



Virtual laboratory



PHYSICS

Electromagnetic Field. Faraday

User
manual

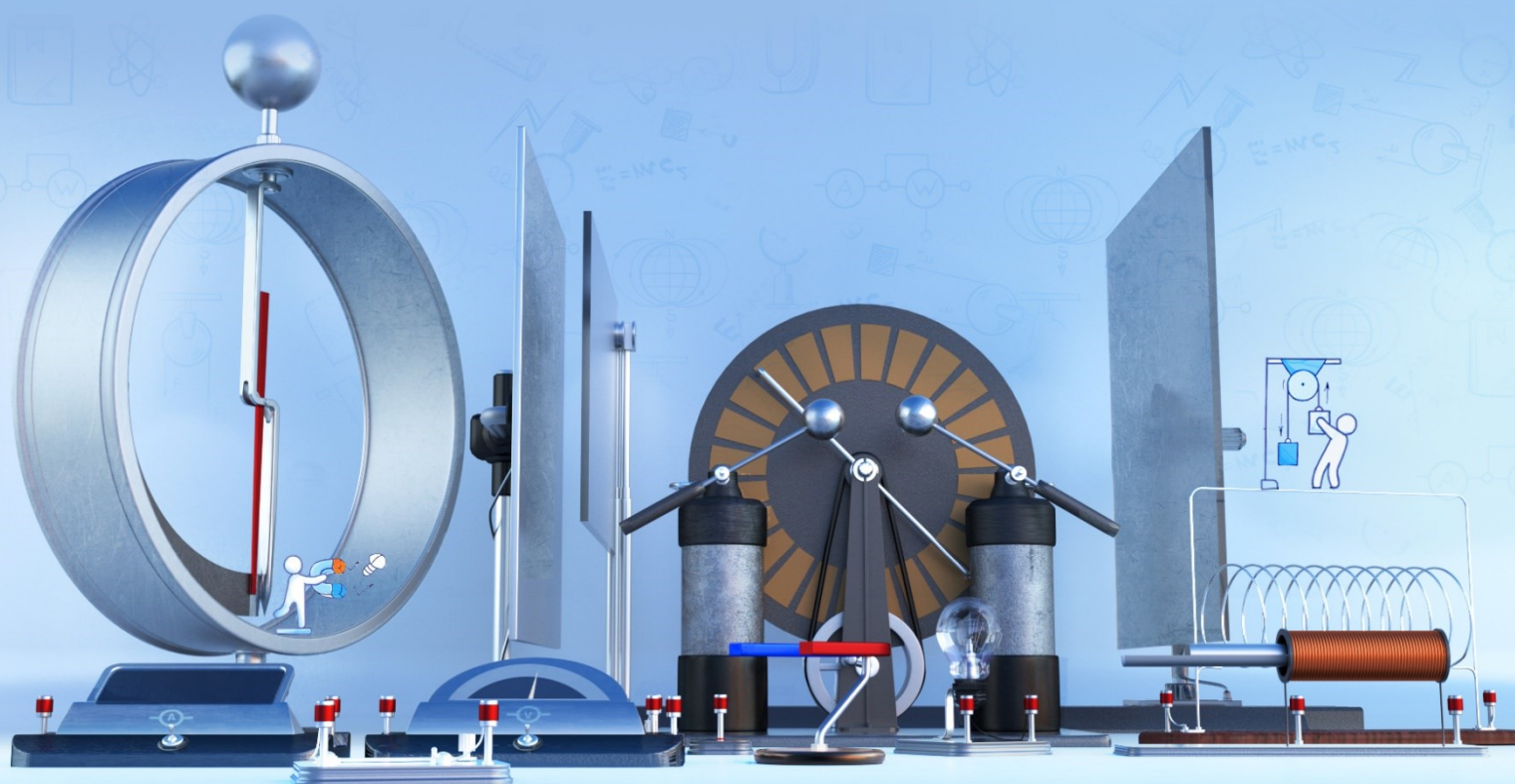


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Terms and definitions

The following common terms and definitions are used in the User's Guide:

Term	Definition
Virtual lab	Appendix Virtual laboratory “Physics” , section “Electromagnetic Field. Faraday”
Scene	Virtual three-dimensional space, where the user can interact with Virtual Lab objects, as well as data of the current study (positions of objects, their parameters, etc.)
Workspace	The part of the scene, where the user can place and interact with Virtual Lab objects. The application workspace consists of a desktop and a shelf
Process simulation	The process of interaction of objects in the scene modeled in the Virtual Lab
Camera	Scene tool, which allows the user to observe everything going on in the Virtual Lab
Click	The action to take: – when using the mouse — move the mouse pointer to the object, press and release the <u>left mouse button</u> without moving the pointer; – when using the touch screen — press your finger on the object and release without moving your finger
Toggle button	A type of button that changes its state from inactive to active and vice versa when the button is pressed. The state is saved until the next press

1 System Requirements

Minimum system requirements for the application **Virtual laboratory “Physics”, section “Electromagnetic Field. Faraday”** are as follows:

- **Processor:** Intel Ivy Bridge series / AMD Bulldozer series and newer.
- **RAM:** 4GB or more.
- Graphics card:
 - integrated: Intel HD Graphics 5000 / Intel Iris and later;
 - discrete: GeForce 400 series or newer / Radeon HD 7000 series or newer.
- **Screen resolution:** 1920x1080 / 1920x1200 and larger (4K and Retina screens require a higher power 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) or higher with WebGL 2.0 driver support;
 - MacOS X Snow Leopard 10.6 or higher with WebGL 2.0 driver support;
 - Linux or Debian with WebGL 2.0 driver support.

