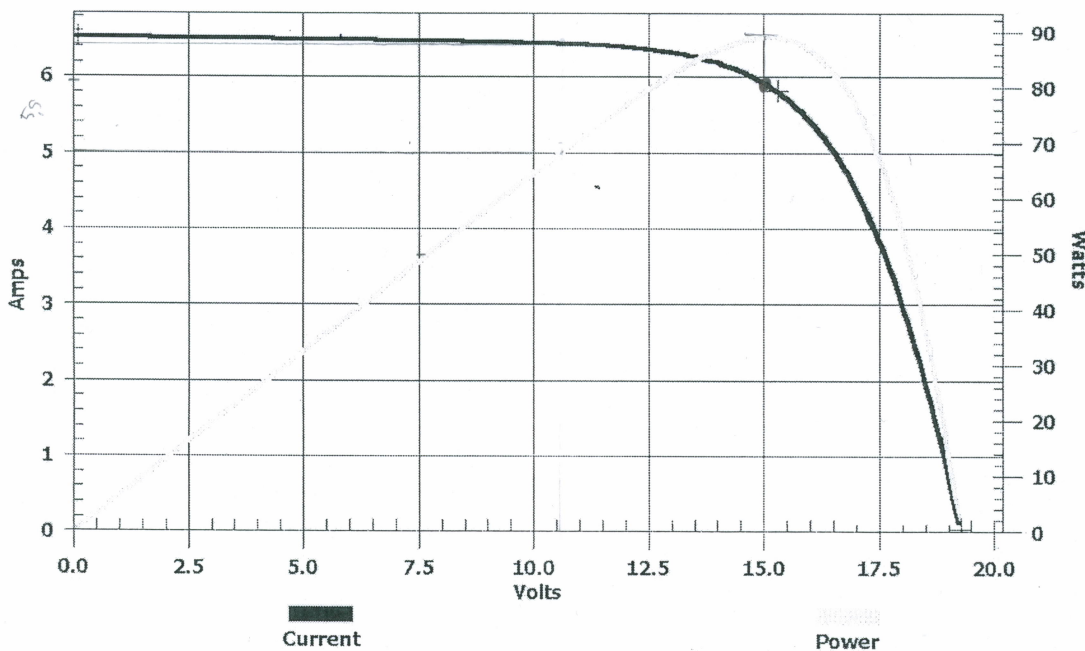


## Examination 25 May 2012

### Tfy-56.4323 Solar Energy Engineering (5cr, L)

Threshold for passing the exam is 12 p.

- Using the azimuth ( $\gamma_s$ ) and zenith angle ( $\theta_z$ ) of sun's position only, derive a relation for the cosine of the incidence angle of beam radiation ( $\cos \theta$ ) on the surface for the following case: The solar concentrator has a north-south axis (NS) and follows the sun's position in the east-west plane, i.e. NS-axis and EW-tracking case. (6p)
- What factors affect the efficiency of a silicon solar cell? (6p)
- The figure below shows the current – voltage (IV) curve of a solar module (black curve) and corresponding power curves (power as the function of voltage, gray curve), measured at the standard test conditions (STC, radiation intensity  $1000 \text{ W/m}^2$ ,  $T=25^\circ\text{C}$ ). The dimensions of the module are  $600 \times 1000 \text{ mm}$ . Estimate the open circuit voltage ( $V_{OC}$ ), short circuit current ( $I_{SC}$ ), fill factor ( $FF$ ), and energy conversion efficiency ( $\eta$ ) of the module in the following cases:
  - Initial case, as in the Figure (3 p);
  - The same initial case, but with an additional shunt resistance ( $R_{SH}$ ) of  $10 \Omega$  connected between the positive and negative electrical terminals of the module (3 p)



- A solar heating system consists of solar collectors that have the following parameter values:  $F_R \tau \alpha = 0.8$  and  $F_R U_L = 2 \text{ W/m}^2\text{K}$ .
  - Explain what kind of collector type is this? (1p)
  - Draw the efficiency curve of the solar collector e.g. using  $(T_{in} - T_{amb})/I_{so1}$  as x-axis (2p)
  - How high collector temperature is reached on a clear and warm summer day when the circulation pump is turned off? (3p)
- Explain shortly following definitions (each 1p)
  - Air-mass
  - Thermosyphon
  - Maximum concentration ratio
  - Electricity produced in a year by 1-kWp grid-connected PV system Southern Finland
  - Organic solar cell
  - Pyrheliometer