



Virtual laboratory



SCIENCE

Study of the magnetic properties of "Hysteresis loop"

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 magnetic properties of the substance. Hysteresis loop" 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.)
Camera	A scene tool with which the user observes everything that happens in the Virtual laboratory.
Process simulation	The process of interaction of objects in a scene modeled 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 magnetic properties of the substance. Hysteresis loop" 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 virtual three-dimensional environment for conducting experiments to study the hysteresis loop and the Curie point of ferromagnetic materials.

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

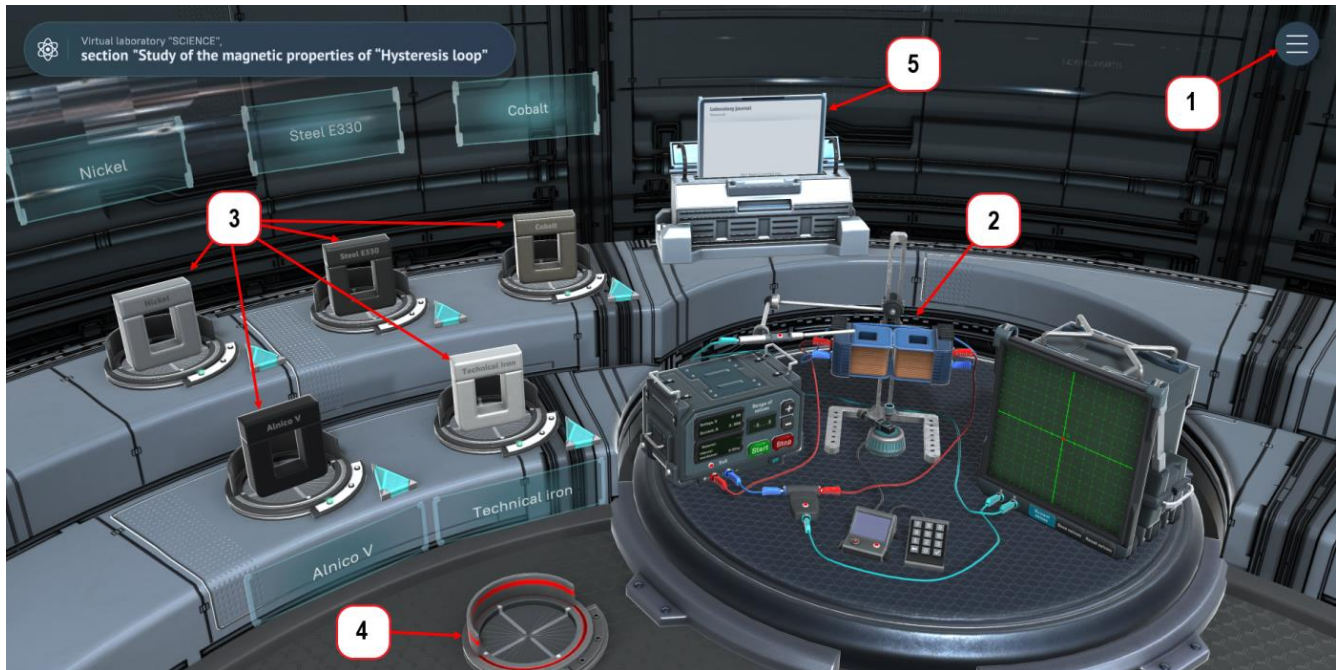


Figure 1 – Virtual laboratory interface

- 1) **Main menu** (see [4 Main menu](#)).
- 2) **Installation for studying magnetic properties** — three-dimensional models that imitate the structure and external properties of real devices and repeat the logic of their behavior (see [5.1 Installation for studying magnetic properties](#)).
- 3) **Core gallery** (see [5.2 Core gallery](#)).
- 4) **Deletion slot** (see [5.2 Core gallery](#)).
- 5) **Laboratory journal** (see [5.3 Laboratory journal](#)).

3 Camera control

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

While the application is loading, the camera is in **default position** — focused at the center of the table (Figure 1).

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 then release it. The camera moves no more than 5° .

To **focus the camera on the installation**, click on any device or rotate the mouse wheel (pinch your fingers when using the touch screen) until the camera moves to focus on the installation (Figure 2).

