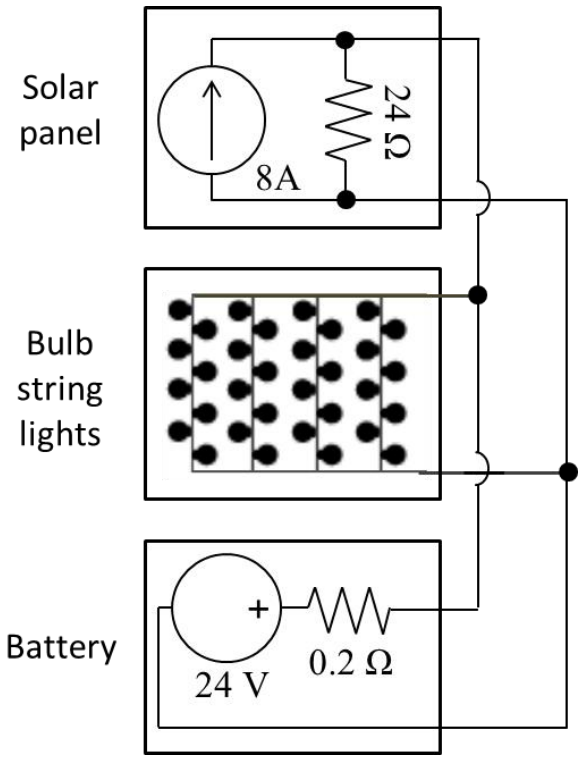
School of Electrical Engineering & Telecommunications

ELEC1111 Tutorial 3

Analysis of a solar powered Christmas tree

In this tutorial you will analyse a solar powered Christmas tree. The tree has a solar panel at the top, a battery at the base, and bulb string lights around it. The bulb string lights are made from 4 parallel strings with 8 light bulbs in series each. Each light bulb has a nominal resistance of 8 Ω. The resistance of the wiring is negligible.

The battery is charged during the day to keep the bulb string lights shining at night. The solar panel acts principally as a current source with a shunt resistor in parallel, while the battery is modelled as a voltage source with a resistance in series[1]. You leave the bulb string lights running day and night to keep your wiring very simple, although this is not the best design choice.



Q1. Draw a circuit diagram of the system described above, replacing the bulb string lights with the corresponding equivalent resistor.

Q2. During a sunny day, the solar panel delivers its rated current for 7 hours. Using superposition, calculate the current through the battery. How many Amp-hours are stored in the battery during the day?

Answer: $i_{battery\_day} = 5.39$ A, $q_{battery\_day} = 37.73$ Ah.

[1] Note: Solar panels and batteries are more complex than this but assume that they behave this way for this tutorial.

Q3. When the sun is not shining for the other 17 hours, the solar panel produces no current, but its shunt resistance remains connected. How many Amp-hours are stored in the battery during the night? Assuming the battery voltage remains constant as it discharges, how many hours will the bulbs stay lit during the night before the battery is completely discharged?

Answer: $i_{battery\_night}$ = 2.45 A, $q_{battery\_night}$ = 41.75 Ah, number of hours = 15.4 hours (< 17 hours).

Q4. During winter, you disconnect the battery (voltage source and internal resistance) and decide to connect a hot water heater in its place. The hot water heater can be modelled as a single resistor. What heater resistance will ensure the maximum transfer of power from the Christmas tree to the heater? What will this maximum power be?

Answer: R_{heater} = 9.6 Ω, P_{max} = 153.6 W.

Q5. (Design and simulation question) *Within your group*, discuss how you could rewire the bulb string lights to ensure they stay lit day and night. Use circuit simulation software to verify your design.

Answer: There are many possible correct designs, which can be verified using simulation. If you are still unsure after simulating your design, contact your lecturer to organise an appointment.