



Virtual laboratory



SCIENCE

Studying the laws
of the photoelectric effect

User
manual



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Terms and Definitions

The following general terms are used in the User Guide:

Virtual Laboratory	Virtual laboratory "Science", "Study of the laws of the photoelectric effect" section
Scene	A virtual three-dimensional space within which the user can interact with the Virtual Laboratory objects. The concept of "scene" also includes the data of the current research (positions of objects, their parameters, etc.)
Process simulation	The process of interaction between objects in a scene modeled in the Virtual Laboratory.
Camera	A scene tool with which the user observes everything that happens in the Virtual Laboratory.
Click	To make a click: — when using a mouse, move the mouse pointer to the object, press and release the left mouse button without moving the pointer; — when using a touchscreen, press the object with a finger and release it without moving the finger along the screen.
Toggle-button	A button that changes its state from inactive to active and vice versa after being pressed. The state is retained until the next interaction.

1 System requirements

Minimum system requirements for the Virtual laboratory "Science", "Study of the laws of the photoelectric effect" section are:

- **Processor:** Intel Ivy Bridge series / AMD Bulldozer series.
- **RAM:** 4 GB.
- **Graphics Card:**
 - Integrated: Intel HD Graphics 5000 / Intel Iris;
 - Discrete: GeForce 400 series or newer / Radeon HD 7000 series.
- **Screen Resolution:** 1920x1080 / 1920x1200 (4K and Retina displays require a more powerful graphics card for comfortable operation).
- **Supported Browsers:** Chrome, Yandex.Browser, Opera 44+, Firefox 51+, Edge 79+, Safari 15+.
- **Supported Operating Systems:**
 - Microsoft Windows 7 (x64 versions) with WebGL 2.0 driver support;
 - MacOS X "Snow Leopard" 10.6 with WebGL 2.0 driver support;
 - Linux or Debian with WebGL 2.0 driver support.

2 Virtual laboratory interface

The virtual laboratory is a three-dimensional virtual environment for conducting experiments to study the laws of the photoelectric effect.

The Virtual Laboratory interface (Figure 1) includes the following elements:

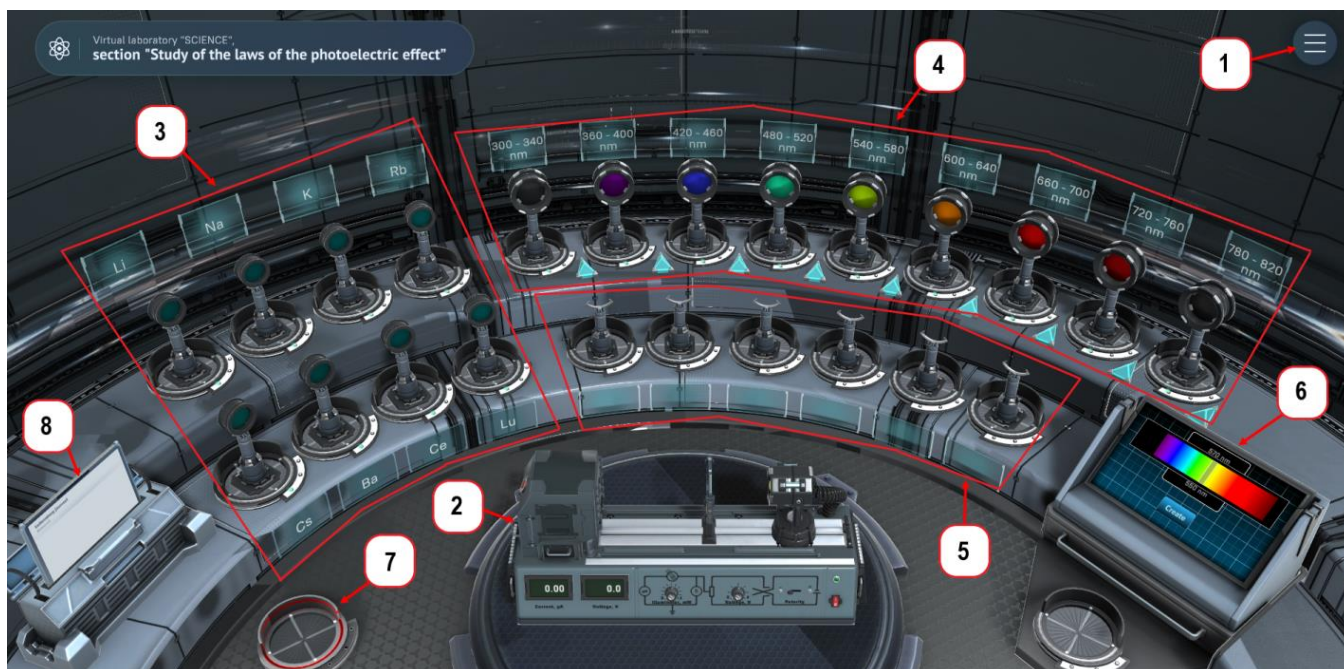


Figure 1 – Virtual laboratory "Science", "Study of the laws of the photoelectric effect" interface

- 1) **Main menu** (see [4 Main menu](#)).
- 2) **Stoletov installation** is a three-dimensional model that imitates the structure of a real device and repeats the logic of its behavior (see [5.1 Stoletoy installation](#)).
- 3) **Gallery of cathodes** (see [5.2 Cathode gallery](#)).
- 4) **Gallery of standard light filters** (see [5.3 Gallery of standard light filters](#)).
- 5) **Storage gallery** (see [5.4 Storage gallery](#)).
- 6) **Light filter generator** (see [5.5 Light filter generator](#)).
- 7) **Deletion slot**.
- 8) **Laboratory journal** (see [5.6 Laboratory journal](#)).

3 Camera control

The camera is controlled using the mouse or your fingers (when using a touch screen).

While the application is loading, the camera is in default position — focused at the center of the table (Figure 2).



