/m of Atlantic ocean waves per unit coastline, and a coastline of 5000 km in southern England and 30 million people living in this part of the UK, work out the power available per person if 10% of the total wave power could be used.

[3]

(c) In no more than 100 words each, explain

- how tides on Earth are formed
- what the ultimate power sources of tides are.

[5]

(d) How can tides be exploited for power production? Give a brief description (less than 100 words) and draw a simple schematic. [2]

(e) Show that the power produced by a tidal turbine can be described by

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

and calculate the power generated by a tide mill with a turbine radius of 8 m, an efficiency of $\epsilon = 50\%$ and an average stream velocity of $v = 1.5$ m/s. The density of water is $\rho \approx 1000$ kg m^{-3}. In one or two sentences, explain why a tide mill, and in fact any mill at all, cannot work at 100% efficiency. [7]

END OF PAPER

Copyright 2013 © University of Southampton