PHYS-E6570 Solar Energy Engineering (5 cr) **1st mid-term exam** **12.2.2018**

Answer all 5 questions.

1. Explain briefly (1p per concept)
    a) Air mass
    b) Yearly annual solar irradiation on horizontal surface ($kWh/m^2/a$) on a clear summer day in Helsinki, Vienna, Rome and a sun-belt country.
    c) Pyranometer
    d) Concentrating solar power plant (CSP)
    e) Selective absorber
    f) Hottel-Whillier-Bliss (HWB) equation

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 the 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. (1p)
    b) Illustrate in the same diagram (secondary *y*-axis, not to scale) the AM1.5G solar irradiance spectrum and the thermal emission spectrum of the collector. (2p)
    c) What is the total absorptance and emittance values of an optimal selective absorber over the whole spectrum of interest? (1p)
    d) Give one example how to realize a selective absorber surface. Short answer only. (1p)
    e) What is the equilibrium temperature of an ideal selective absorber in full sunshine? Stefan Boltzmann constant is $\sigma = 5.67 \times 10^{-8}\ W\ m^{-2}\ K^{-4}$ (1p)

3. A solar heating system consists of solar collectors that have the following parameter values: $F_R\tau\alpha = 0.65$ and $F_RU_L = 2\ W/m^2K$.

    a) Explain what kind of collector type is this? (2p)
    b) Draw the efficiency curve of the solar collector e.g. using $(T_{in} - T_{amb})/I_{sol}$ as x-axis (2p)
    c) How high collector temperature can be reached on a clear and warm summer day when the circulation pump is turned off? (2p)

TURN PAGE

4. Define the equations for beam, diffuse and reflected radiation on a surface as a function of the slope of the surface β. The surface is adjustable 90° around the horizontal east-west axis, so that the surface normal can point somewhere between directly south and directly up. Assume that the beam radiation I_b and horizontal diffuse radiation $I_{d,H}$ are known. The surface is located at latitude Φ, the declination angle of the Sun is δ and that it is midday. Also known are the ground reflectance ρ_g, zenith angle of the Sun θ_z. (6p)

   Angle of incidence:

$$\begin{aligned}\cos\theta = {} & \sin\delta\sin\phi\cos\beta - \sin\delta\cos\phi\sin\beta\cos\gamma \\ & + \cos\delta\cos\phi\cos\beta\cos\omega \\ & + \cos\delta\sin\phi\sin\beta\cos\gamma\cos\omega \\ & + \cos\delta\sin\beta\sin\gamma\sin\omega\end{aligned}$$

   These trigonometric definitions might be useful:

$$\sin(a-b) = \sin a\cos b - \cos a\sin b\ ,\ \cos(a-b) = \sin a\sin b + \cos a\cos b$$

   View factors:

$$F_{c-s} = \frac{1+\cos\beta}{2}\ , F_{c-g} = \frac{1-\cos\beta}{2}$$

5. What are the main factors that determine the yearly amount of solar heat production energy production by a flat plate solar collector, considering both

   a) the amount of available solar radiation, and (3 p)
   b) the materials and construction of the solar collector? (3 p)

   Note that, as the question is extensive, you can provide your answer as an informative a list rather than as an essay answer with full sentences. However, try to provide enough information or explanations to demonstrate your understanding.