2 Application interface

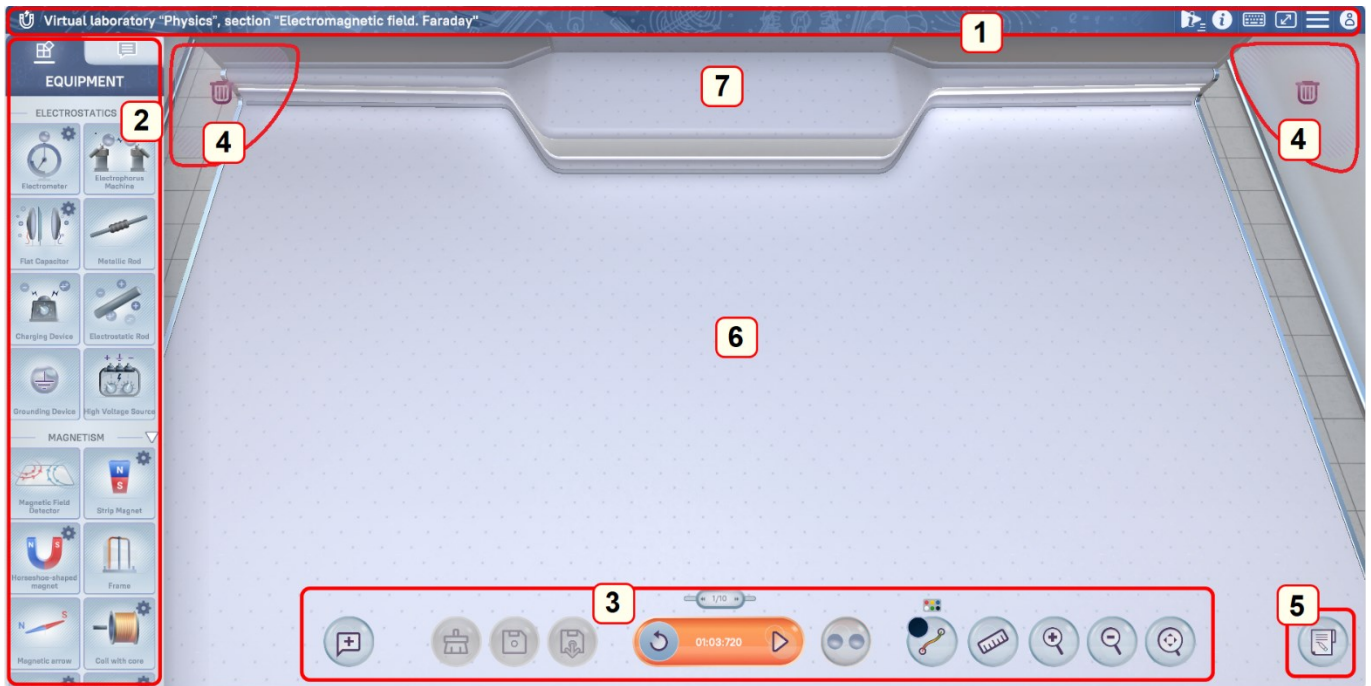


Figure 1 – Virtual Lab interface

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

- 1) The **Application Header panel** contains the Virtual Lab logo and name (left) and a set of functional buttons (right) (see section 13 “Application Header panel”).
- 2) The **component tab** has two tabs (see section 6 “Components panel”):
 -  the **Equipment** tab contains instrument cards that can be used in the scene (see section 8 “Describing the objects”).
 -  the **Comments** tab contains all comments to the scene (see 6.3 “Comments tab”).
- 3) The **control panel** buttons for scene control and process simulation (see section 5 “Control panel”).
- 4) **Object removal zones** (see 7.5 “Removing objects”).
- 5) **Scene card button** (see section 4 “Scene card”).
- 6) The **Desktop** is the part of the scene, where you can create schematics from the available equipment and interact with them. Equipment from all categories except for **Electrostatics** can be placed on the desktop.
- 7) **Shelf** is a raised back part of the desktop for placing devices from the **Electrostatics** category and creating circuits from them.

3 Application Header panel

The **Application Header** panel (Figure 2) contains the Virtual Lab logo and name (left) and a set of functional buttons on the right:



Figure 2 – Function buttons of the Application Header panel

- button to call up video tutorials  (see 3.1 “Video Instruction”);
- button to enable/disable the tips mode  (see 3.2 “Tips mode”);
- button to enable/disable the virtual keyboard mode  (see 3.3 “Virtual Keyboard”);
- button to enable/disable the fullscreen mode  (see 3.4 “Fullscreen mode”);
- button to call up the scene menu  (see 3.5 “Scene menu”);
- profile control button  (see 3.6 “User Profile”).