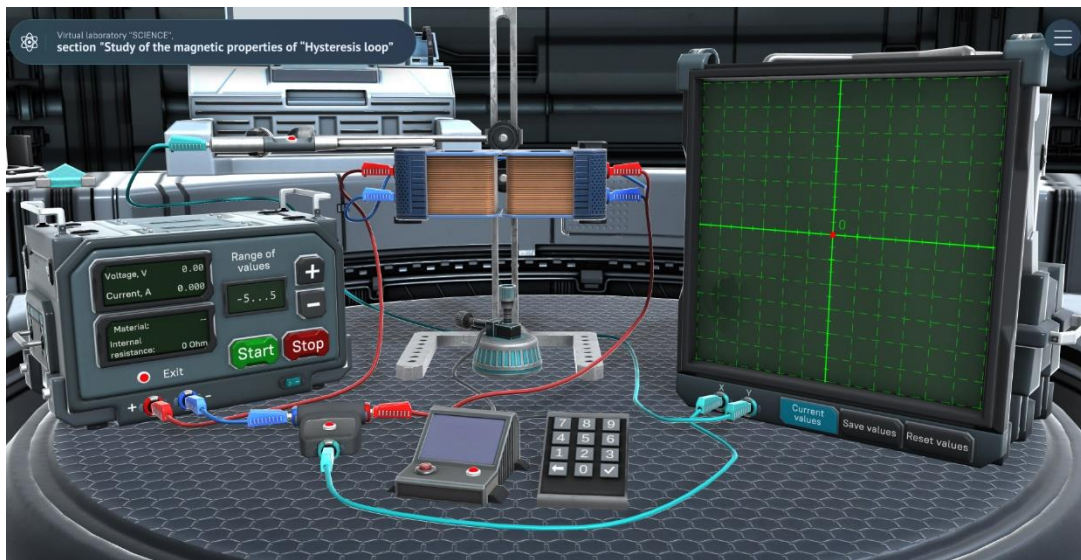


Figure 2 – Focusing the camera on the installation

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 devices or the place around them.

4 Main menu

To open the Main menu, press the  button in the upper right corner of the app (1 in Figure 1). The Main menu consists of the following elements (Figure 3):

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](#)).

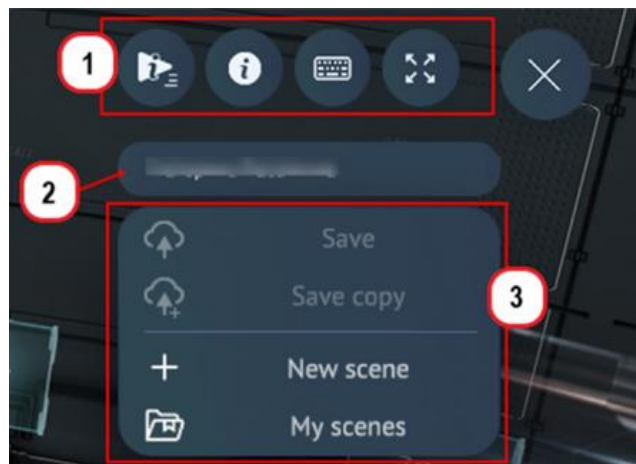


Figure 3 – Main menu

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 3). An instruction selection menu will open (Figure 4). 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".

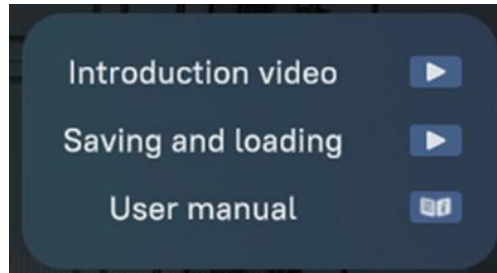


Figure 4 – Menu for selecting instructions

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 5).



Figure 5 – 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 3). 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 6).



Figure 6 – 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 7):

