


## The measurement procedure

1. At the beginning and during your session you should **check how much time is left** to wait (to gain your control) or till the time for your measurement&control has elapsed. [See C) for the details.]
2. Switch the mercury lamp ON if it is off as soon as possible because it needs approx. 4 min to warm up. You needn't to switch it off otherwise the next user would need to wait for too long for valid data. **The lamp runtime is limited** in time which you can read from the infoline! [See D) for the details.]
3. Set the photocurrent **amplification**: for first presentations and introductions the low amplification is recommended (10 MΩ), for precise measurements you should set the high amplification (100 MΩ).

### Photoelectric Effect

#### Volt-Ampere Characteristics of a Vacuum Phototube

A) 

B)

C) 1)

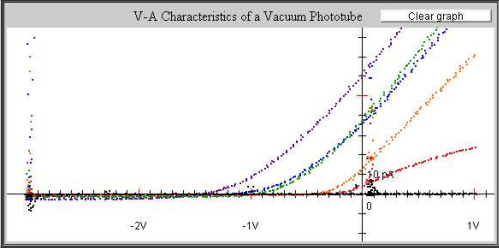
D) **Mercury lamp**  
The mercury lamp is ON. Data are valid.  
Lamp runtime limit: 59064 s left

E)

F) **LED 940 nm** (to be used with filter position F6)

**Amplification** (High amplification recommended)  
    
Amplification-resistor: 100 MegaOhm

000073

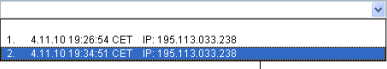
4) 

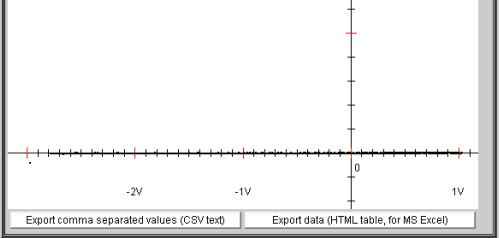
G)

H) **Control of the Voltage on the Phototube**  
0.063 V  
0.000 nA  
 (Recommended)

I) **Change of the Wavelength – Filter Selection**  
Desired filter no. 6 (F6)  
Current filter no. 6 (F6)  
F1 - 365 nm F2 - 405 nm F3 - 436 nm  
F4 - 546 nm F5 - 567 nm F6 - shielded

J) **Data Acquisition**  
2    
 Keep Experiment id

K)   
1. 4.11.10.19.26.54 CET IP: 195.113.033.238  
2. 4.11.10.19.34.51 CET IP: 195.113.033.238

8) 

9)

## Measurements:

4. You can **clear the graph** anytime you need otherwise you can **compare V-A** characteristics.
5. Here you select filters and well known **wavelengths** of light incident onto the photocathode. At the filter position F6 the phototube is well shielded so that you can measure and study:
  - a) the offset in the photocurrent (same for all measurements),
  - b) the leakage current as one of the contributions to the photocurrent. [See I) for the details.]
6. Here you **control the voltage** on the phototube to measure its V-A characteristics (for the selected well known wavelength or the shielded phototube – see the step 5).
  - a) **AUTO scan is recommended** for data with lower noise! You can stop it by the STOP button.
  - b) Manual control with the scrollbar will affect data with greater noise and perhaps (when you change the voltage too fast) charging/discharging of low-pass-filter capacitors. [See H) and I) for the details.]

## Data acquisition (DAQ)

7. Here you can **start and stop data recording** for further process (to determine the leakage current, stopping voltages and finally the Planck constant and the work function). [See J) for the details.]
8. You can browse your or someone else’s data records, compare them and select a desired record for downloading (see the step 9).
9. Click buttons to download the selected experimental data (step 8) for the further process in your office:
  - a) We would recommend to use the „**Export HTML values**“ button (click on the button with mouse perhaps with **CTRL pressed**, depending on your web browser settings!). A new explorer window opens with experimental data and settings information that can be downloaded in a simple way.

Voltage	Photocurrent	Wavelength	Resistor	No of meas.	RMSQ U	RMSQ I
U [V]	I [nA]	Lambda [nm]	MegaOhm	N	[V]	[nA]
-2,7422	-0,0017	365	100	2	0	0
-2,7559	-0,0018	365	100	2	0,0175	0
-2,7383	-0,0018	365	100	3	0,006	0
-2,7442	-0,0018	365	100	2	0,0214	0
-2,7383	-0,0018	365	100	3	0,0039	0,0001

RMSQ X ... Root Mean Square  $\sqrt{\frac{1}{N} \sum_{i=1}^N (\bar{X} - X_i)^2}$ . The values of U, I are the average values  $\bar{X} = \frac{1}{N} \sum_{i=1}^N X_i$ , N is specified.

*Example how to obtain the data under MS Windows (under the other OS similarly):*

- I) Click on the window with data (so that it is active).
- II) Press **CTRL+A** (so that all the data are selected).
- III) Press **CTRL+C** (so that all the data in selection are copied into clipboard).
- IV) Open MS-Excel-like processor and prepare data sheet for your records.
- V) Press **CTRL+V** to insert the data. The values should be inserted into correct cells automatically and easily. Then you can format cells (text alignment, ...).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Voltage	Photocurrent	Wavelength	Resistor	No of meas.	RMSQ U	RMSQ I		Voltage	Photocurrent	Wavelength	Resistor	No of meas.	RMSQ U	RMSQ I	
2	U [V]	I [nA]	Lambda [nm]	MegaOhm	N	[V]	[mA]		U [V]	I [nA]	Lambda [nm]	MegaOhm	N	[V]	[mA]	
3	-2,7422	-0,0017	365	100	2	0	0	-2,8086	-0,0008	405	100	1	0	0		
4	-2,7559	-0,0018	365	100	2	0,0175	0	-2,8125	-0,0008	405	100	2	0,0039	0		
5	-2,7383	-0,0018	365	100	3	0,006	0	-2,806	-0,0008	405	100	3	0,0057	0		
6	-2,7442	-0,0018	365	100	2	0,0214	0	-2,8144	-0,0008	405	100	2	0,0098	0,0001		

Notes: We started DAQ for filter F1 (365 nm), then we selected the cell **I1** in MS Excel work sheet and we pressed CTRL+V to insert experimental data for the filter F2 (the wavelength 405 nm).