3.1 Video Instruction

With this menu you can:

- watch the video tutorial on working with the stage and equipment — **Introduction video**;
- watch the video tutorial to learn how to save created scenes and load saved scenes — **Saving and loading**;
- read how to use the application — **User manual**.

To select educational material, click the **Video Instruction** toggle button  on the **Application Header** panel. A menu for selecting educational material will open (Figure 3).

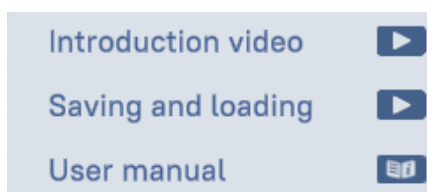


Figure 3 – Educational material selection menu

Click on the title of the desired video to start watching. The video will play on the screen on top of the scene. Control playback with the built-in player (Figure 4).

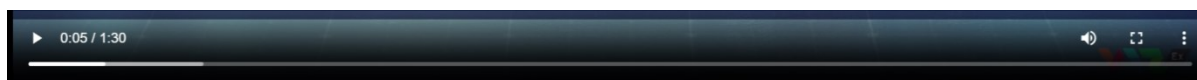


Figure 4 – Player controls

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

3.2 Tips mode

To switch to the interactive tips mode, click the **Tips** toggle button  on the **Application Header** panel. In the scene, tips points will appear next to the objects (Figure 5).



Figure 5 – Tips mode

To open a tip about the desired object, click on the point next to it. To close the tip panel, click the cross in the upper right corner of the panel or click the tip point again.

Tips points change the outline color depending on how the user views the tip (Figure 6):

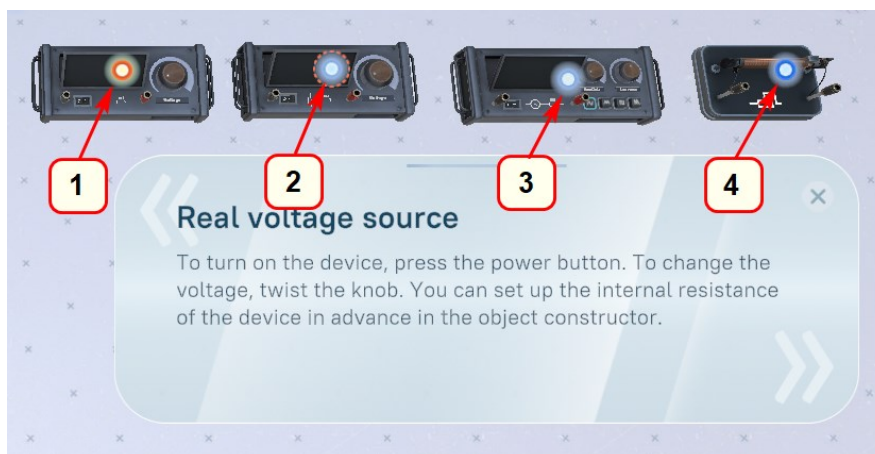


Figure 6 – Point outline color options

- 1) Orange outline point  — the tip point is open on the screen (as in 6).
- 2) If several objects have the same tips, and one of such tips is currently open, the tips points of other objects with the same tip will have a double outline: gray and orange dashed .
- 3) Gray outline point  — the user has previously viewed and closed the tip.
- 4) Blue outline point  — the user has not yet viewed this tip.

Besides, the Virtual Lab has three hidden icons with tips (Figure 7): **Moving objects** (1), **Moving around the scene** (2), **Buttons, sliders, handles** (3). They are only visible in tips mode.



Figure 7 – Icons with tips at the top of the workspace

To exit tips mode, click button  on the **Application Header** panel.

3.3 Virtual Keyboard

To switch to the virtual keyboard mode, press toggle button  in the **Application Header** panel. In this mode, the virtual keyboard will appear automatically when you type in any text field (Figure 8).



Figure 8 – Virtual Keyboard

The virtual keyboard has two layouts: Latin and Symbolic. To switch the layout, press button  on the virtual keyboard.

To exit the virtual keyboard mode, click button  on the **Application Header** panel.

3.4 Fullscreen mode

To enable fullscreen mode, click **Fullscreen** button  on the **Application Header** panel. The application will be expanded to fullscreen; all other elements of the browser and your device's desktop will be hidden. To exit fullscreen mode, press button  or the **Esc** key on the keyboard again.

3.5 Scene menu

Working in the Virtual Lab, you can:

- save the current scene (see 3.5.1 “Saving a scene”);
- save a copy of the current scene (see 3.5.2 “Saving a copy of the scene”);
- create a new scene (see 3.5.3 “Creating a new scene”);

- open the **My scenes** library (see 3.5.4 “Viewing and loading user scenes”);
- share a link to the current scene (see 3.5.5 “Saving a link to a scene”).