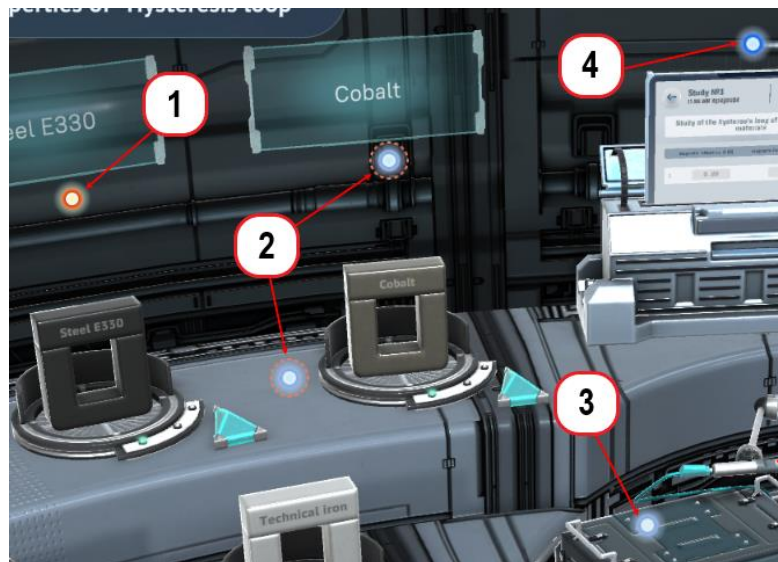


Figure 7 – Point outline color options

- 1) Point with orange outline  — the tip is open on the screen (as in 7).
- 2) If several objects have the same tooltips and one of these tooltips is currently open, then the tooltip points of other objects with the same tooltip 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 3). In this mode, a virtual keyboard will appear on the screen automatically when you start to type in any text field (Figure 8).

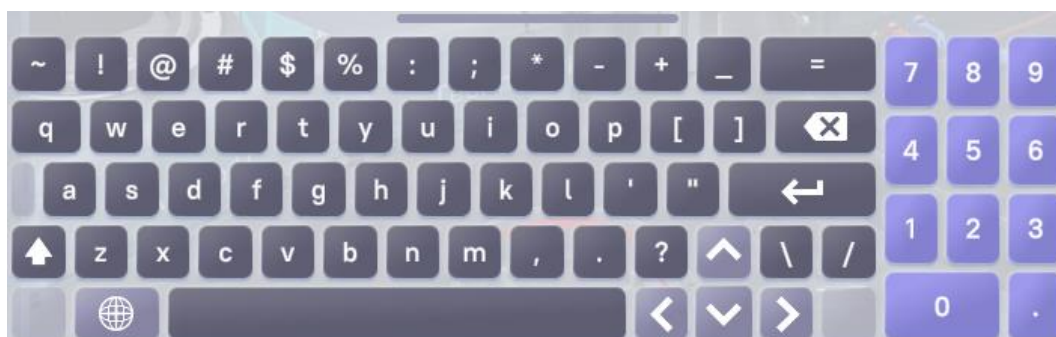


Figure 8 – Virtual keyboard

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 3). 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** 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 the 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 9).



Figure 9 – 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 9). 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 10).

Figure 10 – 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.

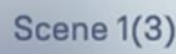
You can use the virtual keyboard if necessary. To do so, use the  button, located to the left of the saving form. This button duplicates the  button in the **Main menu** (see [4.3 Virtual keyboard](#)): if the **Main menu** had the virtual keyboard mode enabled , then the button next to the scene saving 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 9). This will open the form for saving a copy of the scene, which is similar to the scene saving form (Figure 10).

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 — . The scene name and copy number can be adjusted or left unchanged.

Click the  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  button.

4.5.3 Creating a new scene

To create a new scene, select **New scene** in the **Scene menu** (Figure 9). If there are unsaved data, a window with a warning about possible data loss (Figure 11) will open.



Figure 11 – Create new scene window

To avoid losing the current data, click the  button and continue working with the scene. If you do not need to save the data, click the  button, after which 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 9). **My scenes** library page (Figure 12) will open.