Figure 2 – Camera in default position

To zoom in/out, rotate the mouse wheel. When using the touch screen, touch the screen with two fingers, spreading them apart or pressing them together.

To return the camera to the default position, click anywhere in the scene around the installation.

To move the camera, hold down the right mouse button anywhere in the scene, drag the pointer in the desired direction and release. The camera moves no more than 10° .

To focus the camera on the Stoletov installation, click on the device or rotate the mouse wheel (pinch your fingers when using the touch screen) until the camera moves to focus on the installation (Figure 3).

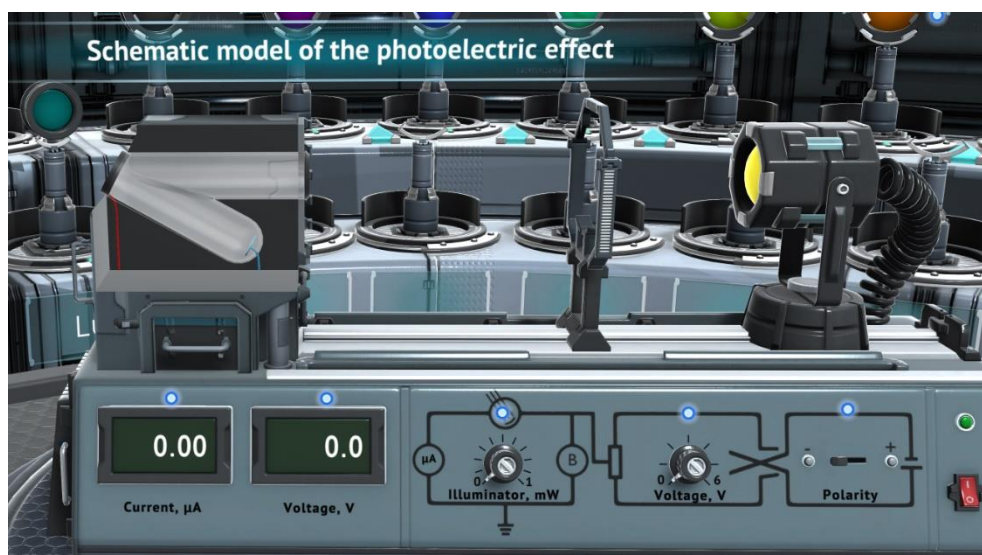


Figure 3 – Focusing the camera on the Stoletov installation

To focus the camera on the filter generator, click on the device or roll the mouse wheel (pinch your fingers when using a touch screen) until the camera moves to focus on the device (Figure 4).

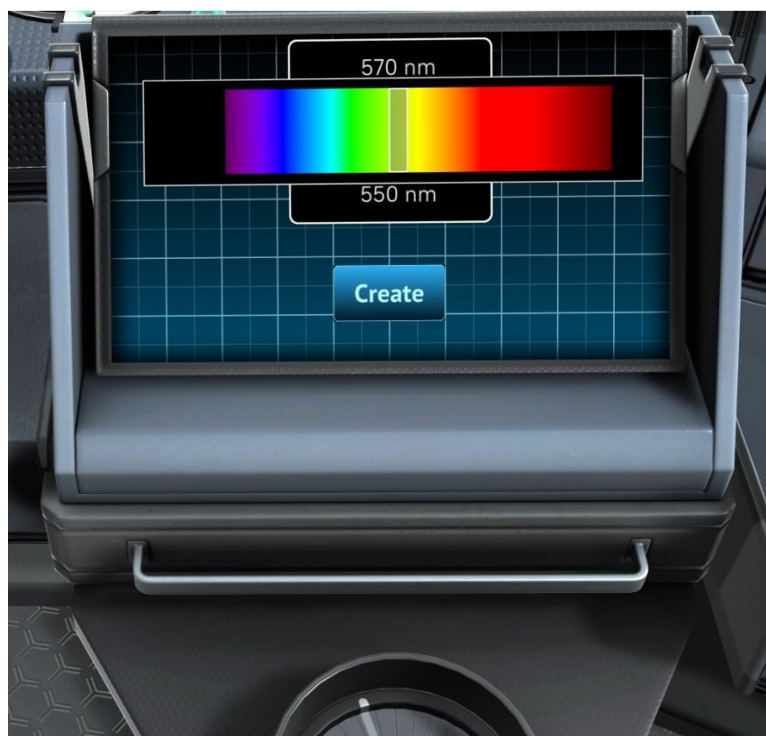


Figure 4 – Focusing the camera on the filter generator

To return the camera to its default position, roll the mouse wheel or spread your fingers apart. You can also return the camera to the default position by clicking on the installation or storage gallery (5 in Figure 1).

4 Main menu

To open the **Main menu**, press the  button in the upper right corner of the application (1 in Figure 1). The **Main menu** consists of the following elements (Figure 5):

- 1) Set of functional buttons:
 - **Instructions** button  (see [4.1 Instructions](#));
 - **Tips mode** button  (see [4.2 Tips mode](#));
 - **Virtual keyboard** button  (see [4.3 Virtual keyboard](#));
 - **Fullscreen mode** button  (see [4.4 Fullscreen mode](#)).
- 2) Username display field.
- 3) **Scene menu** (see [4.5 Scene menu](#)).

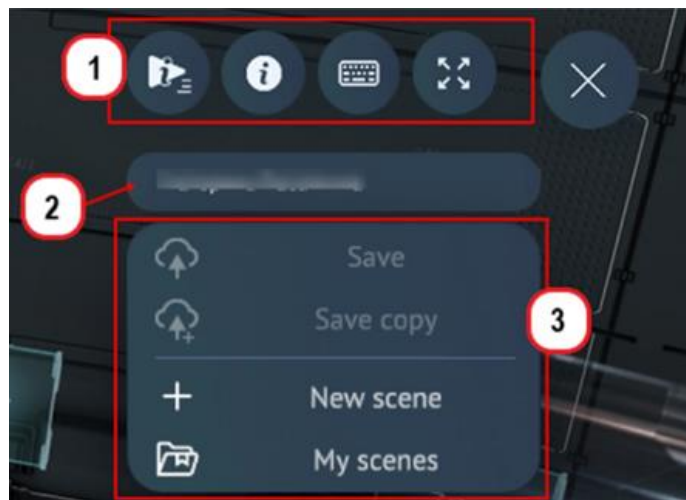


Figure 5 – Main menu

To close the **Main menu**, press the  button or click anywhere in the scene outside the menu.