To switch to one of the actions, click button  on the **Application Header** panel and select the required item of the scene menu (Figure 9).

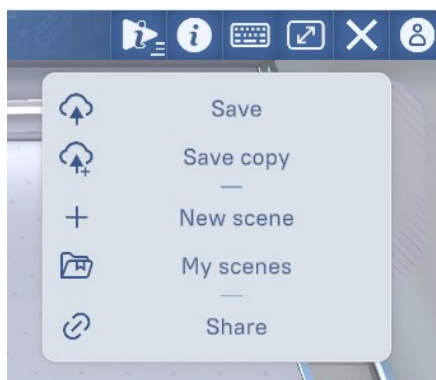


Figure 9 – Scene menu

To close the scene menu, click  or anywhere in the scene outside the menu.

3.5.1 Saving a scene

To save the created scene in the **My scenes** library, select the **Save** item in the scene menu (Figure 9).

If the scene has been previously saved, the application will overwrite the contents of the scene file. If the scene is saved for the first time, the Save Scene form will open (Figure 10).

Figure 10 – Save Scene form

Enter the name of the scene to be saved (max. 36 characters) and its description (max. 1000 characters) in the corresponding fields of the form and click button .

If the **Scene name** and **Scene description** fields were previously filled in the scene card, these values will be displayed when saving the scene (see section 4 “Scene card”).

If necessary, you can call up the virtual keyboard with button  to the left of the save form. This button duplicates button  on the **Application Header** panel (see 3.3 “Virtual Keyboard”): if the virtual keyboard mode  has been enabled on the **Application Header** panel, the button next to the Scene Save form will also be in the active state — .

To cancel saving the scene, press button .

3.5.2 Saving a copy of the scene

To save a copy of the scene in the **My scenes** library, select the **Save copy** item in the scene menu (Figure 9). The form of saving a copy of the scene will be opened, just like the form of saving a scene (Figure 10).

If the scene is saved for the first time, the **Scene name** (max. 36 characters) and **Scene description** (max. 1000 characters) fields must be filled in.

If the scene has been already saved, the **Scene name** field displays the previously saved scene name with the copy number in brackets — **Сцена 1(3)**. You can adjust the scene name and copy number or leave it unchanged.

If the **Scene name** and **Scene description** fields were previously filled in the scene card, these data will be displayed when saving the scene copy (see section 4 “Scene card”).

Press button  to save a copy of the scene.

Once you save a copy, you will continue to work in this scene copy. The scene you were working with before saving the copy will remain in the state of its last save.

To cancel saving a copy of the scene, press button .

3.5.3 Creating a new scene

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

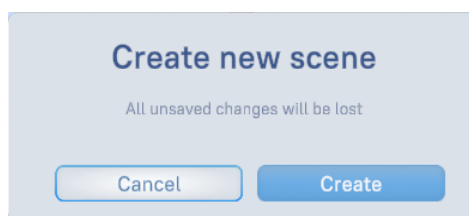


Figure 11 – “Creating a new scene” window

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

3.5.4 Viewing and loading user scenes

To view a list of your saved scenes, select **My scenes** from the scene menu (Figure 9). The **My scenes** library page will open (Figure 12).

