PHYS-E6570 Solar Energy Engineering (5 cr); 1st half-exam, 17 February 2016
You may use a calculator in the exam. Answer 5 questions.

1. You have two alternatives to choose from (either 1a or 1 b):
   a. Derive and explain Kirchoff's law of thermal radiation
   /OR/
   b. Explain the principles of passive solar heating systems.

2. The fin efficiency describes the heat transfer from absorber plate to heat transfer pipes (surface). Definitions: F'= fin efficiency = $X^{-1} \times \tanh(X)$, where X= $[U_L/(k\delta)]^{1/2} \times (W-D)/2$, U_L=heat loss factor, δ= thickness of absorber plate, k= thermal conductivity of absorber plate. W= width of an absorber strip, D= diameter of heat transfer pipe. See also the figure below.
   Using the definition of the fin efficiency, design an absorber plate, incl. heat transfer pipes or channels, for a flat-plate collector. Your design should minimize total material cost for absorber while maintaining a high fin efficiency. You can use Cu, Al and/or plastics.

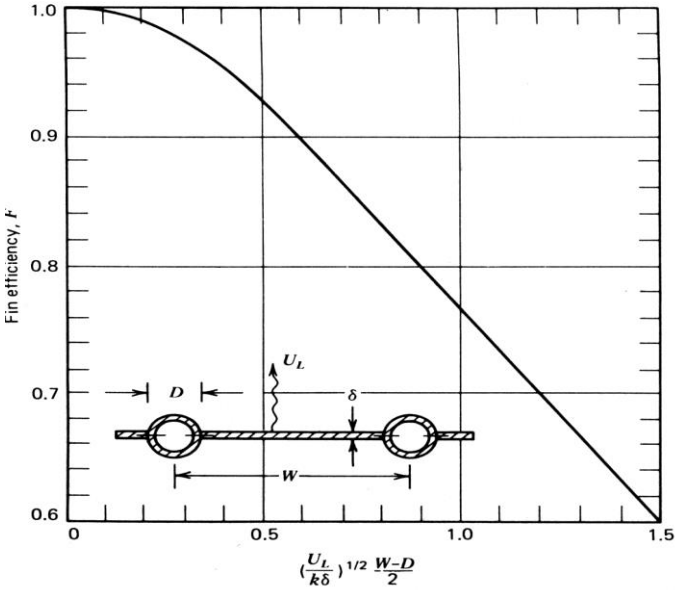

Figure 6.5.3 Fin efficiency for tube and sheet solar collectors.

Thermal conductivity (W/Km): Aluminum 211, Copper 385, Plastic 1;

Material costs ($/ton): Copper 7000, Aluminum 2000, Plastics 1000

Density (kg/m^3): Aluminum 2700, Copper 8940, Plastic 1175

3. The 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 a 1-axis tracker with the following geometry: A vertical surface which follows the sun's position in the azimuth plane. Determine the incidence angle of beam radiation on the surface using solar azimuth γ_s and solar zenith angles θ_z.

4. A parabolic dish solar concentrator has a concentration ratio of C=500.
   a) How much solar radiation (W/m^2) is received in the focal point of a concentrator (absorber) if the direct solar radiation on the collector plane is 800 W/m^2 and diffuse radiation 200 W/m^2 ? (2 p)
   b) How accurately needs the concentrator follow the movement of the sun in order to be able to concentrate the radiation to the focal point (choose A, B, C, or D; maximum misalignment error A= about 5^o, B= about 2^o; C=about 1^0, D= <0.5^o) (1p)
   c) How much heat (W/m^2) could the above concentrator deliver if its optical efficiency is 0.8 and the heat loss factor is 5 W/m^{2}K (per m^2 = per absorber area)? (3p)

5. Give a short and precise answer to each of the following questions, 2-3 lines for each.
   a) Solar constant
   b) Maximum concentration ratio
   c) Shadow-ring pyranometer
   d) Vacuum tube collector
   e) Maximum solar radiation intensity on a surface (W/m^2) on a clear summer day in Helsinki, Vienna, Rome or a sun-belt country. Choose one country only.
   f) CPC solar collector