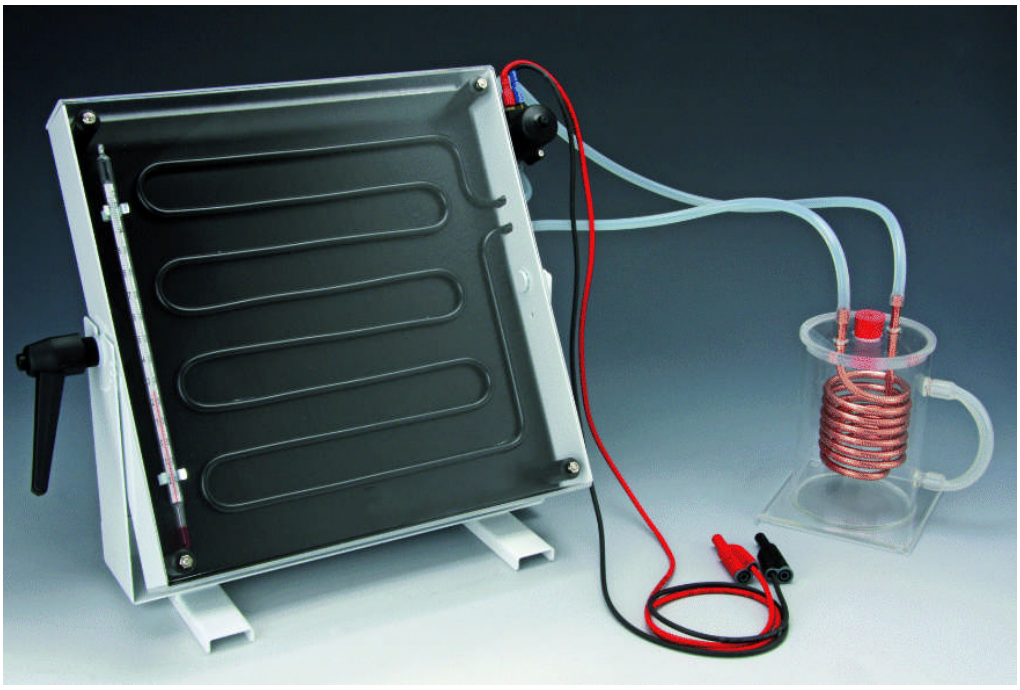
Manual for Solar Thermal Collector



Solar Thermal Collector 5037.20

The solar collector is used to demonstrate how solar energy can be converted into thermal energy.

The unit is complete with water pump and storage tank with heat exchanger. The storage tank can function like a hot water tank in a house – or (without water) it can illustrate a radiator in a room to be heated.

Function

Solar radiation is absorbed by the black-painted absorber, which consists of a metal plate with copper tubes welded on. The back of the collector is insulated from the absorber. On the front is a transparent acrylic plate, which reduces heat loss by convection. The black-painted copper tubing is connected with plastic tubes to the water pump and the copper coil in the storage tank. Pipes and tubes are filled with water which is circulated in the system by the water pump. With a thermometer the temperature in the storage tank can be measured. When the amount of water in the tank is known, the heat input can be calculated from the rise in temperature. Two different stoppers are included: The one with the large hole is for an ordinary thermometer - the one with the small hole is for a thermal sensor that eventually may be connected to a data logging system.

The solar collector is provided with a thermometer to allow the temperature behind the glass to be measured. The solar collector can be set at various angles with the lever on the side. The solar collector is built for educational purposes to demonstrate the principles of the technology. The insulation is minimal – some parts are not isolated at all. One cannot expect the same high efficiency as with a real panel solar collector.

Preparation

The unit is filled with water by connecting the pump to a power supply and pour water into the container. The two hoses from the solar collector are placed in the container with water and the pump is started.

Experiments with the solar collector (calculation example)

The piping is filled as described, and the pump voltage is set to 2 V. The current consumption is measured to be 0.7 A.

The storage tank is filled with 0.6 litres of water at 16.8° C. To read representative temperatures in the storage tank, place it on a magnetic stirrer. The temperature in the storage tank is measured at intervals of 2 minutes through 30 minutes.

Light intensity (irradiance) Φ is measured to be 930 W/m^2. The black absorption plate measures 29.0 x 29.4 cm which gives an area of 0.0853 m^2.

Measurement results:

t (minutes)	T_{Tank} (°C)	$T_{Collector}$ (°C)
0	16.8	29
2	18.0	
4	20.0	
6	21.5	47
8	23.5	
10	25.2	
12	27.2	60
14	29.2	
16	31.2	
18	33.0	70
20	35.0	
22	36.9	
24	38.7	76
26	40.2	
28	42.2	
30	43.6	82

Calculation of the collector efficiency:

$Q_{Rad} = \Phi \cdot A \cdot t = 930 W/m^2 \cdot 0{,}0853\ m^2 \cdot 60 \cdot 30\ s = 142.8\ kJ$

$Q_{Tank} = c_w \cdot mw \cdot T = 4.18\ kJ/(kg \cdot K) \cdot 0.6\ kg \cdot 26.8\ K = 672\ kJ$

$\eta = Q_{Tank}/Q_{Rad} = 67{,}2\ kJ/142{,}8\ kJ = 0{,}47 = 47\ \%$

If we consider the energy consumed by the pump: $E = U \cdot I \cdot t = 2\ V \cdot 0.7\ V \cdot 60 \cdot 30\ s = 2.5\ kJ$ we get:

$\eta = 67.2\ kJ/(142.8\ kJ + 2.5\ kJ) = 0.46 = 46\ \%$

Experiments with data logging

The experiment can also be performed with data logging equipment. With two temperature sensors it is easy to follow the temperature changes in the solar collector and the storage tank. You do not need to manually read the temperature every two minutes, but are free to do something else.

Specifications

Solar Panel

Absorber area: 29.0 cm x 29.4 cm = 852.6 cm^2

Heat capacity of absorber incl. tubing: 410 J/K

Water Pump

0 - 12 V DC. The pump is connected to an adjustable voltage source. (The pump is typically used with voltages below 4 V - there is usually no need for larger water flows.)

Storage Tank

The material is acrylic. The walls are 3 mm thick; the bottom is 4 mm thick.

Inner diameter of tank: 94 mm

Heat capacity of copper coil: 83 J/K

Required accessories

Power supply with adjustable DC voltage

A sun – either the real one or a powerful lamp

Magnetic stirrer

Pyranometer