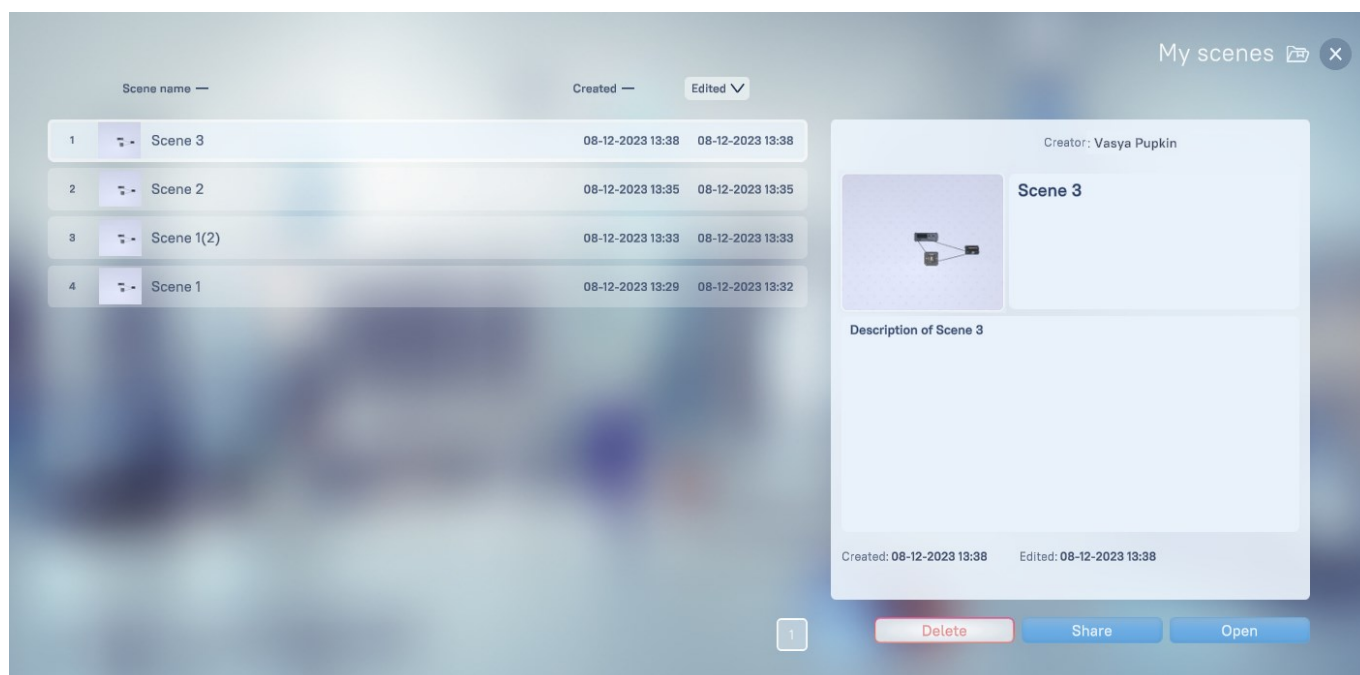


Figure 12 – My scenes library

On the left side of the screen, in the table, a list of all saved scenes is displayed. The list can be sorted by name, creation date, and modification date. To sort the list, click on the name of the corresponding table column (**Scene name**, **Created**, or **Edited**). The icon  next to the column name will change to a check mark indicating the sort direction: .

If the list of scenes does not fit on one screen, it will be paginated. Page navigation is accomplished using the buttons with page numbers located on the right side below the table.

The card of the scene selected in the list is displayed to the right of the table. Use the buttons below the card to open the selected scene, delete it, or share a link to it.

3.5.5 Saving a link to a scene

To share a link to the current scene, select the **Share** item in the scene menu (Figure 9). The link will be copied to the clipboard, and the scene will be saved at the same time. If you have never saved this scene before, the Save Scene form will open (Figure 10). You can save or send the link from the clipboard to someone.

3.6 User Profile

When you click the **Profile** button  on the **Application Header** panel, the user menu opens and the user login (Figure 13) is displayed above it.

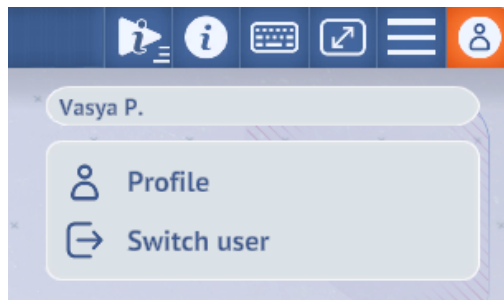


Figure 13 – User Profile

Select the **Profile** menu item to access your profile details. The data will open in a new browser tab.

If you select **Switch user**, two buttons will be displayed below the menu: click [Logout](#) to change the current account, or click [Cancel](#) to continue using the current account.

To close the menu, press button  or anywhere in the application window outside the menu.

4 Scene card

The scene card (Figure 14) allows you to fill in and view the information about the scene that you will need when saving the scene. The scene card opens:

- by clicking the **Scene card** button  in the lower right corner of the application window (Figure 1);
- when saving a scene or its copy, see 3.5.1 “Saving a scene” and 3.5.2 “Saving a copy of the scene”),
- when you select a scene in the **My scenes** library (see 3.5.4 “Viewing and loading user scenes”).

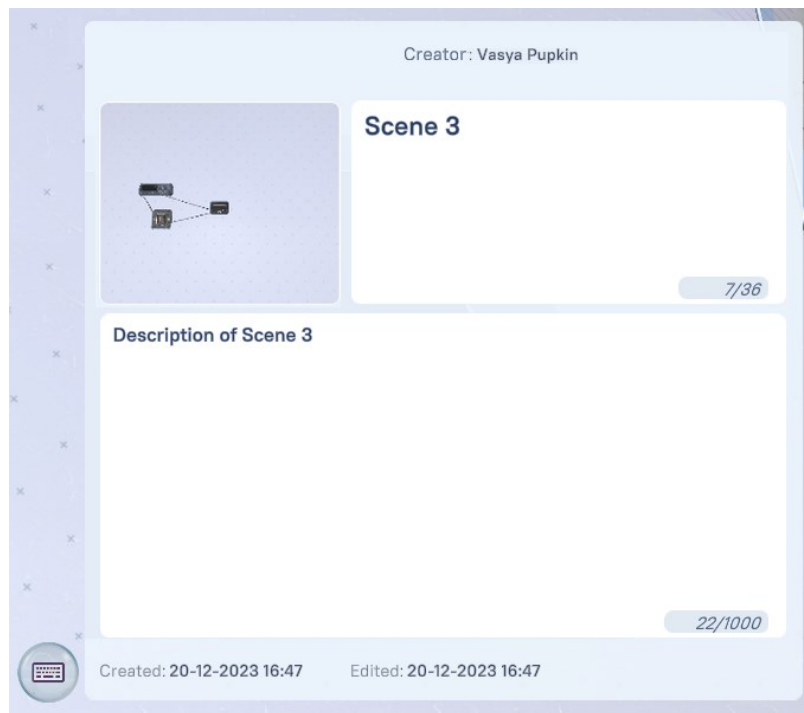


Figure 14 – Scene card

The **Scene name** and **Scene description** card fields will be filled in if:

- you have already filled in a scene card,
- you have already saved a scene or a copy of a scene,
- you opened a scene with a filled card via a link from another user,
- you opened a public scene with the card filled in.