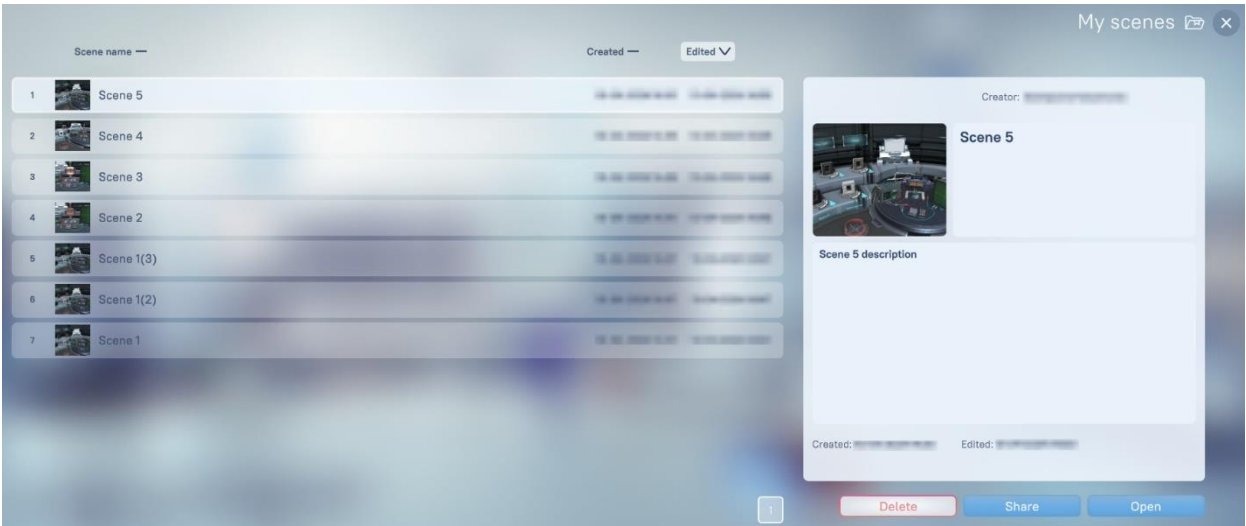


Figure 12 – My scenes library

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 Installation for studying magnetic properties

The installation for studying magnetic properties is a three-dimensional model that imitates the structure of real devices and repeats the logic of their behavior.

In the process of studying magnetic properties, you can study cores from different materials (see [5.2 Core gallery](#)) and record the observation results in the laboratory journal (see [5.3 Laboratory journal](#)).

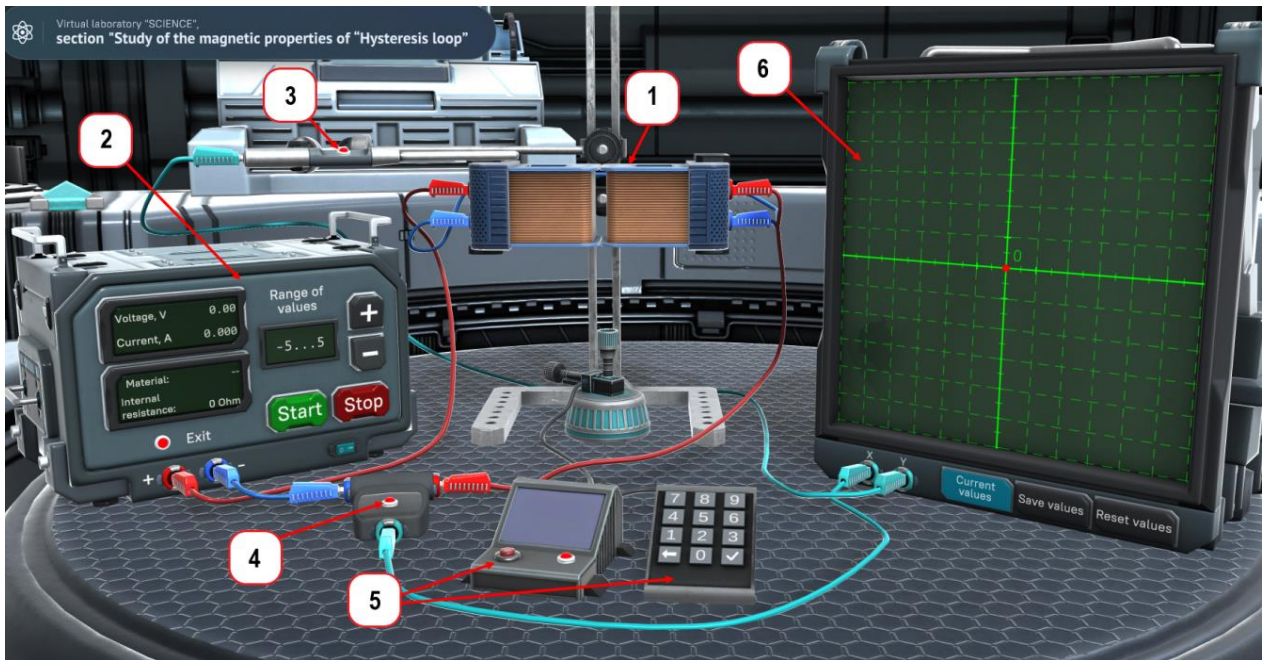


Figure 13 – Appearance of the installation for studying magnetic properties

The installation consists of the following elements (Figure 13):

- 1) coils with a core slot;
- 2) power source;
- 3) magnetic field sensor;
- 4) current sensor;
- 5) burner control unit;
- 6) information display.

