EXERCISES

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PROBLEMS

1. Solar radiation and solar constant

Outside of our atmosphere, for a plane oriented perpendicularly to the rays of sunlight, the irradiance—the energy current density of solar radiation—is equal to 1370 W/m^2 (this number is called the solar constant).

TASKS

a. What is the total energy current of solar radiation falling upon the Earth? The Earth is a sphere with a radius of 6400 km.

b. On average, our planet reflects 30% of the incoming radiation. What is the energy absorption rate of the planet? What is the energy absorption rate per square meter of the surface of our planet?

c. How much energy is absorbed by the planet in one year?

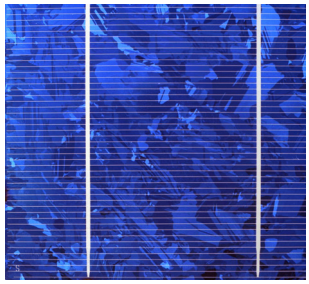
d. Meteorological stations measure the energy current density of solar radiation for the horizontal plane of their location. Use http://meteo.zhwin.ch/ to find the solar radiation for a day you can choose. How much energy did we receive during that day per square meter?

e. What is the solar constant for Jupiter? Jupiter is 5.2 times as far from the Sun as our planet.

f. What is the energy current of solar radiation leaving the surface of the Sun? The Sun is 150 million km away from us.

2. Energy flows and PV cells

A solar cell—a photovoltaic cell—uses solar radiation to drive an electric current.



TASKS

a. Sketch a process diagram of a solar cell.

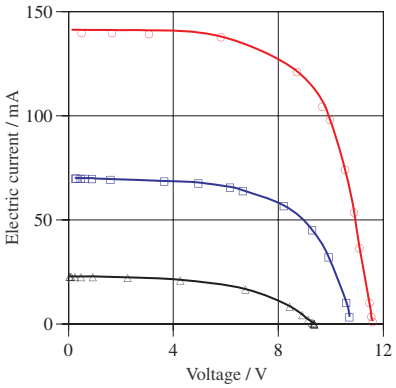
b. Explain the elements of your sketch.

c. Use the process diagram to define the efficiency of the cell.

d. If speaking in everyday terms, we often say that a solar cell converts solar radiation into electricity. Use your process diagram to explain what may, or may not, be meant by these words.

3. Model and Maximum Power Point of PV array

A small photovoltaic panel consisting of 21 cells arranged in series is exposed to sunlight. (The surface area of a single cell is about 15 cm^2.) It is connected to a load resistor with variable resistance. Voltage and electric current for the load resistor have been measured for different values of the resistance (see graph). Irradiation was about 60 W/m^2 for the first, 200 W/m^2 for the second, and nearly 400 W/m^2 for the third (the highest) curve.



TASKS

a. Calculate the electric power of the panel for a voltage of 4.0 V for the three characteristic curves.

b. Determine the maximum values of the electric power for the three cases. What are the values of the load resistance for the maximum power point for the three curves?

c. Determine the efficiency of the panel for maximum power point conditions for the three cases.

4. Energy stored and released: Artificial lake and power plant compared to PV plant

Imagine an artificial lake in the mountains in the shape of a cuboid of 10.0 km^2 surface area, and 50 m depth. The turbine station of a power plant is located 150 m below the bottom of the lake. Assume that the lake can be filled and drained once a year.

TASKS

a. How large is the energy stored with the water if we take the bottom of the lake as our reference level? (Assume the lake to be full.)

b. How large is the energy stored with the water if we take the turbine station as our reference level?

c. How large is the power of the water flowing out of the lake to the power plant if the lake is full? If it is almost empty? Take a flow of 20.0 m^3/s.

d. How much energy is released by the water flowing out of the lake and down to the power plant if the lake is drained completely once a year?

e. Now we cover the lake with photovoltaic cells. How much energy can we gain from them in one year if we assume the cells to have an efficiency of 10%.

5. Energy in charging of a capacitor

A capacitor having a capacitance of 1.0 F is charged in a simple circuit with a 100 Ω resistor and a power supply setting up a constant voltage of 20 V. Consider the moment when the voltage across the capacitor is 1/3 of its final value.

TASKS

a. What is the electric power of the resistor at that moment?

b. How much energy is stored in the capacitor?

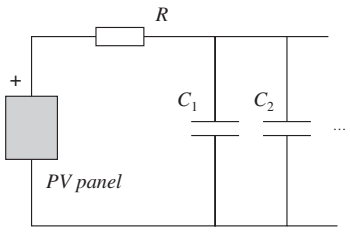
c. What is the energy current into the capacitor?

d. What is the rate of change of the energy of the capacitor?

e. What is the electric power of the power supply?

6. Charging capacitors with a PV array

Assume that 4 capacitors of 1.0 F capacitance each are connected in parallel. We want to charge them with the help of the photovoltaic panel of Problem 3. The sun shines at 400 W/m^2 which yields the characteristic curve shown in the diagram. A resistor is between the panel and the capacitors.



TASKS

a. Choose the resistor so that if it were the only element in the circuit, we would have maximum power conditions.

b. What will be the electric current right at the beginning (when the capacitors are still uncharged)? What is the energy current flowing into the capacitors at that moment?

c. At a certain moment, the current through the circuit is 80 mA. What is the voltage across the capacitors at that time? What is the energy current flowing into the capacitor at that time? What are the electric power of the cells and the power of the resistor?

d. At a certain moment, the voltage across the capacitors is 5.0 V. What is the current through the circuit at that moment? (You will have to solve a set of nonlinear equations.) What will be the energy current flowing into the capacitor?