In other cases, the **Scene name** and **Scene description** fields will be empty.

The information in the card can be edited and deleted. When filling in or editing the **Scene name** and **Scene description** fields, you can use your device's keyboard or virtual keyboard. For details on how to use the virtual keyboard, see 3.3 “Virtual Keyboard” and 3.5.1 “Saving a scene”.

To close the scene card, click the **Scene card** button again or anywhere in the application window outside the card.

5 Control panel

The control panel is located at the bottom of the screen and consists of four blocks (Figure 15):

- 1) scene control block (see 5.1 “Scene control”);
- 2) simulation control block (see 5.2 “Process simulation management”);
- 3) button for switching the display modes of information layers (see 5.3 “Switching the display modes of information layers”);
- 4) wire color setting button (see 5.4 “Selecting the color of connections”);
- 5) ruler (see 5.5 “Measuring dimensions and distances”);
- 6) camera control block (see 5.6 “Camera control”).

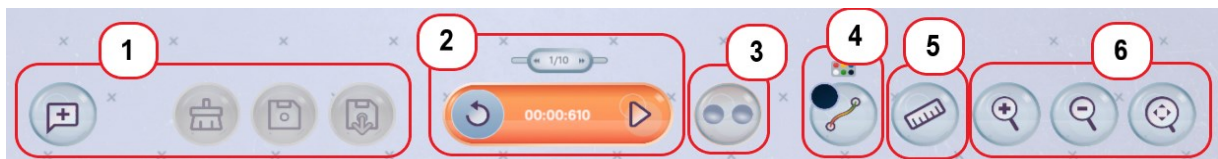


Figure 15 – Control panel

5.1 Scene control

The scene control block (Figure 16) contains buttons that can be used to create a comment, clear the scene, save, and later load the current state of the scene.



Figure 16 – Scene control buttons

5.1.1 Create comment button

To add a comment to the scene, press button , drag the pointer into the scene and release it — the comment will be created at the place where you release the pointer (Figure 17). You can place a comment anywhere on your desktop, including equipment.

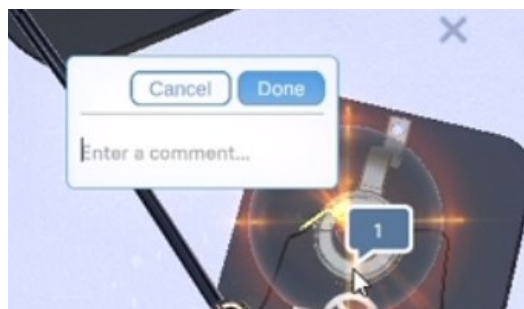


Figure 17 – Comment creation window

Enter the comment text using the keyboard on your device or use the virtual keyboard (see 3.3 “Virtual Keyboard”). Click  to save a comment. To cancel the creation of a comment, press .

All comments are numbered in order of creation, the number of the comment is displayed on its icon (Figure 17).

All comments are displayed on the **Comments** tab of the components panel on the left side of the screen (see 6.3 “Comments tab”).

To move a comment, hold down the icon with its number and drag it to the desired location on the desktop.

To change a comment, select it by clicking on the number icon  or on the card in the list of comments on the **Comments** tab (see 6.3 “Comments tab”). The icon of the selected comment will change color — , the comment editing window will open (Figure 18).

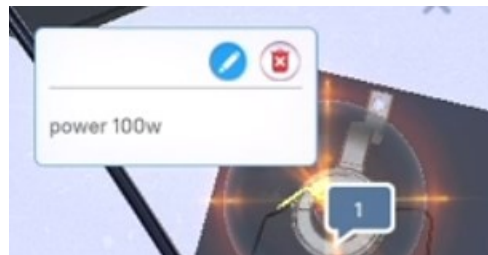


Figure 18 – Comment editing window

Press  to edit a comment, make changes and save them with button . You can cancel the changes with button .

To delete a comment, select it and click icon  in the comment editing window.

5.1.2 Clear scene button

The **Clear scene** button  is available if at least one object is placed in the scene. If you press the button, the confirmation window opens (Figure 19).

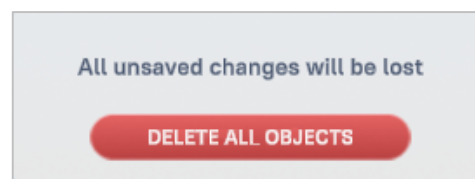


Figure 19 – Scene clearing confirmation window

Click the **Delete all objects** button to clear the scene. To cancel the deletion of all objects, click anywhere on the screen outside the window.