4.1 Instructions

To select an instruction to view, click the **Instructions**  toggle-button in the **Main menu** (Figure 5). A video instruction selection menu will open (Figure 6). Read **User Manual** or watch video instructions to learn:

- how to work with the scene and equipment — "Introduction video";
- how to save created scenes and load saved scenes — "Saving and loading".

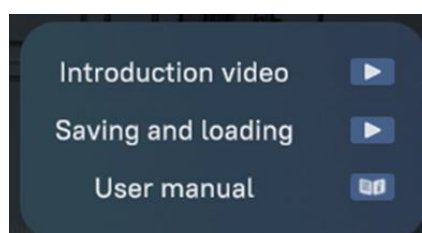


Figure 6 – Instruction selection menu

Click on the video title to start watching. The video will play on the screen over the scene. Control playback using the built-in player (Figure 7).



Figure 7 – Player control elements

To close the playback screen, click the **Close** button  in the top right corner of the screen.

To close the video instructions selection menu, press the  button.

4.2 Tips mode

To switch to the interactive tips mode, click the **Tips mode** toggle-button  in the **Main menu** (Figure 5). Tips points will appear next to the objects in the scene, and a description of the installation will open on the left side of the screen (Figure 8).

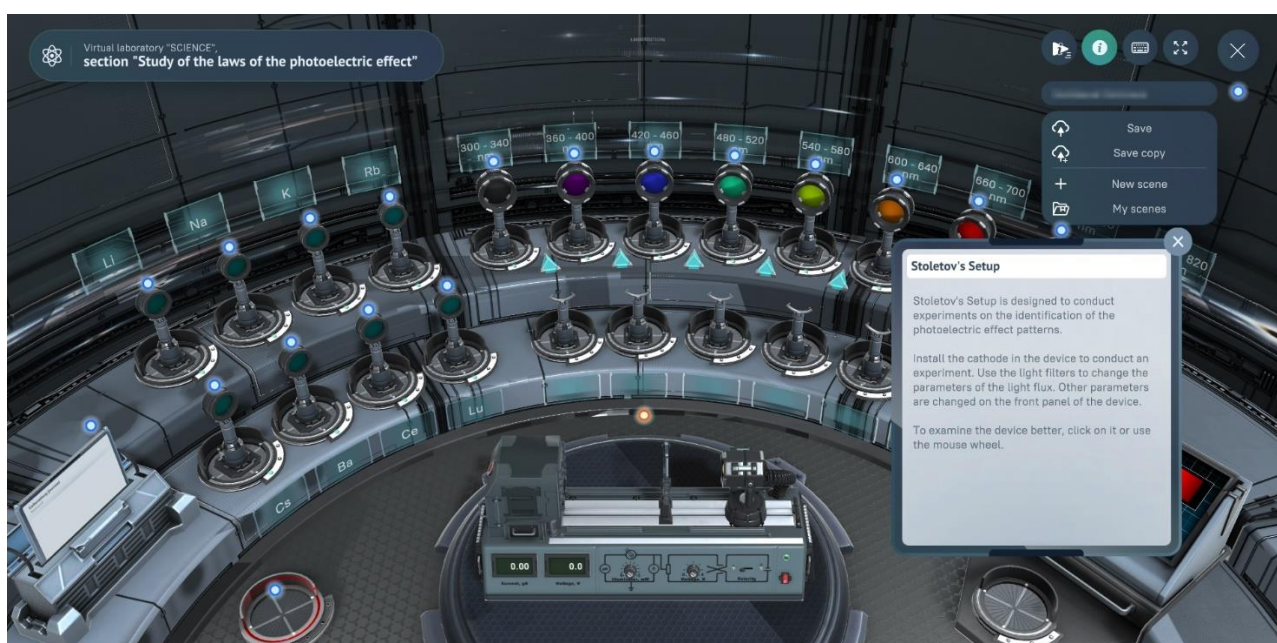


Figure 8 – Tips mode

To view a tip, press the point. To close the tip panel, press the tip point again or click on the cross in the upper right corner of the panel.

Tip points change their outline color depending on whether the user has viewed the tip or not (Figure 9):



Figure 9 – Point outline color options

- 1) Point with orange outline  — the tip is open on the screen (as in Figure 9).
- 2) If several objects have the same tips and one of these tips is currently open, then the tip points of other objects with the same tip will have a double outline: dotted gray and orange .
- 3) Point with gray outline  — the user previously viewed and closed the tip.
- 4) Point with blue outline  — the user has not yet viewed this tip.

To exit the **Tips mode**, press the  button in the **Main menu**.

4.3 Virtual keyboard

To switch to the **Virtual keyboard mode**, press the toggle-button  in the **Main menu** (Figure 5). In this mode, a virtual keyboard will appear on the screen automatically when you start to type in any text field (Figure 10).