To begin a study, place the core (see [5.2 Core gallery](#)) into the coils slot (1 in 13). To do this, hold the core with the left mouse button, drag the pointer over the coils and release — the core will be automatically installed in the slot (Figure 19).



Coil resistance is 2.5 Ohm.

The current in the coils is equal to the current at the output of the power source.

Power supply (2 in Figure 13) works in automatic mode. The device starts at 0V and increases the voltage by 1V until it reaches the upper limit of the set range. The source then decreases the value by 1V until it reaches the lower end of the range. At the lower limit of the range, the source changes direction again, etc. The period of value change is 1 second.

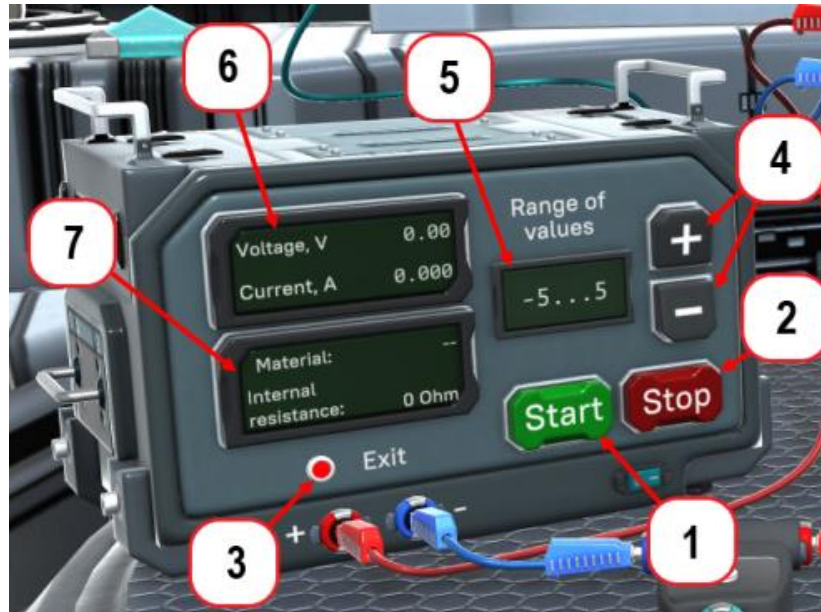


Figure 14 – Power supply

To start the power supply, press the Start button (1 in Figure 14), to stop it, press the Stop button (2). When the source is running, the indicator (3) lights up green, and when it stops, it lights up red.

To change output voltage range of the power supply, press the "+" and "-" buttons (4). The following voltage ranges are available:

- from -5 to 5 V (set by default);
- from -10 to 10 V;
- from -15 to 15 V;
- from -20 to 20 V.

The set value range will be displayed on the screen (5). The screen (6) displays the voltage values on the coils and the current in the circuit. The screen (7) displays information about the core installed in the coils: its material and internal resistance.

The magnetic field sensor (3 in Figure 13) lights up red if the magnetic induction of the core is 0. For other values of magnetic induction, the sensor lights up green.

The current sensor (4 in Figure 13) lights up red if there is no current in the circuit. If there is current in the circuit, the sensor lights up green.

Burner control unit (5 in Figure 13) consists of a digital panel and a screen (Figure 15). To turn on the control unit, press button (1). The top line of the screen (2) will display the current core temperature (20°C by default). Using the numeric keypad, enter the temperature to which you want the core to be heated — this value will be displayed on the bottom line of the screen (3). The maximum core temperature is 1200°C. To adjust the value, use the  button. To start the heating, press the  button (4) — the burner will start working (Figure 16). During heating, the indicator (5) lights green.

