The Norwegian University of Science and Technology ENGLISH
Department of physics

Contact person:
Name: Turid Worren
Tel: 7359 0386

EXAM IN TFY 4300 Energy and environmental physics

Friday December 2nd 2005
Duration: 9-13

Number of pages: 5
Grades to be announced before: December 23rd 2005

Permitted aids: C

Physical parameters are listed after the questions and a list of equations is given in the appendix.

Problem 1 (5% + 5% = 10%)

a) Explain how you can obtain information about prehistoric climates by measuring the isotope ratio of ^{16}O and ^{18}O in the ice on Greenland.

b) Give examples of natural causes for climate change.

Problem 2 (10% + 5% + 10% + 10% = 35%)

a) Let the sun be a black body with surface temperature T_{sun}. Give an expression for the irradiated/incoming power per square meter, just outside the atmosphere of the earth, when you in addition know the radius of the sun r_s, the distance between the sun and the earth d_{se} and the radius of the earth r_e. What is this amount of incoming solar radiation outside the atmosphere called? Ignore the thickness of the atmosphere.

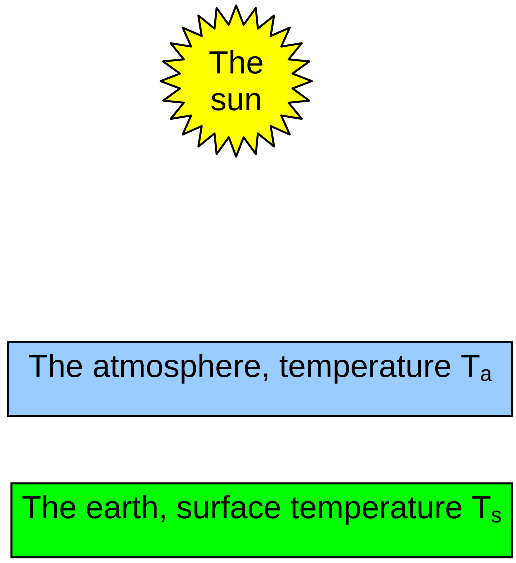
b) What is albedo? How will it change if the earth warms up?

c) Assume first that there is no atmosphere on earth. Draw a simple model for the (radiation) energy balance on earth, where the only energy source is solar radiation. Name the physical quantities that are involved in the model.

Use this simple model to calculate the temperature of the surface of the earth, having an average albedo (for solar radiation) of a=0.34. Assume that the emissivity of the earth is 1 in the thermal wavelength range. (The values for necessary physical parameters are listed after the problems.)

Explain why the calculated temperature deviates from the real average surface temperature of the earth of 15°C.

d) Now, look at a model where the atmosphere is included as a single layer over the surface of the earth, as shown in the figure below. Make a copy of this model and include radiation fluxes (energy per area and time unit) from the sun, in and out of the atmosphere and in and out of the surface of the earth. Include also energy transfer between the earth and the atmosphere that is not caused by radiation. (The sun is still the only energy source.) Name the physical quantities that are involved.



Use the model including the energy fluxes, to set up one equation for the energy balance for the atmosphere, and one for the surface of the earth.

Explain how you can use these equations to study the effects of global warming.

Problem 3 (15% + 10% = 25%)

a) A house is supposed to use solar energy to cover parts of the energy needs. Explain how solar energy can be utilized in different ways to meet different energy needs. Make simple drawings of how you would design the house, to utilize the solar energy in the best way.

b) Assume now that a room in the house is supposed to be heated by solar radiation transmitted through a window with area A_w and transmittance τ. The solar radiation is absorbed by a black, massive concrete structure with area A_a and absorbance α. The irradiated power per square meter is G.

   i. Give a general expression for the total power absorbed by the black concrete structure.
   ii. Give a general expression for the heat loss if the room has a temperature T_r and the ambient (outside) has temperature T_a. Assume that the total resistance to heat flow is R.
   iii. What mechanisms for heat transport (through walls, roof, floor and windows) are relevant?
   iv. Give a general expression for the irradiance G that is needed to keep a given temperature T_r in the room.

<u>Problem 4 (30%)</u>

Answer <u>three</u> of the following five problems.

a) Where in the atmosphere do we find the ozone layer, and why is it good for us that it is there? How do human activities affect the formation and destruction of ozone? Is ozone at the ground level too a good thing? State the reasons for you answer.

b) How large was the energy "consumption" (measured in joules) in 2003? Approximately what portion of this was in the form of fossil fuels, in the EU and in Norway? From the known reserves, for how many years (ca) can we keep using the various conventional energy sources (coal, oil, gas and uranium) if they are used at the same rate and using the same technology as today (i.e. without breeder reactors). If one could build a fusion power station, for how long (ca) could that power station supply the world's need of energy, if the deuterium in the sea was used as fuel? If the developing countries reach the level of development of the developed countries, how will that influence the energy needs (amount and form of energy).

c) Compare the safety issues of nuclear power stations based on fusion and based on fission. What are the practical problems with fusion power plants, and how does one try to solve the problems? Formulate the Lawson-criterion in words.

d) What is the connection between solar energy and wind? How can the energy in the wind be converted to mechanical and electrical energy? Make simple drawings and give relevant equations. What is the main difference between a windmill that is used for water pumping and one that is used for electricity production? Why can we not extract 100% of the energy in the wind?

e) What is bioenergy/biomass energy? Why is it considered to be a clean, renewable energy source even if CO_2 is emitted when the bio energy is converted? What forms of biofuels (primary and secondary) are used today? Which one of these has the highest energy density (measured in J/kg)? How can biofuels be used to meet various energy needs?

Physical constants

Planck's constant: $h = 6.626\times10^{-34}$ Js

The speed of light: $c = 2.998\times10^{8}$ m/s

Boltzmann's constant: $k = 1.38\times10^{-23}$ J/K

Stefan-Boltzmann's constant: $\sigma = 5.672\times10^{-8}$ W/(m^{2}K^4)

Avogadro's number: $N_A = 6.022\times10^{23}$ mol^{-1}

The electron charge: $e = 1.602\times10^{-19}$ C

The radius of the sun: $r_s = 6.96\times10^{8}$ m

The radius of the earth: $r_e = 6.4\times10^{6}$ m

The sun-earth distance: $d_{se} = 1.49\times10^{11}$ m

The surface temperature of the sun: T_{sun}=5800K