5.1.3 Save point button

The save point is the fixed state of the scene. To create a save point, click button . The application will save object settings, their location in the scene, and the time on the timer. Selection of objects in a scene is not saved. The application can store only one scene state. Re-saving a scene changes the previously recorded state of the scene to its current state.

The **Save point** button  is available if at least one object is placed in the scene.

5.1.4 Return to save poin button

The **Return to save point** button  becomes available after creating a save point using the **Save point** button . Press button  to return to the last saved scene state.

5.2 Process simulation management

The simulation starts automatically when you start the Virtual Lab. If an error occurs that makes further simulation impossible, the simulation stops.

The simulation control block (Figure 20) contains:

- 1) **Simulation** button;
- 2) **Simulation reset** button;
- 3) **Timer**;
- 4) **Simulation speed control** button.

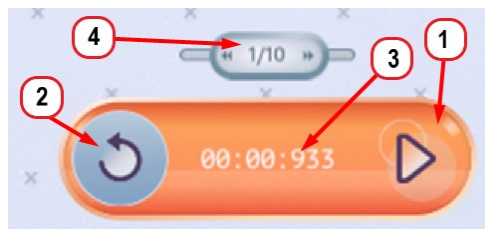
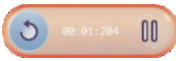


Figure 20 – Simulation control block

To stop electrodynamic processes in the scene, click the **Simulation** button. During the pause, the button changes color — , icon  changes to icon ; the processes in electric circuits and timer countdown stop. To continue, click the **Simulation** button again or click on any object in the scene. Interacting with objects in the scene (except for moving wires) and creating new objects/connections also starts the simulation from the date at which it was stopped.

The **Simulation Reset** button  resets all electrodynamic results in the scene, restarts the timer and turns off all instruments.

The **Timer** displays the flow of time and is needed for relative estimation of the simulation speed. The time countdown stops during a pause in the simulation. The rate of change of the timer accommodates the speed of the simulation.

The **Simulation speed control** button allows you to set a convenient process simulation speed. When the application starts, the maximum simulation speed is set to 10 times slower than real time; the button shows it as 1/10 (Figure 20). To slow down the process simulation, press the button and drag it to the left along the opened speed scale to the desired value (Figure 21). Release the button — the speed scale will disappear; the button will display the set speed.



Figure 21 – Speed setting scale

5.3 Switching the display modes of information layers



Figure 22 – Menu for selecting the display mode of information layers

The information layers display additional information about the location of charges and potentials.

Each action in the Virtual Lab triggers a recalculation of the position of charges and potentials. The calculation process may take some time. Until the end of the calculation process, the loading points rotate around the button

for switching the display modes of the information layers: .

To select the display mode of information layers, press button  on the control panel (Figure 15) and click the desired mode in the menu that opens (Figure 22). The selected mode will be displayed on the button.

The following modes of displaying information layers are available in Virtual Lab:

- 1) **Charge mapping**  demonstrates the distribution of charges in conductors and dielectrics.
- 2) **Potential mapping**  demonstrates potentials on conductors and dielectrics.
- 3) **Calculation status**  displays grid cells showing the object's position in space at the time of the last calculation.
- 4) **Additional information is not displayed** . This mode is set by default.

Positive charges and potentials are displayed in red, negative charges and potentials in blue. Color saturation characterizes the magnitude of charges and potentials.

5.4 Selecting the color of connections



Figure 23 – Wire color selection palette

To select a wire color, press button  on the control panel and click on the desired color in the palette that opens Figure 15 (Figure 23). The selected color will be displayed on the button.

You can only choose the color of the wire before you create it. The color of a wire that has already been created cannot be changed.

5.5 Measuring dimensions and distances

The application uses a ruler to measure dimensions and distances. The ruler is only available on the electrostatics object shelf.

To create a ruler, click button  on the control panel. The ruler will appear in the center of the screen.

To move the ruler, right-click it or use two fingers (if using the touch screen) and drag it to the desired location. The ruler can be moved strictly vertically or horizontally: to do this, left-click it or use one finger and drag it up, down, right, or left to the desired position.

To rotate the ruler, hover the pointer over it and rotate the mouse wheel or press with two fingers. The ruler will rotate relative to the pointer or finger position point.

To adjust the length of the ruler, pull the right edge.

To align the ruler vertically or horizontally, click icon . This icon is available when the ruler position differs from strictly vertical or strictly horizontal.

To delete a ruler, click button  on the control panel or the cross on it.

5.6 Camera control

The camera is controlled using the magnifying glass buttons on the control panel (Figure 15), the mouse, or your fingers (when using the touch screen).

When the application loads, the camera is in the default position — pointing at the center of the desktop. The camera can be quickly returned to this position at any time using the **Whole scene** button



To move the camera, click on any free space in the scene with the left or right mouse button (or with one finger when using the touch screen) and, without releasing, drag the pointer in the desired direction.



Press  /  buttons or rotate the mouse wheel to zoom in/out the camera. When using the touch screen, touch the screen with two fingers, spread them apart, or bring them together. Use double-click on an object in the scene to bring the camera as close to it as possible.

