Exam introduction to Energy and Environment

8-4-2014, 9-12 o'clock

Write (clearly!) your name, birth date, and study number on the first sheet of paper; on every following paper your name.
Use of any supporting material is not allowed, except for a calculator. Ask for extra paper if needed.

General recommendations:

- ***Calculate, where applicable, symbolically as long as possible; only fill in numbers in the final step(s)!***
- ***Make that every calculation or line of reasoning is comprehensible, also for the corrector***
- ***Everywhere where explanations are requested, be as complete and concrete as possible, but "complete" is not the same as "lengthy"***
- ***If one is asked to "calculate" or "find" a result, it requires deduction of the result and not simply giving/reproducing the result***

Question 1. The RWE coal-fired power plant in the Eemshaven (indication: 7 of total 30 points)

The RWE coal fired plant is a modern example of a classical electricity generator plant. The coal fire heats water and transfers it into steam, which drives a turbine that is connected to a generator for electricity production. The steam is subsequently condensed, from which point the cycles starts from the beginning. Figure 1 shows an overview.
Strongly idealized, the system is described with the so-called "Rankine cycle". Figure 2 shows this idealized cycle in the form of a S-T diagram.

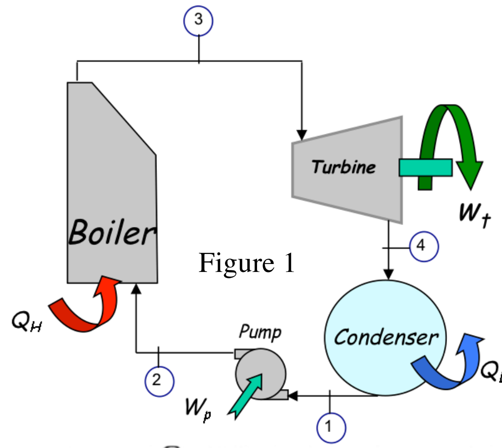


Figure 1

(a) Describe qualitatively, for the ideal case of a Rankine cycle as shown in figure 2, what, thermodynamically spoken, the trajectories represent in the different steps in figure 1, so respectively (1) to (2), from (2) to (3), (3) to (4), and finally from (4) to (1). Use for this the terms adiabatic, isotherm, isobar etc., and compression or expansion. Also indicate the phase(s) of the water.

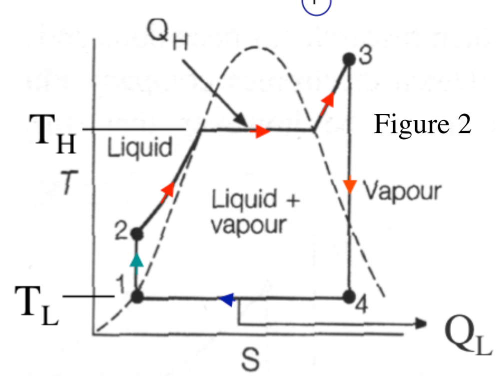


Figure 2

(b) Give the principal expression for the efficiency of the cycle, based on the heats and "works" mentioned in figure 1. Subsequently, rewrite those expressions in expressions with T and S based on figure 2 (you may leave integrals in the expressions if they occur).

This expression leads, in good approximation, to the final expression for the efficiency: $\eta \approx 1 - \frac{T_L}{T_H}$

(c) Which approximation(s) is/are necessary to derive this expression for your answer at (b), and why is/are this/these allowed?

