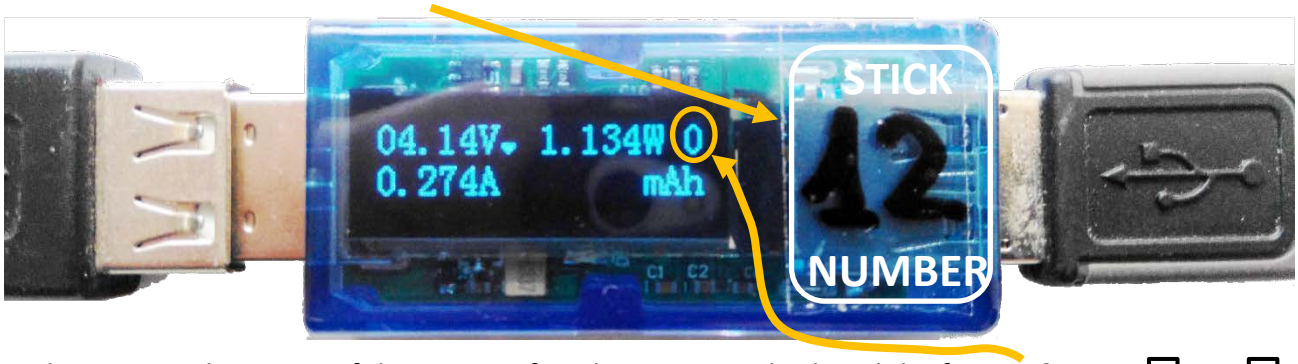
Full Name: ..... Section or platoon: .....

Data sheet from the battery recharging experiment

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: ☐

Does voltage meet USB 2.0 specifications? In other words: 4.75 V ≤ U_0 ≤ 5.25 V ? 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 voltage meet USB 2.0 specifications? In other words: 4.75 V ≤ U_1 ≤ 5.25 V ? Yes: ☐ No: ☐

Does the current meet the USB specifications for battery charging? I.e., 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? $U_1 > U_0$ ☐ $U_1 \leq U_0$ ☐

If $U_1 < U_0$, then estimate of the inner resistance of the USB port: $R = \frac{\Delta U}{\Delta I} = \frac{U_0 - U_1}{I_1 - I_0} = ...\Omega$

Note: some premium chargers compensate their internal voltage drop and their voltage can stay almost constant indistinctly of the current. Moreover, if the control compensates also for the resistance of the cable, the output voltage will rise slightly. In both cases, the charger can be considered an ideal power source (null resistance).

Data acquisition #2: ***After charging for 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 = ...

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

Average current in the time interval: $i_{average} = (I_1 + I_2)/2$ = …… A

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

$$Q_2 = \int_{t_1}^{t_2} i(t)\cdot dt \approx i_{average}\Delta t = \text{…… A …… h = ……Ah = ……mAh}$$

Does this estimation match the value Q_2 of the table ± 10 %? Yes: ☐ No: ☐

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

Average power in the time interval: $P_{average}$ = $(P_1 + P_2)/2$ = …… W

$$E_2 = \int_{t_1}^{t_2} P(t)\cdot dt \approx P_{average}\Delta t = \text{…… W …… h = ……Wh= ……mWh}$$

Does this estimation match the value E_2 of the table ± 10? Yes: ☐ No: ☐

Relationship between transferred charge and energy

$$u_{average} \approx \frac{\int_{t_1}^{t_2} u_{average} i(t)\cdot dt}{\int_{t_1}^{t_2} i(t)\cdot dt} \approx \frac{E_2}{Q_2} = \text{——————} = \text{……V}$$

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 = ……

Charge transferred, battery level and the net capacity of the battery

Estimate the maximum available charge:

$$Q_{available} = 100\frac{Q_3}{B_3 - B_1} = \text{…… mAh}$$

Is $Q_{available}$ slightly lower than the battery capacity advertised in your phone? Yes: ☐ No: ☐

(Look for the nominal capacity on the internet and, if you do not find it, assume a typical value of 2000 mAh).

How much power does it imply if the average terminal voltage of the battery is 3.8 V?

$$E_{max-disp} = U_{promedio} Q_{max-disp} = \text{…… mWh = …… Wh}$$

How many joules is the previous energy amount?

$$E_{max-disp} = \text{……Wh} \cdot 1\frac{J/s}{W} \cdot 3600\frac{s}{h} = = \text{…… J}$$

Is the current constant throughout all the charging process? Yes: ☐ No: ☐

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