Assignments related to efficiency

Questions to test understanding

Efficiency – generally abbreviated with the symbol "η" (Greek "eta") – describes the efficiency of an energy conversion process and is defined as the quotient resulting from dividing useful energy by energy consumption, as expressed in:

$$\eta = \frac{\Delta E_{useful}}{\Delta E_{expended}}$$

a) What physical law determines the maximum value of efficiency?
b) How large (in percent) can the maximum efficiency therefore be?
c) What is the formula for efficiency when it is expressed in terms of power output?
d) How is total efficiency calculated when several energy converters are connected in series?

Calculation tasks

Task 1: Carnot efficiency

The Carnot process represents the ideal thermodynamic cyclic process with the maximum efficiency. The process performs mechanical work (W) when heat (Q_2) is withdrawn from a hot reservoir (temperature T_2) and heat (Q_1) is fed to a colder reservoir (temperature T_1) (a heat engine). Conversely, heat can be withdrawn from a colder reservoir by applying mechanical work and fed to a hotter reservoir (heat pump or refrigerating machine acting as an inverse heat engine).

a) Draw the flow directions of mechanical work (W) and the heats (Q_1, Q_2) for the two principal types of machine: heat engine and inverse heat engine.
b) Calculate the efficiency of an ideal heat engine, given the following two magnitudes: T_1 (low) = 600°C, T_2 (high) = 2,000°C.
c) Calculate the efficiency of an ideal heat pump, given the following two magnitudes: T_1 (outside temperature) = 10°C, T_2 (supply flow temperature) = 40°C.
d) Calculate the efficiency of a refrigerator, given the following magnitudes: T_1 (freezer compartment) = –23°C, T_2 (ambient air) = 25°C.
e) What do you ascertain? Do your results from c. and d. contradict the law of conservation of energy according to which efficiency cannot exceed 100 percent? Give reasons for your answer.
f) Why is the efficiency of the heat engine lower in practice than the calculated value?

Task 2: Efficiency of a solar cell

The sun shines on the earth's surface with a power of approximately 700 W/m^2. A photovoltaic system of 5 m^2 is installed on a house roof. It consists of a large number of solar cells, each of which measures 0.01 m^2 and has an electrical output of 800 mW.

Calculate the efficiency of the entire installation.

Task 3: Efficiency of a natural gas stove

The object is to bring 0.5 liters of spring water (T_1 = 10°C) to a boil (T_2 = 100°C) with a gas camping stove.

a) How many liters of gas have to be burned if the efficiency of the stove is 52 percent?
   The following values are to be used as the basis for calculation:
   Calorific value of natural gas: H_{gas} = 10.4 kWh/m³;
   Specific heat capacity of water c_w = 4.18 J/(°C · g)
b) If the stove's efficiency is 52 percent, what has happened to the other 48 percent?