NTNU
Norwegian University of Science and Technology

Faculty of Physics,
Informatics og Mathematics
Department of Physics, Lade

EKSAMINATION IN: MNF FY221 ENERGY AND ENVIRONMENTAL PHYSICS

DATE: Thursday 16 December 1999 TIME: 9.00 - 15.00

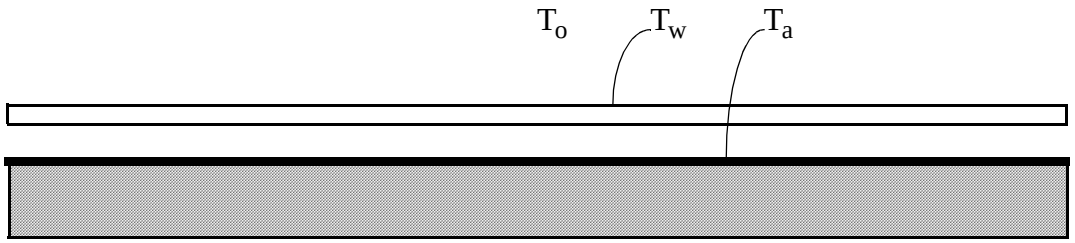
Number of points: 4
Number of pages: 2
Grades to be announced on 25 January 2000

Permitted aids:
Mathematical tables and calculator

Problem 1
There is a growing evidence indicating that the global temperature is increasing. Discuss the main elements and factors in the climate models that have predicted and can explain this temperature increase.

Problem 2
Answer any two of the sub-problems below, i.e. a) & b) or a) & c) or b) & c).

a) The figure shows schematically a cross section through part of a flat plate solar collector covered with a transparent window.



Derive and discuss a formula that gives the net heat current per unit area that may be extracted from a solar collector of this type when there is a direct solar beam of intensity $I(\theta)$, where θ is the angle relative to the surface normal, and a diffuse solar irradiance E_d. Neglect edge effects. Introduce the parameters and assumptions that are necessary for the discussion. Discuss briefly how the choice of the various constructional parameters will influence the net heat production.

b) Heat is extracted from a solar collector (flat plate or concentrating) by two different principles:
(1): Heating of a fluid flowing through the collector in close contact with the absorber, and coolig in the receiving unit.
(2): Evaporation of a liquid inside the collector, and condensation in the receiving unit (phase change)
Find the ratios between the exergy transferred in the two cases and discuss practical implications. In which applications will the difference be of particular importance?

c) Give a short discussion of concentrating solar energy systems.

Problem 3

a) Bernoulli's equation state that

$$\frac{p}{\rho g} + z + \frac{u^2}{2g} = \text{constant}$$

Define the meaning of the symbols, and discuss briefly the derivation of this relation and the conditions for validity.

b) The so-called Betz criterion gives a limit for the maximum power that a turbine with cross section A can extract from a wind field with velocity u_i. Derive and discuss this criterion.

c) Find an expression for the thrust or axial force on a wind turbine, if the power has the maximum value derived above.

d) The distribution of wind speed for a location is often assumed to follow the Rayleigh distribution, according to which the probability of finding a wind speed exceeding u' is given by (cumulative distribution)

$$\Phi_{u > u'} = \exp\left[-\left(\frac{u'}{c}\right)^2\right]$$

Discuss briefly this expression, find the corresponding probability density distribution of wind speed and state how mean values of powers of the wind speed can be calculated.

e) With a background in the results above, discuss how the power curve (electrical power produced versus wind speed) is chosen for a conventional commercial wind turbine. Define the expectation value of the annual mean production when the wind distribution is known.

Please note: The students will find the examination results (grades) on special notice boards. Telephone inquiries about grades, when necessary, should be made to the relevant department or NR 8154 8014. The office of examinations does not answer such inquiries.