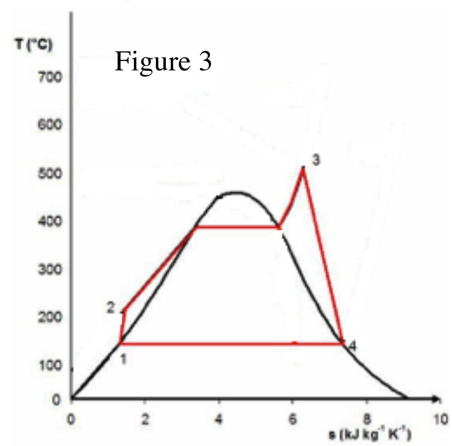


Figure 3

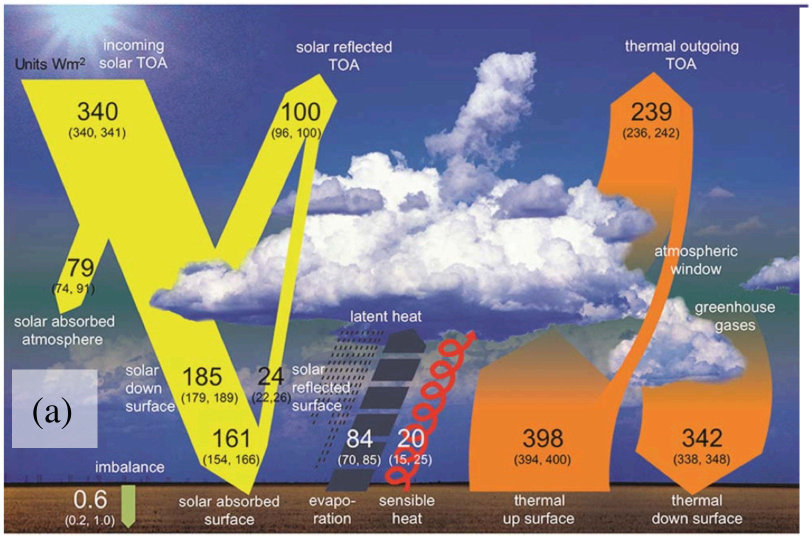
As said, the Rankine cycle is an idealisation of reality. In figure (3) you see an S-T diagram that is one step more realistic: trajectories 1-2 and 3-4 are no longer vertical.

(d) Specify what this means for those trajectories.

The RWE plant will be a coal-fired one with a record high efficiency for such a plant. This is achieved by the fact that one can use higher temperatures than before (higher than for example in figure 3).

(e) For the RWE plant T_3 = 610°C and T_L= 115°C, what is the efficiency? (hint: estimate the necessary T_H *using the shape of* figure 3, so not *from* figure 3). Calculate the efficiency for the cycle as given in figure 3 as well, and compare.

Question 2. The radiation balance of the earth (indication: 8 of total 30 points)



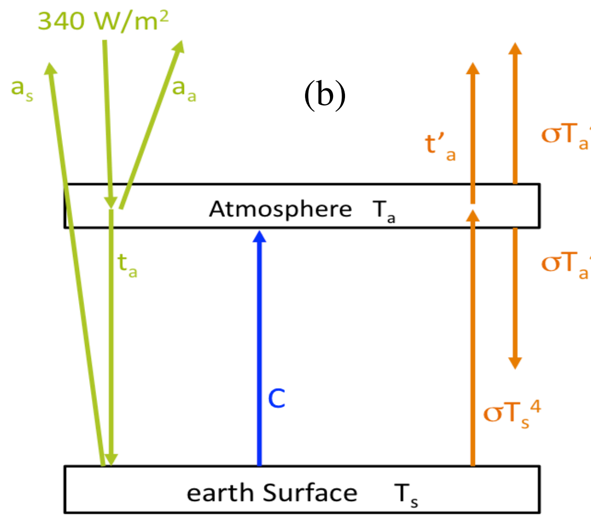


Figure (a) shows the radiation balance of the earth system. To the left, the yellowish arrows show the power per unit area connected to incoming solar radiation. The left part of figure (b) shows a schematic representation of the same, but now no longer with absolute powers, but rather with coefficients. t_a represents the transmission coefficient of the atmosphere for solar radiation, a_a the reflection ("albedo") from the atmosphere back into space, and a_s the reflection of the earth's surface to space.

(a) Determine the values of these three coefficients, based on the numbers of the left figure (only use the big font numbers, the other indicate uncertainty margins which are not used here).

In the middle of both figures, the fluxes of latent and sensible heat are given.

(b) Explain the character of those fluxes and give the value for C.

The right parts of both figures represent the thermal infrared part of the radiation balance.

(c) What is typically the wavelength of this thermal infrared?

Only a fraction t'_a of the thermal infrared radiation from the earth's surface is transmitted directly to space. The power (per unit area) of this "atmospheric window" is not shown in the left figure.

(d) if t'_a is 0.1, what would be that power?

The thermal radiation emitted by the earth's surface corresponds to the Stefan Boltzmann expression σT_s^4.
The value of σ is 5.67×10^{-8} W/(m^{2}K^4)

(e) Calculate the earth surface temperature T_s

Analogously, the thermal infrared radiation form the atmosphere is connected to its temperature. However, the thermal infrared powers emitted upwards and downwards are vastly different.