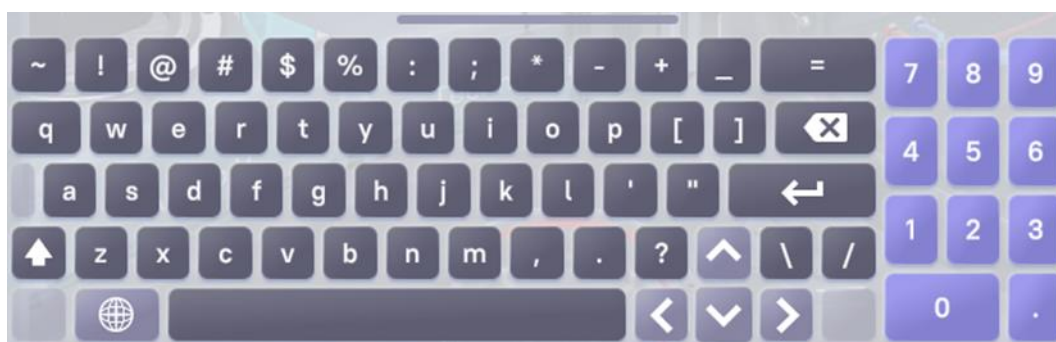


Figure 10 – Virtual keyboard

The virtual keyboard has two layouts: Latin and symbolic. The layout is changed using the button



on the virtual keyboard.

To exit the **Virtual keyboard mode**, press the button  in the **Main menu**.

4.4 Fullscreen mode

To enable full screen mode, press the **Fullscreen mode** button  in the **Main menu** (Figure 5). The application will expand to full screen, hiding the browser frame and the OS taskbar. To exit full screen mode, press the  button or the **Esc** button on your keyboard.

4.5 Scene menu

Working in the Virtual laboratory, you can:

- save the current scene (see [4.5.1 Saving a scene](#));
- save a copy of the current scene (see [4.5.2 Saving a copy of a scene](#));
- create a new scene (see [4.5.3 Creating a new scene](#));
- open the **My scenes** library (see [4.5.4 Viewing and loading user scenes](#)).

To go to one of the actions, select the desired item in the **Scene menu** (Figure 11).

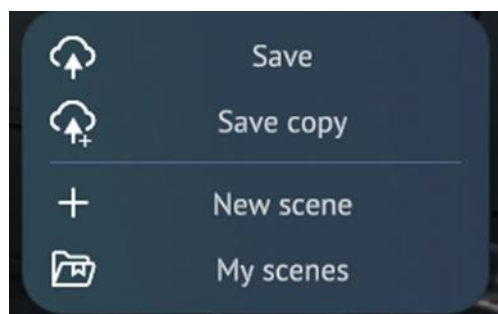


Figure 11 – Scene menu

To close the **Scene menu** and the **Main menu**, press the  button or click anywhere in the scene outside the menu.

4.5.1 Saving a scene

To save the created scene in the **My Scenes** library, select **Save** in the **Scene menu** (Figure 12). The scene state and laboratory journal's entries will be saved.

If the scene has already been saved, the application will overwrite the contents of the scene file. If the scene is being saved for the first time, the save scene form will open. (Figure 12).

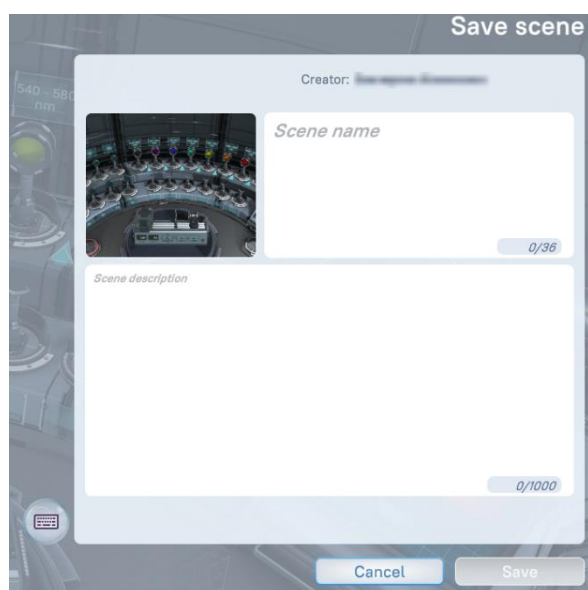


Figure 12 – Scene saving form

Enter the **name** of the scene to be saved (no more than 36 characters) and its **description** (no more than 1000 characters) in the appropriate fields of the form and click the  button.

You can use the virtual keyboard if necessary. To do so, use the  button, located to the left of the saving form. This button duplicates the  button on the **Main menu** (see 4.3 Virtual keyboard): if the **Main menu** had the virtual keyboard mode enabled , then the button next to the scene saving form will also be in the active state  and vice versa.

If you want to cancel the saving of the scene, press the  button.

4.5.2 Saving a copy of a scene

To save a copy of the scene in the **My Scenes** library, select **Save copy** in the **Main menu** (Figure 5). This will open the form for saving a copy of the scene, which is similar to the scene saving form (Figure 12).

If the scene is being saved for the first time, you must fill in the **Scene name** (no more than 36 characters) and **Scene description** (no more than 1000 characters) fields.

If the scene has already been saved, the previously saved scene name with the copy number in brackets will be displayed in the **Scene name** field — **Scene 1(3)**. The scene name and copy number can be adjusted or left unchanged.

Click the **Save** button to save a copy of the scene.

After you have saved a copy, you will continue to work with it, and the copy of the scene you worked with before will remain in the state of its last save.

If you do not need to save the scene copy, press the **Cancel** button.

4.5.3 Creating a new scene

To create a new scene, select **New scene** in the **Main menu** (Figure 5). If there are unsaved data, a window with a warning about possible data loss (Figure 13) will open.

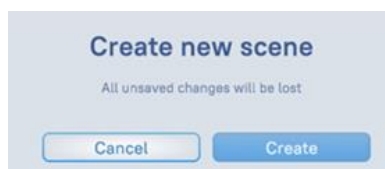


Figure 13 – Create new scene window

To avoid losing the current data, click the **Cancel** button and continue working with the scene. If you do not need to save the data, click the **Create** button, and all unsaved data will be lost and a new empty scene will open.

4.5.4 Viewing and loading user scenes

To view a list of scenes, select **My Scenes** in the **Main menu** (Figure 5). **My Scenes** library page (Figure 14) will open.