Advanced users may appreciate export in the CSV format (comma separated values).

*For complete measurement repeat the steps 5–7 (perhaps 1 and 4) for each filter position F1–F6! Your data should be available (steps 8, 9) for downloading even after your time for control has elapsed.*

## Description and typical usage

- A) In the experiment view window you can see and check the **current filter position 1–6** on the left side of the field of view.
- B) **Red LED below** indicates that the LED 940 nm is lit. Although its infra-red light is not visible for eyes, it can be found in the field of view (especially during night-time) – it glows between the filter wheel and the input hole shielding of the phototube. Moreover, the red LED controlled in the box E) may serve for a **camera test** as well. (The last picture is usually a little delayed.)
- C) **Connection and control state:**  
 \* **Empty line** means that only you are connected (nobody else is in the queue). Your control and measurement are not limited in time. But if you have not pressed any button within **3 minutes** than your session will be ended by **time-out** message in all the buttons.  
 \* **A message** usually tells you for **how long you need to wait** till your control starts, or **how much time is left** for your measurement & control because somebody else is waiting in the queue. One user has **10 minutes** for his/her measurement if there is a queue.
- D) Here you may control the **mercury lamp** and check its state as well as the **validity of data**.  
 a) **The lamp is OFF**, thus data for filter positions F1–F5 are not valid. You can switch the lamp ON.  
 b) After the „Switch the lamp ON“ button is pressed the mercury lamp is **warming up** and the data for selected filter positions F1–F5 are not valid because the **signal-to-noise ratio (SNR)** is low. (Real values of the photocurrent are less than level of the noise, and thus they are unmeasurable.) The warming-up state takes **4 minutes**, you can study only the leakage current and check the offset (as with F6) and you should start your measurements preferably for filters F5 and F4 as late as possible.  
 c) In the normal state „**Lamp is ON**“ all data are valid and you can measure for all filter positions.  
 d) After „Switch the lamp OFF“ button is pressed or the runtime limit for the mercury lamp has elapsed, the lamp **cools down** for **4 min**. During this period of time it cannot be switched ON, you can study only the leakage current and the offset in photocurrent (as with F6).
- E) Here you can **control the LED 940 nm** to verify the threshold behaviour of the photoelectric effect, and perhaps to check whether the web-camera is operating OK (a picture change may be a little delayed, and you should take a *careful look during day-time*).
- F) Here you can set the **amplification**. For the measurement we recommend to set „**High amplif.**“ – the resistor 100 MegaOhms is set. For first explanations in a class we would recommend to set the low amplification so that other unwanted contributions are not seen.
- G) Graph window with your or somebody else's **measured Volt-Ampere characteristics**. On the left you can see **filter-capacitor discharging**. New points are added. The window can be cleared whenever by pressing the „**Clear graph**“ button.
- H) Here you can **control the voltage** on the phototube to measure V-A characteristics. You can set the voltage **manually** (using the scrollbar), or by pressing „**AUTO**“ you can start an **automatic scan** of V-A characteristics (from –3 V to +1 V or till the „**STOP**“ button is pressed) which provides **data with lower noise!** The values of the current voltage and photocurrent can be read on the right. The photocurrent scale is fixed and valid for high amplification but its calibration is not crucial. (Calibration was performed by the Keithley picoammeter 6487.)
- I) Here you can **select desired filter position F1-F6**. For the positions F1–F5 **well known wavelength** of light incident onto the photocathode is set, for the position **F6** the phototube is well **shielded** (even with the lamp ON) so that you can study the **leakage current and the offset in photocurrent**. You need to wait till the „Desired filter no.“ is physically set, i.e. it is equal to the „Current filter no.“ value that should correspond to the view of the experiment (the picture may be delayed); otherwise you need to edit downloaded data (the wavelength) manually. To ensure that the data are valid please read the max. voltage at zero photocurrent and compare it to the table below.
- J) Here you can **start and stop recording the experimental data** for further process. All the data measured within the period *between the START and STOP buttons are pressed* will be plotted just in one graph. Characteristics for various wavelengths are always in different colours so that they can be compared.
- K) Here you can have a look at your and perhaps somebody else's **recorded experimental data** and you can download it. Your data will be available till the re-start of the server. Usually, you should measure first and after the time for your control has elapsed you can browse and download your data for the further process (steps 8, 9).

For the available wavelengths the photocurrent starts to raise at these voltages (max. voltages at zero photocurrent):

F1: 365 nm ... (1,4 ± 0,1) V

F2: 405 nm ... (1,1 ± 0,1) V

F3: 436 nm ... (0,9 ± 0,1) V

F4: 546 nm ... (0,4 ± 0,1) V

F5: 568 nm ... (0,3 ± 0,1) V

You should determine the stopping voltages for various wavelengths more precisely, these values serve only for checking the validity of data (otherwise there might have been a problem with the filter wheel, etc.). Your result stopping voltages may depend on the state of the mercury lamp with luminophore (its temperature, run-time, ...) but they should always correspond to the values and errors above.