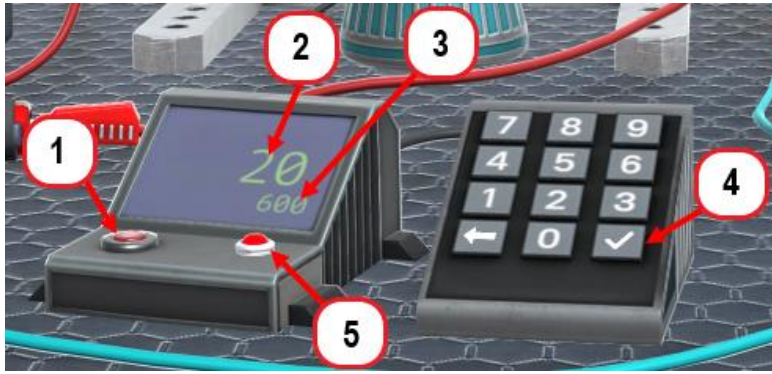


Figure 15 – Burner control unit

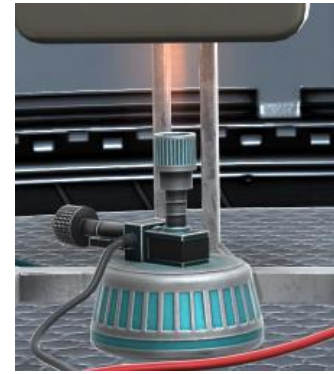


Figure 16 – Burner

The **informational display** (6 in Figure 13) displays the values of the magnetic field of the coils (H) and the magnetic induction of the core (B).

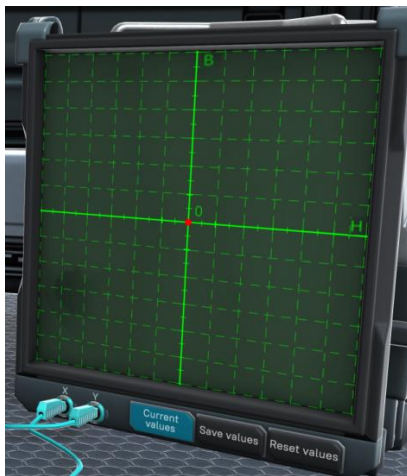


Figure 17 – Informational display

The display operates in two modes:

- in the "Current Values" mode, one red dot is displayed, corresponding to the H and B values at the current moment.
- in the "Save values" mode, a red dot of the current values of H and B and fainter points of the previous values of H and B are displayed. The points are connected by a smooth line and form a graph.

To select the value display mode or reset the values, click the corresponding button on the bottom panel of the display (Figure 17).

5.2 Core gallery

The core is a ferromagnet in the form of a composite structure for studying magnetic properties. Cores made of nickel, steel E330, cobalt, Alnico V and technical iron are available in the Virtual Laboratory. The names of the substances from which the cores are made are indicated on the cards in the gallery and on the top of the cores (Figure 18).



Figure 18 – Cores

To move a core, hold it with the left mouse button, drag the pointer to the desired location and release it. The core can be placed in the coils (Figure 19) or in the delete slot (Figure 20). Once the core is installed in the coils or deleted, a new sample of the same material is generated in its place in the gallery.

To remove a core from the scene, hold it with the left mouse button, move it to the deletion slot (6 in Figure 1) and release it.

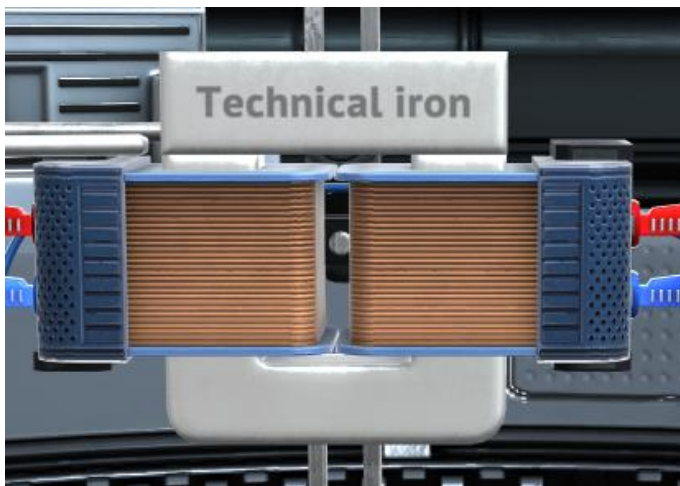


Figure 19 – Core installed in the coils



Figure 20 – Deleting the core

5.3 Laboratory journal

Laboratory journal (5 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 [5.3.1 Opening a journal](#));
- view the list of studies and delete unnecessary ones (see [5.3.2 Viewing the list of studies](#));
- create a new study (see [5.3.3 Creating a new study](#)).

5.3.1 Opening a journal



Figure 21 – Opening a journal

To open a journal, click on the journal or on its stand (Figure 21).

The journal will open on the left side of the screen (Figure 22). 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 22 – Lab journal

5.3.2 Viewing the list of studies

The list of studies is a set of cards (Figure 23), each of which contains data about the study: number, time and date of creation, name of the study, the core used and the number of records about the results of the study.