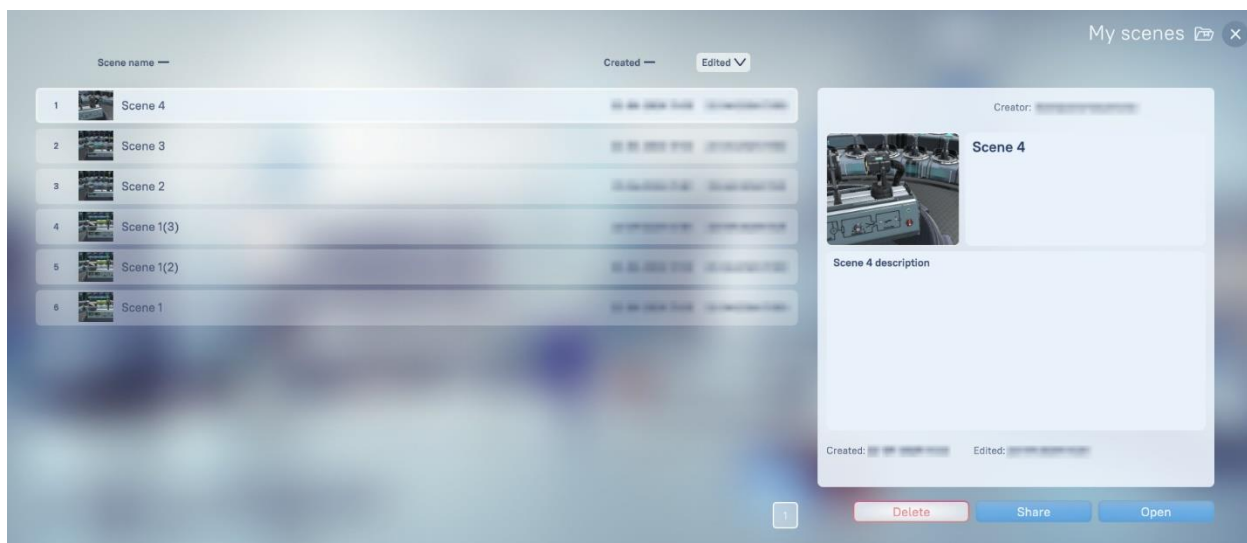
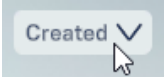


Figure 14 – My scenes library

On the left side of the screen, a list of all saved scenes will be displayed. You can sort the data by scene name, creation date, and modification date. To sort, click on the name of the corresponding table

column (Name, Created or Modified). The "-" icon next to the name will change to a check mark, indicating

the sorting direction .

If the list of scenes does not fit on one screen, it will be split into pages. Navigation through the pages is done using a series of buttons with page numbers, located to the right under the table.

The information about the selected scene is in the scene card to the right of the table. If necessary, you can open, delete, or share the selected scene using the buttons located under the scene card.

5 Objects description

5.1 Stoletov installation

The Stoletov installation is a device for studying the laws of the photoelectric effect. To conduct the study, install a cathode and a light filter and adjust the illuminator power controls, as well as the voltage and polarity of the device. To observe the photoelectric effect phenomena, focus the camera on the installation (see [3 Camera control](#)).

During the research process, you can adjust the installation parameters, use cathodes from different materials and light filters with different wavelengths, create your own light filters to study (see [5.5 Light filter generator](#)) and record the results of observations in the laboratory journal (see [5.6 Laboratory journal](#)).

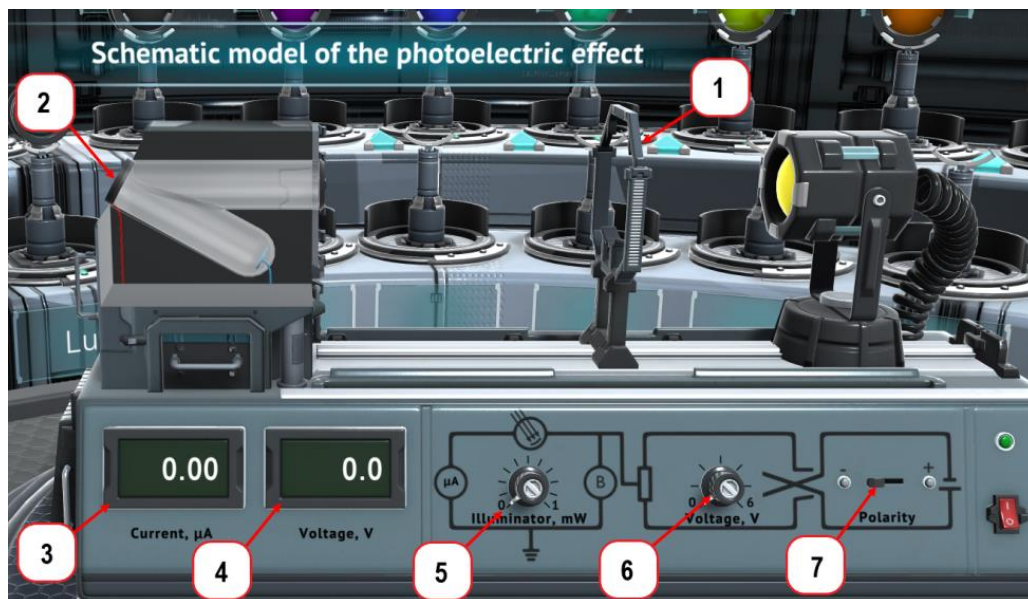


Figure 15 – Appearance of Stoletov installation

Stoletov installation consists of the following elements (Figure 15):

- 1) cathode holder;
- 2) filter holder;
- 3) digital ammeter;
- 4) digital voltmeter;
- 5) light regulator;
- 6) voltage regulator;
- 7) voltage direction switch.