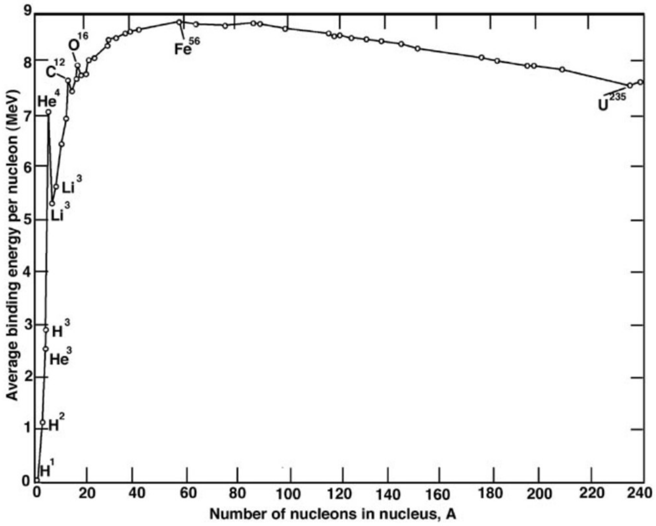
(f) Calculate the atmospheric temperatures connected to both infrared powers.

(g) Why are these two temperatures for the atmosphere so different and what do they represent?

Question 3. Nuclear fusion (indication: 4 of total 30 points)

For nuclear fusion, the following four processes are possible in principle:

$^2D + {}^3T \rightarrow {}^4He + n^o + 17.6$ MeV (1)
$^2D + {}^2D \rightarrow {}^3He + n^o + 3.27$ MeV (2)
$^2D + {}^2D \rightarrow {}^3T + {}^1H + 4.03$ MeV (3)
$^2D + {}^3He \rightarrow {}^4He + {}^1H + 18.3$ MeV (4)



Average binding energy per nucleon as a function of the mass number

(a) In practice (that is in the present test reactors) only reaction (1) is used. Why?

(b) ^3T is not found in nature. How is this isotope produced for the fusion reaction?

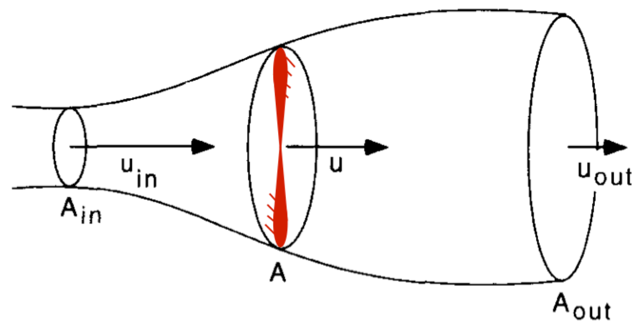
(c). Use the figure A to calculate how much energy is released with reaction (1) .

(d). How is this energy converted into electricity?

Question 4. wind energy (indication: 7 of total 30 points)

The kinetic energy of moving air is $E_k = \frac{1}{2} J_m u^2$ with J_m the air mass that passes through an area A perpendicular to the air velocity u during a time interval Δt. The density of the air is ρ.

(a) Give the expression of the kinetic energy per unit time and area (equivalent to the power per surface area), expressed exclusively in u and ρ.



In the figure the wind profile around the blades of a wind mill is sketched. Using the expression for the kinetic energy, naively one would find for the efficiency of this specific wind will:

$$\eta_o = \frac{\text{decrease kin. energy}}{\text{input kin. energy}}$$

$$= \frac{\frac{1}{2} J_m u_{in}^2 - \frac{1}{2} J_m u_{out}^2}{\frac{1}{2} J_m u_{in}^2} = 1 - \left(\frac{u_{out}}{u_{in}} \right)^2$$

(b) What is wrong with this expression? By which term can this expression be completed to make it correct?

(c) Show that $u = (u_{in} + u_{out})/2$ (Hint: work=force x distance = mass x deceleration x distance)

(d) using (b) and (c), calculate the maximum efficiency for a wind turbine (the Betz limit)

Question 5. (indication: 4 of total 30 points)

Below you find 10 statements; some are true, some are false.
Please indicate for each statement whether it is true or false.

1. The concept of 'accomodation space' in stratigraphy is determined by climate	true/false?
2. When a sourcerock is buried, it will first produce gas and then, at greater depth, oil will be generated	true/false?
3. The compressibility factor Z is independent on the type of gas	true/false?
4. Gypsum is the first mineral which precipitates when a sea or salt lake dries out through evaporation	true/false?
5. Fluvial point bars have a limited lateral continuity	true/false?
6. Subsidence and sea-level rise have an opposite effect on marine sedimentation	true/false?
7. A compressional subsurface stress field generates reverse faulting	true/false?
8. Reflection seismic data yield higher resolution subsurface images than gravity data	true/false?
9. Gas hydrates represent the largest fossil fuel resources on the planet	true/false?
10. One barrel-of-oil-equivalent (boe) is approximately equal to 1 m^3 of gas at standard conditions	true/false?