Answer all 5 questions.

1. Explain briefly (1 p per concept)
   a) Solar constant
   b) Maximum solar radiation intensity on a freely oriented surface (W/m^2) on a clear summer day at noon in Helsinki, Vienna, Rome and a sun-belt country.
   c) Main physical heat loss mechanisms in solar thermal collector
   d) Kirchhoff's law of thermal radiation
   e) Vacuum tube solar collector
   f) Passive solar heating

2. 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. (2 p)
   b) How large fraction of Sun's radiation hits the Earth? (2 p)
   c) Estimate the solar constant (= incident radiation intensity per m^2 above the atmosphere). (2 p)
   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 $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}

3. Using the azimuth (γ_s) and zenith angle (θ_z) of sun's position only, <u>derive</u> a relation for the cosine of the incidence angle of beam radiation ($\cos \theta$) on the surface for the following case:

   a) The solar concentrator axis is horizontally placed, with its axis in north-south direction and it follows the sun's position in the east-west direction (NS-axis, EW-tracking). (6 p)

4. The concentration ratio of a parabolic trough concentrator is C = 100.

   a) How much solar radiation is received in the focal point of the concentrator if solar radiation on a plane is 900 W/m^2 direct radiation and 100 W/m^2 diffuse radiation? (2 p)
   b) How much heat (W/m^2) could the above concentrator deliver if its optical efficiency is 0.9 and the heat loss factor is 10 W/m^2K (per m^2 = per absorber area)? (2p)
   c) How accurately does the concentrator need to 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 $5°$, B = about $2°$; C = about $1°$, D < $0.5°$) (1p)
   d) How would you install the parabolic trough concentrator/collector to maximize its yearly solar irradiance collection? (1p)

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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.