The SUSE solar vehicle 4

Solar vehicle with GoldCap energy storage (without own solar cell)
to be charged at solar filling station
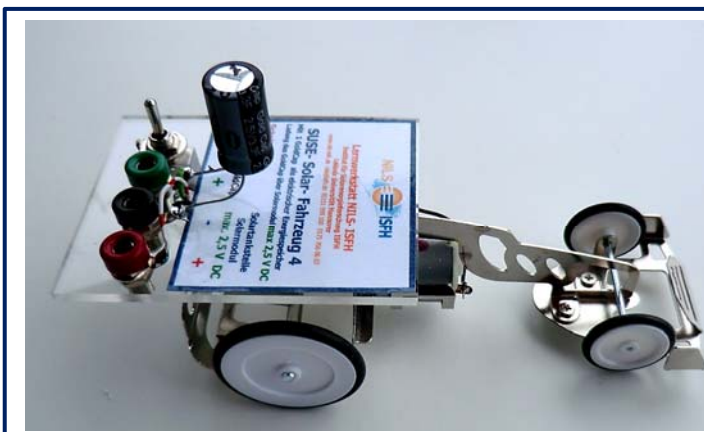### V_{max} = 2.5 V   Drive by SUSE solar motor and single-stage gear

Learning station
D13

The SUSE solar vehicle 4 with GoldCap for V_{max}= 2.5 V DC
Technical manual and experiments
Especially suited for solar filling station SUSE 4.34

View onto the vehicle from above:
At the top there is the electric circuit board with the electric energy storage (GoldCap), the operating switch, and the 3 jacks.

For charging the GoldCap lab wires can be plugged into the red(+)-black(-) jack pair, the green jack is a test jack for the measurement of the electric voltage at the GoldCap.

Below the circuit board there is the solar electric motor and the single-level gear for the drive of the rear axle.

The switch has **3 positions**:

Switched to the back: Charging of the GoldCap
Central: OFF
Switched to the front: Drive

The vehicle does not have its own solar cell, instead it is „fueled" before driving at a solar filling station, in doing so the electric energy storage GoldCap is **charged with 2.5 V DC max.**, storing an electric **energy of up to 10 J** in the process.

With one filling the car drives with a **high speed for approx. 50 m**. Depending on the light intensity (= irradiance S) the charging process only takes about one minute to a few minutes.

This way the vehicle can also be charged with a heavily clouded sky, a vehicle relying purely on solar cells would not drive under these conditions. Extensive experiments (e.g. capacitor charging/discharging) can be conducted with the vehicle.

To charge the GoldCap lab wires, that lead to the solar module, are plugged into the jacks.

For photovoltaics experiments with the solar module SUSE 4.34 there is a separate, extensive experimentation manual.

The **solar vehicle 4** with the solar filling station (solar module) **SUSE 4.34 (2.4V/ 630 mA)** Below the circuit board the solar electric motor is visible (with wire yellow/black).

The **operating switch has 3 positions**:

1. Charging (switched to the back)
2. OFF (Central position)
3. Drive (switched to the front)
The charging or discharging process at the GoldCap can be observed and measured through a voltage measurement at the green jack (GoldCap +) or through a current measurement in the supply lines from the solar module. The vehicle can also be charged with a 1.5 V Mignon battery (AA).

For the **charging** on up to **4 solar cells in series connection** the vehicle is fitted with 1 GoldCap. Especially suited as a solar filling station 2.5 V is the solar module **SUSE 4.34** or **4 solar modules SUSE CM6B** in series connection.
The vehicle **does not have an own solar cell**, instead it is **"fueled"** before driving at a **solar filling station**, in doing so the electric energy storage GoldCap (capacitor) is charged with 2.5 V DC max., storing an electric **energy of up to 10 J** in the process (according to the equation W = ½ CV²).
With one filling the car drives with a high speed for approx. 50 m.
Depending on the light intensity = irradiance S the charging process only takes about 30 s to a few minutes.
This way the vehicle can also be charged with a heavily clouded sky, a vehicle relying purely on solar cells would not drive under these conditions. Extensive experiments (e.g. capacitor charging/discharging) can be conducted with the vehicle.
To charge the GoldCap lab wires, that lead to the solar module, are plugged into the red-black jack pair.
The charging or discharging process at the GoldCap can be observed and measured through a voltage measurement at the GoldCap (green-black jack pair) or through a current measurement in the supply lines from the solar module.

Experiments with the solar vehicle 4

The GoldCap is an energy storage, that can be charged to a maximum of 2.5 V DC. With V = 2.5 V the **stored energy** is **10 J** according to W = ½ CV².

In **practice of real solar vehicles** there will never be cars, that are fitted with solar cells or solar modules themselves. The vehicles will always have an electric energy storage on board, that is charged with electric energy from the power line, ideally with electric energy from regenerative energy sources.

With the SUSE solar vehicle 4 this practice can be conducted on a model:

Necessary experimental devices for the experiments

1 SUSE solar vehicle 4
1 Solar module with 4 solar cells in series connection or single solar cells, e.g. 1x SUSE 4.34 or 4x SUSE solar modules with 1 solar cell each, e.g. SUSE CM6B or CM6MS, **especially suited: 5 V solar filling station SUSE 4.34** with 2.4 V DC
1 Light source, if the experiment is not conducted outdoors with natural light: e.g. basic device SUSE 4.0 or halogen spot light 150 W or overhead projector
2 Lab wires 1x red + 1x black
1 Multimeter for measurements of the charging and discharging with 2 lab wires
1 Folding rule and 1 stopp watch (or stopp watch in the smartphone) to determine the speed

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1. Charging of the GoldCap energy storage:

With a solar module with 4 solar cells max. in series connection or with the 2.5 V solar filling station SUSE 4.34 the GoldCap energy storage is charged, for this the switch has to be **switched to the back**, then the GoldCap energy storage is connected electrically to the binding post pair. The positive wire from the solar module is plugged into the red jack, the negative wire into the black jack of the vehicle.

