Full Name: ..... Section or platoon: .....

Data sheet from the battery recharging experiment

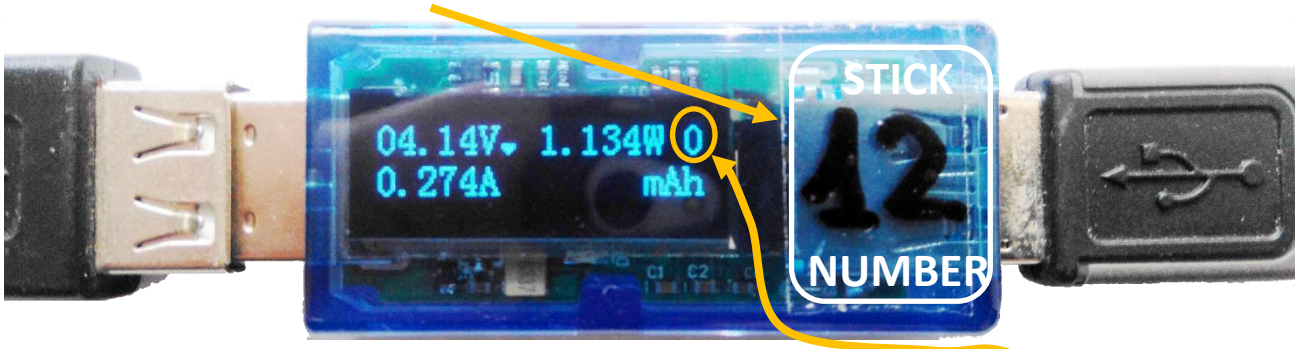
This activity is easy to perform with a regular charger (for example, an old USB charger or an USB computer port).

If quick chargers are used, the current, voltage and power will fluctuate greatly due to the charge algorithms. In this case, you might use averaged values although the tables were tougher to fill in.

Initial data acquisition #0: ***Start values (before plugging in the mobile phone or device)***

Hour (hh:mm)	Voltage (V)	Intensity (A)	Power (W)
t_0 =..... :	U_0 =.....V	$I_0 \approx 0$ A	$P_0 \approx 0$ W

Your USB stick number is : ..... (it is hand-written in black indelible marker in YOUR stick)



In the upper right corner of the meter, after the power, is displayed the figure 0? Yes: ☐ No: ☐

(If not so, push the back button repeatedly until this counter is set to 0).

Does voltage meet USB 2.0 specifications (4.75 V ≤ U_0 ≤ 5.25 V) before plugging in?

Yes: ☐ No: ☐

Data acquisition #1: ***Just after plugging in the mobile phone or device***

Hour (hh:mm)	(%)	Voltage (V)	Intensity (A)	Power (W)	Charge (mAh)	Energy (mWh)
t_1=..... :	B_1=.....%	U_1 =.....	I_1=.....	P_1=.....	$Q_1 \approx 0$ mAh	$E_1 \approx 0$ mWh

Does the device charge quickly? In other words, $U_1 > 5.25$ V and $I_1 > 1{,}5$ A Yes: ☐ No: ☐

The electric power is the product of the voltage by the intensity. Does the product of voltage by current coincide approximately with the power measured? I.e., $U_1 I_1 \approx P_1$? Yes: ☐ No: ☐

Is the charging voltage U_1 higher or lower than the initial voltage U_0? $U_1 > U_0$ ☐ $U_1 \leq U_0$ ☐

Note 1: The charge process is controlled by the software on the mobile device, and the values can vary greatly due to its algorithms. Moreover, some premium chargers communicate with the mobile device and they increase their voltage in order to achieve a quicker charge.

Note 2: For switching between the charge (mAh) and energy (mWh) display, the easiest procedure is to press the back button (yellow KEY circle sticker) for about 3 seconds (release the key just when a red led flashes). Alternatively, you can double-press the back button very quickly (less than 0,5 s between pushes). If you push the back button shorter or longer than due, you might have to set again the right corner counter to 0. The USB meter instruction sheet has detailed information about the effect of short (1 s), long (3 s), super-long (4 s) and extra-long (6 s) pushes.

Data acquisition #2: ***After charging for about an hour (set the telephone timer to warn you)***

Hour (hh:mm)	(%)	Voltage (V)	Intensity (A)	Power (W)	Charge (mAh)	Energy (mWh)
t_2=…… : ……	B_2=……%	U_2 =……	I_2=……	P_2=……	Q_2 = ……	E_2 = ……

Elapsed time in hours: $\Delta t = t_2 - t_1$ = …… h

The charge Q_2 transferred between times t_1 and t_2 is the integral of the current i(t).

Average current: $I_{average} = \frac{I_{average}\Delta t}{\Delta t} \approx \frac{\int_{t_1}^{t_2} i(t)\cdot dt}{\Delta t} = \frac{Q_2 - Q_1}{\Delta t} = \frac{\text{…… mAh}}{\text{…… h}} =$ …… mA = …… A

Is the average current between initial and second intensities? $I_2 \le I_{average} \le I_1$ Yes: ☐ No: ☐

The energy E transferred from time t_1 to time t_2 is the integral of the power P(t).

Average power: $P_{average} = \frac{P_{average}\Delta t}{\Delta t} \approx \frac{\int_{t_1}^{t_2} P(t)\cdot dt}{\Delta t} = \frac{E_2 - E_1}{\Delta t} = \frac{\text{…… mWh}}{\text{…… h}} =$ …… mW = …… W

Is the average power between initial and second power values? $P_2 \le P_{average} \le P_1$ Yes: ☐ No: ☐

Average voltage estimated as the ratio between transferred charge and energy:

$$U_{average} = \frac{U_{average} I_{average}}{I_{average}} \approx \frac{P_{average}}{I_{average}} = \frac{\text{W}}{\text{A}} = \text{……V}$$

Does this estimation match the voltage observed during the charging? Yes: ☐ No: ☐

Data acquisition #3: ***Fully charged battery (end of the charging process)***

Hour (hh:mm)	(%)	Voltage (V)	Intensity (A)	Power (W)	Charge (mAh)	Energy (mWh)
t_3=…… : ……	B_3≈ ……%	U_3 =……	$I_3 \approx 0$ A	$P_3 \approx 0$ W	Q_3 = ……	E_3 = ……

Estimate the battery maximum available energy in milliwatt-hours and in joules:

$$E_{max} = 100\frac{E_3 - E_1}{B_3 - B_1} = \text{…… mWh}$$

$$E_{max} = \text{……mWh} \cdot \frac{1\ \text{J/s}}{1000\ \text{mW}} \cdot \frac{3600\ \text{s}}{1\ \text{h}} = = \text{…… J}$$

How much battery charge does it imply if the average terminal voltage of the battery* is 4 V?

$$Q_{max} = \frac{E_{max}}{4\ \text{V}} = \frac{\text{mWh}}{4\ \text{V}} = \text{…… mAh}$$

Is Q_{max} similar to the battery capacity advertised in your phone? Yes: ☐ No: ☐

Does the current decrease when the end of charging is approaching? Yes: ☐ No: ☐

* *Li-Po battery voltage depends on its actual technology, temperature, charge state and current. The nominal capacity specification can be found on the internet (usual values are between 2000 mAh and 3500 mAh).*