To begin a study place the cathode (see [5.2 Cathode gallery](#)) in the cathode holder (1 in Figure 15), and the filter into the filter holder (2 in Figure 15) on the Stoletov installation. To do this, hold the cathode or filter with the left mouse button, drag the mouse pointer to the holder and release it (Figure 16).

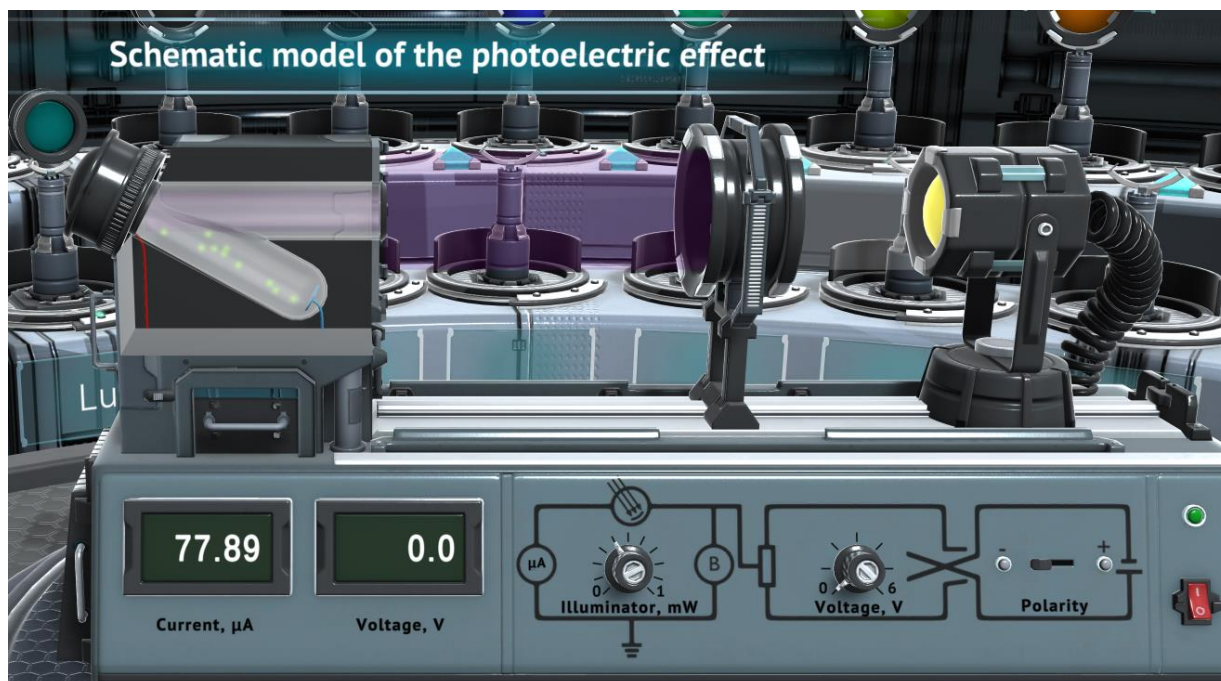


Figure 16 – Observation of the photoelectric effect on Stoletov installation

On the screen of a digital ammeter (3 in Figure 15) the current value of the photocurrent in the circuit is displayed (in microamps). To change the light output, hover your mouse over the regulator (5 in Figure 15) and rotate the mouse wheel or hold down the regulator with the left mouse button and turn it to the desired value: clockwise to increase the voltage, counterclockwise to decrease it.

- i Power adjustment range: 0–1 mW;
Adjustment accuracy: 0.1 mW.

To change the cathode voltage, hover your mouse over the regulator (6 in Figure 15) and rotate the mouse wheel or hold down the voltage regulator with the left mouse button and turn it to the desired value: clockwise to increase the voltage, counterclockwise to decrease it. The set value is displayed on the digital voltmeter screen (4 in Figure 15).

- i Voltage adjustment range: 0–6 V;
Adjustment accuracy: 0.1 V.

To change the power direction, use the voltage direction switch (7 in Figure 15). In the left position of the switch, the cathode is connected to the "-" voltage source, in the right position — to the "+" source.

5.2 Cathode gallery

Cathode gallery (3 in Figure 15) contains 8 cathodes made of different materials (Figure 17): cesium (Cs), barium (Ba), cerium (Ce), lutetium (Lu), lithium (Li), sodium (Na), potassium (K), rubidium (Rb). The cathode material is displayed on a card next to its holder.



Figure 17 – Cathodes

To move the cathode, hold down the left mouse button, drag the pointer to the desired location in the scene, and release it. The cathode can only be placed in the holder of the Stoletov installation (1 in Figure 15) or in a cathode gallery holder. It is not possible to remove the cathode from the scene.

5.3 Gallery of standard light filters

The gallery of standard filters contains 9 filters with a fixed wavelength range. The range of the filter is displayed on the card above it.

To move a light filter, hold down the left mouse button, drag the pointer to the desired location in the scene, and release it. The filter can be placed in the holder of Stoletov installation (2 in Figure 15) and in holders of the standard filter gallery and storage gallery (see [5.4 Storage gallery](#)). It is impossible to remove a standard light filter from a scene.



Figure 18 – Gallery of standard light filters

5.4 Storage gallery

Storage gallery holders are used for the temporary storage of light filters (5 in Figure 1). To place a light filter in the gallery, hold it with the left mouse button, move the mouse pointer to the gallery holder and release it.

The storage gallery can accommodate standard and custom filters (see [5.5 Light filter generator](#)). A card with the wavelength range of the filter is displayed under each filter holder. (Figure 19).



Figure 19 – Storage gallery

5.5 Light filter generator

Filter generator (6 in Figure 1) allows you to create filters with a selected wavelength range (Figure 20).