Depending on light intensity the charging process takes just approx. 30 s to a few minutes, the GoldCap energy storage charges up to the module voltage. With a voltmeter at the green-black jack pair the charging process can be observed (measurement range 20 V DC). When the voltage does not increase anymore, the GoldCap is fully charged. Now the storage is charged, the switch is switched to the central position, so that the energy storage cannot discharge over the module, important! The wires are disconnected from the jacks.

2. Driving the vehicle:

The vehicle is placed on the ground, optimally on a smooth surface. The switch is switched to the front and now the vehicle starts to drive with high speed, becomes slower continuously and finally comes to a halt. The driving distance is 50 – approx. 100 m depending on the ground's texture.

3. Electric measurements on charging and discharging:

> **Caution! Before each measurement the capacitor should be discharged completely,**
> to do so **short-circuit** the green-black jack pair **for about 3 s!**

3.1 Voltage measurement while charging:

Use a voltmeter in the measurement range of 20 V DC.
The GoldCap storage should be empty before measuring, short-circuit it. Afterwards switch the switch to the central position. Connect both wires from the solar module and both wires of the voltmeter with the right polarity to the red-black jack pair. The voltmeter now shows the current module voltage. Now switch to "charge" by pushing the switch to the back. The voltage will minimize and then slowly increase while charging until the module voltage is reached again, then the energy storage is fully charged. This voltage change against time can also be measured well with a PC interface to obtain a charging curve.

Charging of the GoldCap energy storage
Measurement of the charging voltage in V

> The experiments can also be processed with the aid of Excel or the like!

t in s Time	0	5	10	15	20	25	30	35	40	45	50	55	60	65
V in V Voltage														

The graph can be drawn on the attached mm paper or displayed with Excel.

3.2 Voltage measurement while discharging:

Actually the voltmeter would have to go with the vehicle, that's impractical, therefor we jack the vehicle up in a way that the wheels can rotate freely and connect the voltmeter with crocodile clips to the green-black jack pair of the GoldCap energy storage.
Now we switch the switch to the front, the GoldCap energy storage discharges over the electric motor, the voltage decreases continuously from the module voltage to 0, at about 0.4 V the motor stops, but the discharging process continues over the coil in the motor to 0 V.

Discharging voltage in V

t in s Time	0	30	60	90	120	180	240	300	360	420	480	540	600
V in V Voltage													

The graph can be drawn on the attached mm paper or displayed with Excel.

3.3 Current measurement while charging:

Before the measurement the GoldCap should be completely discharged. Then an amperemeter in the measurement range of 10 A is looped-in into the positive line from the solar module, afterwards switch the switch to the central position. Connect both wires of the solar module to the red-black jack

pair. The amperemeter first shows 0 A, because the charging process has not yet begun. Now switch to "Charge" by pushing the switch to the back. The current is immediately high (in the beginning the short-circuit current of the solar module) and becomes smaller continuously down to 0, then the GoldCap is fully charged. This current development can also well be measured and displayed graphically with a PC interface.

Charging current in A

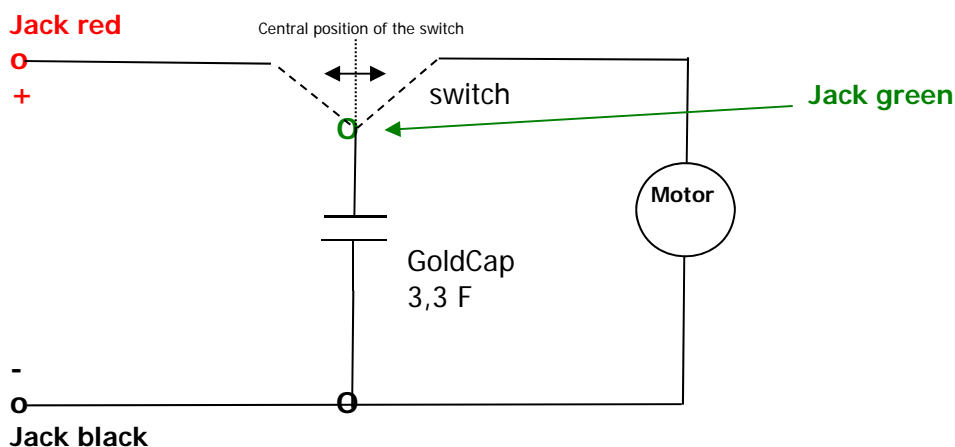| t in s Time	0	5	10	15	20	25	30	35	40	45	50	55	60
I in A Current													

The graph can be drawn on the attached mm paper or displayed with Excel.

Additional questions:

1. Display of the charging and discharging graphs with a PC interface (Cassy or Vernier), test this version in the NILS lab, the NILS consultant will happily advise you!

2. How can the efficiency factor be determined from the electric energy (in storage) over the mechanical energy (rotating wheels)? Think about a measuring setup! Build a measuring system and determine the efficiency factor!

3. How can the range of the vehicle be doubled? (Caution, maximum motor voltage 5 V DC!) Come up with a version. After consulting a NILS advisor build this version and test it!

4. How can the speed during the first 2 m test drive be determined? Come up with a version. After consulting a NILS advisor build this version and test it!

Caution! Voltages over 2.5 V DC or false polarity destroy the GoldCap energy storage.

The electric circuit of the vehicle:

mm- paper