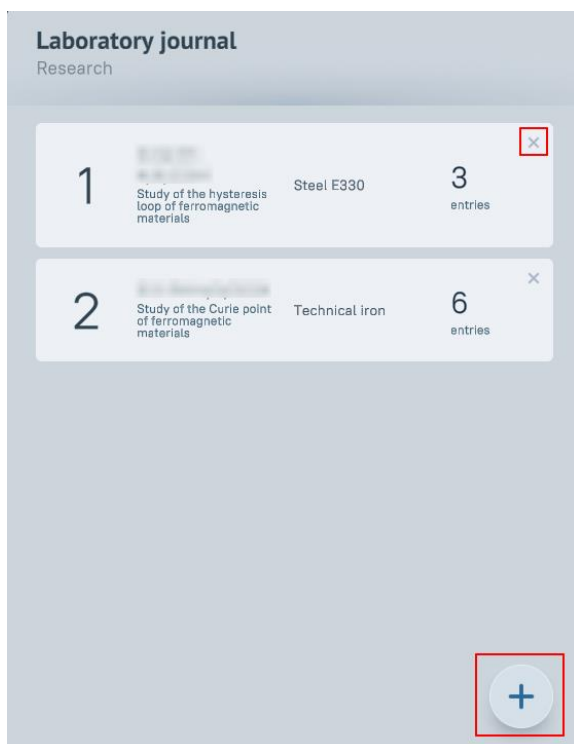


Figure 23 – The list of studies

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 23).

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.

5.3.3 Creating a new study

To create a new study, click the  button in the lower right corner of the journal (Figure 23) — a panel with study options will open (Figure 24). To select the type of study, click the corresponding button.

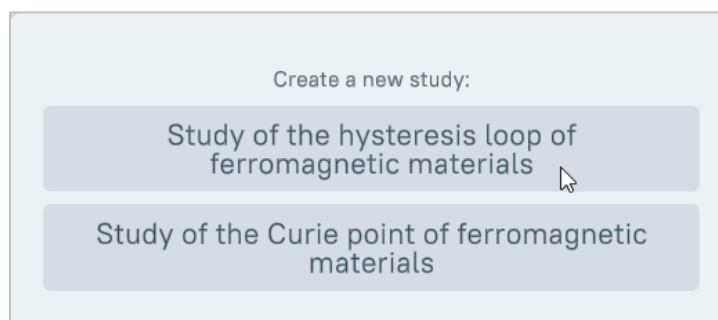


Figure 24 – Select the type of study

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

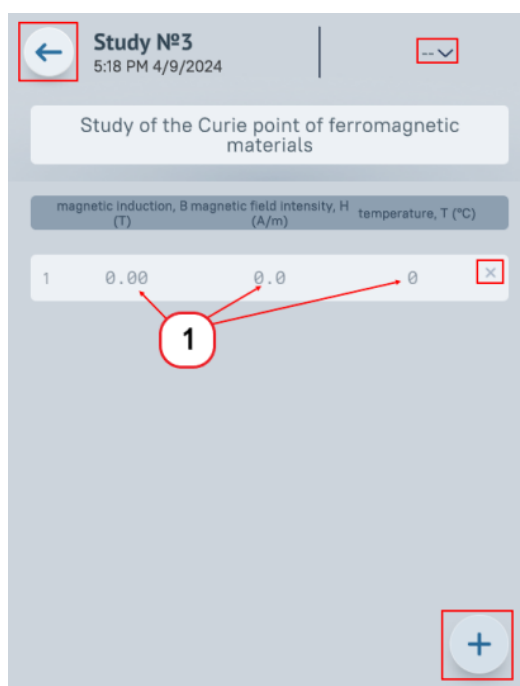


Figure 25 – Entry page



Figure 26 – Core material selection menu

To add a line for more entries, press the button  in the lower right corner of the page (Figure 25).

To select the material of the cores used, click on the icon  in the upper right corner (1 in Figure 25) — the core material selection menu will open (Figure 26). In the menu, click on the desired material.

To enter data obtained as a result of the study, click on the corresponding input field (2 in Figure 25) 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.