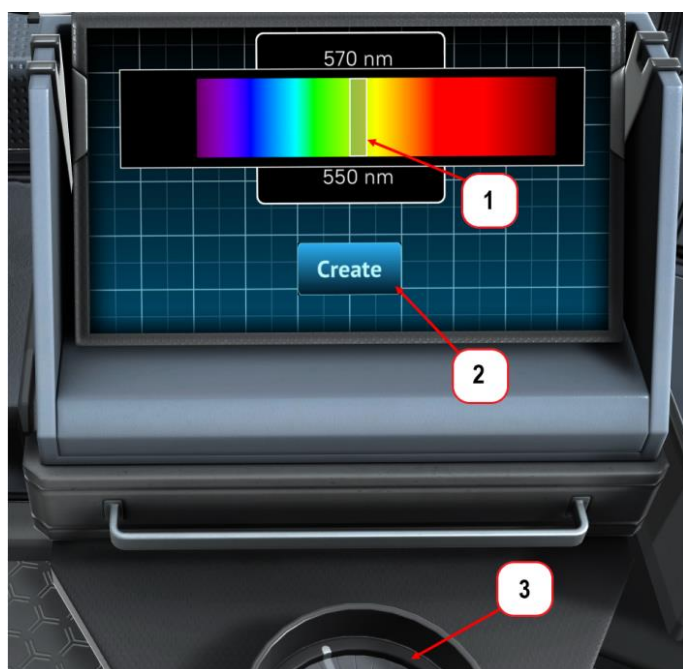


Figure 20 – Filter generator



Figure 21 – Created filter

To select the wavelength range of the filter, hold the slider on the spectrum (1 in Figure 20), pull to the right or left to the desired position and release it. The boundaries of the selected range are displayed above and below the spectrum. Click the **Create** button (2) to create a filter with the selected wavelength

range. The finished custom filter will appear in the filter slot (3). Custom filters can be placed in the storage gallery (see [5.4 Storage gallery](#)).

To remove a light filter from the scene, hold it with the left mouse button, drag it to the deletion slot (7 in Figure 1) and release it. You can only delete custom filters created by the filter generator. Standard light filters cannot be removed from a scene.



Figure 22 – Removing of a light filter

5.6 Laboratory journal

Laboratory journal (8 in Figure 1) is used to record the results of observing the spectrum of the substance under study. While working with the journal, you can:

- open the journal (see [5.6.1 Opening a journal](#));
- view the list of studies and delete unnecessary ones (see [5.6.2 Viewing the list of studies](#));
- create a new study (see [5.6.3 Creating a new study](#)).

5.6.1 Opening a journal



Figure 23 –Opening a journal

To open a journal, click on the journal or on its stand (Figure 23).

The journal will open on the left side of the screen (Figure 24). If journal entries have already been made in the current scene, they will be displayed in the open journal. If there were no entries, an empty journal will open.

To collapse an open journal, click on its stand or hold down the journal with the left mouse button and drag it off the screen border on the left.



Figure 24 – Lab journal on the left side of the screen

5.6.2 Viewing the list of studies

The list of studies is a set of cards, each of which contains data about the study: number, time and date of creation, type of the study, cathode material and the number of records about the results of the study (Figure 25).

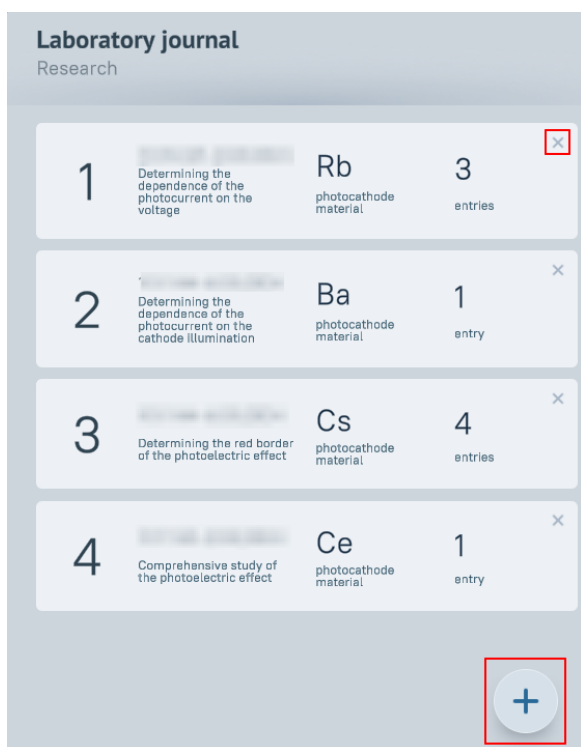


Figure 25 – The list of studies

5.6.3 Creating a new study

To create a new study, press the  button in the lower right corner of the journal (Figure 25). A panel with research options will open (Figure 26). To select a study type, click the appropriate button.

To open a study card, left-click on it.

To create a new study, press the  button in the lower right corner of the journal (Figure 25).

To delete a study, press the  button in the upper right corner of the study card.

If the list of studies does not fit on the screen, a scroll bar will appear to the right of the list. To view the list, hover your mouse over the journal and roll the mouse wheel or drag the scroll bar up or down. When using the touch screen, scroll through the list with your finger.

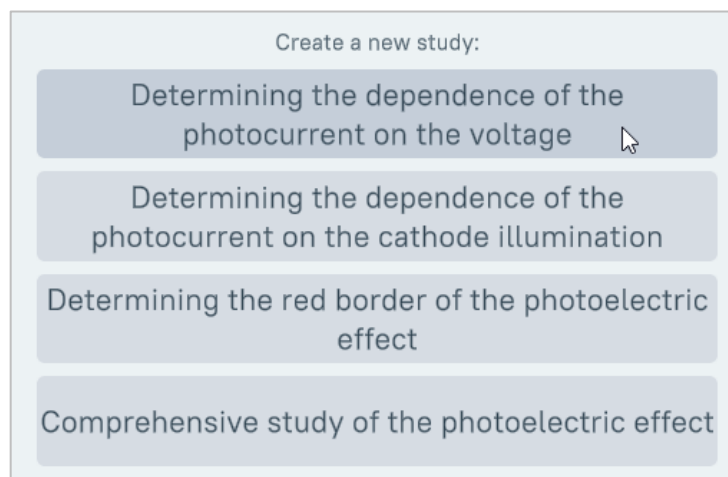


Figure 26 – Choosing the type of study

After this, the entry page will open. The appearance of the recording page depends on the type of study selected.

