Exam (tentti) 24 May 2014

PHYS-E6570 Solar Energy Engineering (5 cr, L)
Tfy-56.4323 Solar Energy Engineering P (5 cr)

1. The amount of solar radiation on a surface can be increased through sun-tracking, i.e. by following the movement of the sun and trying to minimize the incidence angle θ.

   Let's assume that we have a so-called 1-axis tracker with the following geometry:
   - The surface is inclined (tilted) to a fixed angle of α (pinnan kallistuskulma)
   - The surface follows accurately the sun's movement in the azimuth plane (x,y)

Determine now the incidence angle of beam radiation on the above surface using the solar azimuth γ_s and solar zenith angles θ_z.

2. The fin efficiency is a key parameter of a solar collector. It describes the heat transfer from absorber plate to heat transfer pipes (surface). 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 the amount of materials needed or the total material cost of the absorber, while maintaining high fin efficiency. You can use Cu, Al and/or plastics. 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.

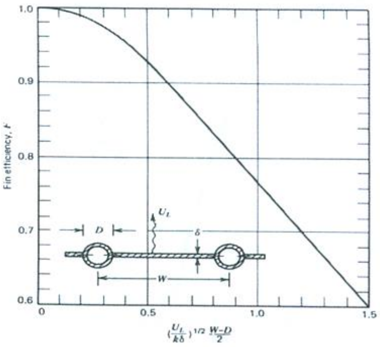


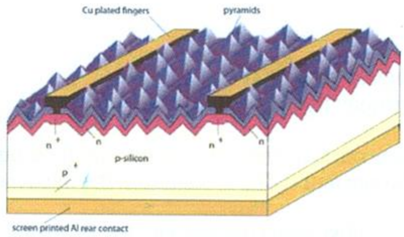
Figure 6.5.3 Fin efficiency for tube and sheet solar collectors.

Thermal conductivity (W/(m·K)): Aluminum 211, Copper 385, Plastic 1;

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

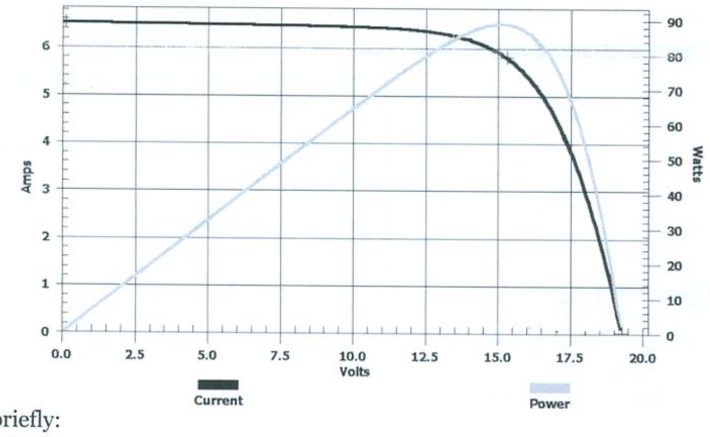
Density (kg/m^3): Aluminum 2700, Copper 8940, Plastic 1175

3. Explain how the following three principal steps in photovoltaic energy conversion take place in a crystalline silicon solar cell (see figures below) and the losses associated with each step:
   a) Absorption of light – Generation of charge carriers (2 p.)
   b) Separation of charge carriers (2 p.)
   c) Collection of the carriers at the electrodes (2 p.)



3. The figure below shows the current – voltage (IV) curve of a crystalline silicon photovoltaic module (black curve) and the corresponding power curves (power as the function of voltage, gray curve), measured at the standard test conditions (STC, radiation intensity 1000 W/m², T=25°C). The dimensions of the module are 500 x 1000 mm. Estimate from the figure or with approximate calculations, the open circuit voltage (V_{OC}), short circuit current (I_{SC}), fill factor (*FF*), and energy conversion efficiency (η) of the module in the following conditions:

   a) At the STC, corresponding to the IV curve of the figure below (2 p)
   b) Outdoors in Helsinki on a cold winter day (Tair = -30°C) with clear skies, when the module is facing directly to the sun but is covered with snow that blocks 50 % of the incident light (2 p.)
   c) Outdoors in Sahara desert (Tair = 50°C) with clear skies, in the afternoon when the sun is at 45° angle with respect to the module surface. (2 p.)



5. Explain briefly:
   a) Air mass
   b) Pyranometer
   c) Spectrally selective solar absorber material
   d) Concentrating solar power plant (CSP)
   e) Electron diffusion length (in a solar cell)
   f) N-type crystalline silicon

Some natural constants:

Boltzmann's constant $k = 1.3807 \cdot 10^{-23}$ J/K
Elementary charge $q = 1.6022 \cdot 10^{-19}$ C