PHYS-E6570 Solar Energy Engineering (5 cr); 1st half-exam,15 February 2016
You may use a calculator in the exam.

1. You have two alternatives to choose from:

   The Sun is a huge energy source driven by fusion reactions.

   a) Estimate Sun's radiative power based on its effective surface temperature and diameter.
   b) How large fraction of Sun's radiation hits the Earth?
   c) Estimate the solar constant (= incident radiation intensity per m^2 above the atmosphere).

   The effective surface temperature of the Sun is 5762 K and its diameter is 1.39×10^9 m. The mean distance between the Sun and the Earth is 1.5×10^{11} m, and the radius of the Earth 6370 km. Stefan Boltzmann constant is $\sigma = 5.670373 \times 10^{-8}$ W m^{-2} K^{-4}

/OR/ Explain all main components and operating principle of a solar heating system.

2. The reflectance ρ of a surface is one of the key optical parameters in solar energy engineering. It determines both the absorptance α and emittance ε of a surface.

   a) Illustrate in a diagram the reflectance values (y-axis, 0-100%) as a function of the wavelength (x-axis, nm) of an ideal selective absorber for a solar thermal collector. What is the total absorptance and emittance values of an optimal selective absorber over the whole spectrum of interest?
   b) Give 2 examples how to realize a selective absorber surface. Short answers only.
   c) What is the equilibrium temperature of an ideal selective absorber in full sunshine? Stefan Boltzmann constant is $\sigma = 5.670373 \times 10^{-8}$ W m^{-2} K^{-4}

3. The amount of solar radiation on a surface can be increased through sun-tracking by following the movement of the sun and trying to minimize the incidence angle θ_i.

   Let's assume that we have a so-called 1-axis tracker with the following geometry: north-south axis (NS-axis) and east-west tracking (EW-tracking). The surface is vertical. Determine the incidence angle of beam radiation on the surface using the solar azimuth γ_s and solar zenith angles θ_z.

4. A solar heating system consists of solar collectors that have the following parameter values: $F_R\tau\alpha$=0.7 and F_RU_L = 2W/m^2K in the Hottel-Whillier-Bliss (HWB) equation.

   a) What kind of collector could this be? (1p)
   b) Draw the efficiency curve of the solar collector using $(T_{f,i}-T_a)/G$ as x-axis (2p)
   c) How high temperature could the collector reach on a sunny warm summer day, if the circulation pump is turned off? (3p)

5. Give a short and precise answer to each of the following questions, 2-3 lines for each.

   a) Air mass
   b) Maximum concentration ratio
   c) Pyranometer
   d) Ratio of diffuse radiation on a vertical surface to a horizontal surface
   e) Amount of solar radiation on an optimally inclined surface: Helsinki, Vienna, Rome or a sun-belt country in kWh/m^2 per year. Choose one country only.
   f) Thermosiphon