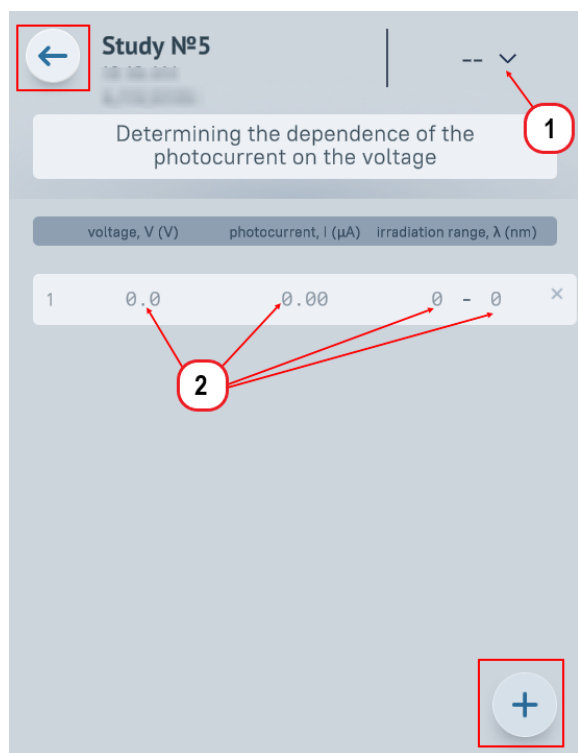


Figure 27 – Entries page

To add a line for more entries, press the button  in the lower right corner of the page (Figure 27).

To select the cathode material, click on the "--" icon in the upper right corner (1 in Figure 27) — the material selection menu will open (Figure 28). In the menu, click on the cathode material used in the study.

To enter data obtained as a result of the study, click on the corresponding input field (2 in Figure 27) and enter the value using the keyboard of your device or the virtual keyboard (see [4.3 Virtual keyboard](#)).

To delete a line of entries, press the  button in the upper right corner of the line. To return to the list of studies in the journal, press the  button in the upper left corner of the page.

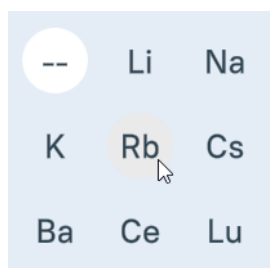


Figure 28 – Selecting a cathode material

6 The procedure for studying the photoelectric effect

To start observing the photoelectric effect (Figure 29), focus the camera on the device (see [3 Camera control](#)), place the cathode and light filter on the Stoletov installation and configure the device parameters (see [5.1 Stoletov installation](#)).

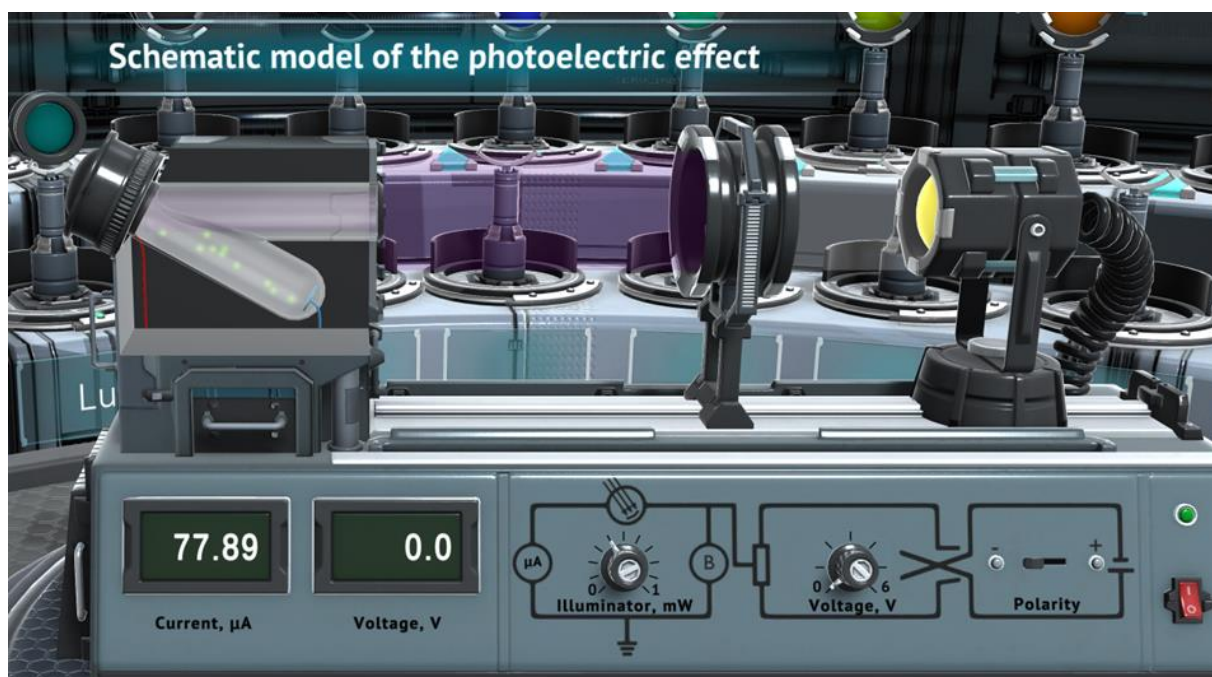


Figure 29 – Observation of the photoelectric effect phenomena

Use standard and custom filters (see [5.5 Light filter generator](#)). Record the observation results in the laboratory journal (see [5.6 Laboratory journal](#)).