6 Procedure for studying the magnetic properties of a substance

6.1 Study of the hysteresis loop of ferromagnetic materials

To observe the hysteresis loop of ferromagnetic materials (Figure 27), follow these steps:

- 1) focus the camera on the installation (see [3 Camera control](#));
- 2) place the core into the coils (see [5.2 Core gallery](#));
- 3) set the desired voltage range on the power supply and start it (see [5.1 Installation for studying magnetic properties](#));
- 4) select the mode for displaying the obtained values on the information display;
- 5) observe the graph on the informational display. If necessary, record results in the laboratory journal. (see [5.3 Laboratory journal](#)). It is recommended to test the core in four different voltage ranges.



Figure 27 – Study of the hysteresis loop

6.2 Study of the Curie point of ferromagnetic materials

To observe the Curie point of ferromagnetic materials (Figure 28), follow these steps:

- 1) focus the camera on the installation (see [3 Camera control](#));
- 2) place the core into the coils (see [5.2 Core gallery](#));
- 3) turn on the burner control unit (see [5.1 Installation for studying magnetic properties](#));
- 4) set the temperature to which the core needs to be heated and start heating;
- 5) set the range from -20 V to 20 V on the power supply and start it;
- 6) select the mode for displaying the obtained values on the informational display;

- 7) observe the change in the graph, gradually increasing the burner temperature to a value at which the hysteresis loop completely turns into a straight line. If necessary, record results in the laboratory journal. (see [5.3 Laboratory journal](#)).

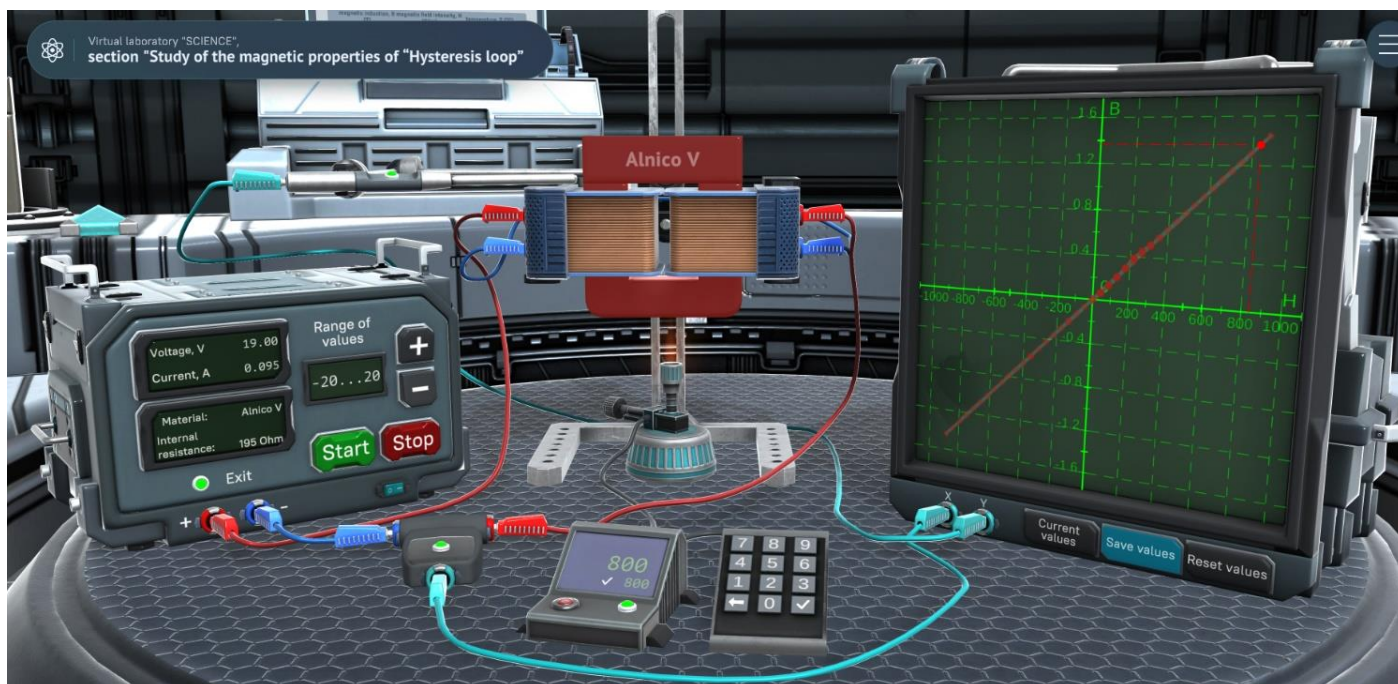


Figure 28 – Study of the Curie point