To switch the camera view from the desktop to the shelf and back again, click on any free space in the scene with the left or right mouse button (or one finger if using the touch screen) and, without releasing, pull up or down as far as it will go. You can also switch the camera view by clicking on the shelf or desktop.

6 Components panel

The components panel is located on the left side of the Virtual Lab screen and has two tabs:

- the **Equipment** tab  contains equipment cards that can be used in the scene (see section 8 “Describing the objects”).
- the **Comments** tab  contains all comments to the scene (see 6.3 “Comments tab”).



Equipment cards are grouped by category (Figure 24):

- electrostatics (see 8.1 “Electrostatics”);
- magnetism (see 8.2 “Magnetism”);
- power supplies (see 8.3 “Power supplies”);
- passive elements (see 8.4 “Passive elements”);
- semiconductors (see 8.5 “Semiconductors”);
- meters (see 8.6 “Meters”);
- switching (see 8.7 “Switching”).

There are arrows to the right of the category names: click  to collapse the category, or click  to expand it.

Each card contains a picture and the name of the equipment. The cards of some objects are marked with icon . These objects can be customized before placement in the scene using the object constructor.

Figure 24 – Equipment tab



Figure 25 – Activating an object card

Clicking on the object card (1 in Figure 25) opens the info panel with the description of the selected object (2), and if the object has a constructor, the constructor panel (3) (see 6.1 “Object constructor”).

Clicking the card again closes the info panel and the constructor panel.

6.1 Object constructor

The object constructor contains an image of the object and fields for setting its parameters (Figure 26).



Figure 26 – Object constructor

Each parameter has a name (1) and its current value (2). For parameters with in-range setting, the range of possible values (3) is indicated.

The application provides two options to customize the parameters:

- selecting a value from the list;
- selecting a value within the range.

To set the parameter value from the list, click on icon  (4 in 26) and select the desired option (Figure 27) in the menu that opens.



Figure 27 – Selecting a parameter value from the menu

To set the exact value of a parameter within the range, click on icon  (5 in 26) and enter the value using the numpad (see 6.2 “Numpad”).

To close the constructor, click on the object card on the **Equipment** tab. The object settings are saved after the constructor is closed. If you place another object of the same type in the scene, the changes in the constructor will be applied to it as well.

6.2 Numpad

Numpad (Figure 28) is used to set the exact value of a parameter within the available range. Click icon  in the object constructor (see 6.1 “Object constructor”) to call up the numpad.

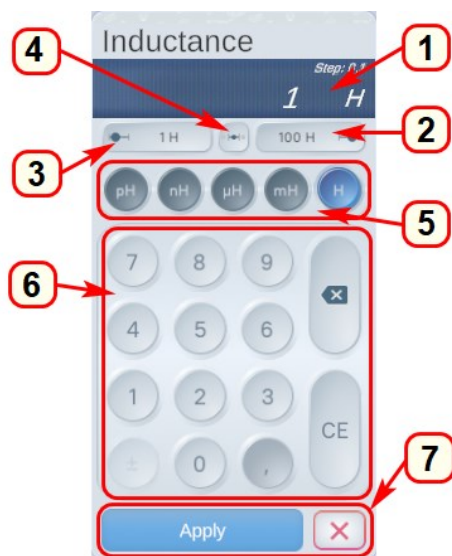


Figure 28 – Numpad

Use the virtual keyboard (6) or your device's keyboard to enter or change values.

To apply or cancel changes, press the corresponding button on the panel (7). The button



becomes active when the correct parameter value is set in the input field.

6.3 Comments tab



Figure 29 – Comments tab

To switch to the **Comments** tab, click the tab label



in the components panel (Figure 29).

The number on the tab label indicates the number of comments in the scene. You can switch between comments in a scene by clicking on them in the comment list.

For more information about creating and working with comments, see 5.1.1 “Create comment button”.

7 Interaction with instruments

7.1 Creating an instrument

To create an instrument in the workspace:

- 1) If you need to customize the parameters of the object you are creating, click on its card. The screen will display the info panel and the constructor panel (Figure 25). Set the parameter values in the constructor (Figure 26).
- 2) Drag the object to the desktop and shelf and drop it where you want to place the instrument. When the pointer moves to the desktop area, a three-dimensional model of the instrument to be created appears under the pointer.

The instrument model changes color to red in an area where the instrument cannot be placed. If you release the pointer at this point, the instrument will not be created (Figure 30).



Figure 30 – Instrument in an area that is not available for placement

To customize an object already placed in the scene, use the customization elements of the object itself (toggle buttons, knobs, switches, controls) — press or drag in the desired direction, just like in reality.



Figure 31 – Warning about the limit of instruments in the scene

Some instruments may be added to the scene in limited quantities. If the maximum possible number of instruments is already placed in the scene, adding one more will not be possible. A warning (Figure 31) will be displayed on the card of the unavailable instrument.

7.2 Connecting instruments with wires

Wires are used to connect instruments on the desktop. A connection can only be created between the instrument terminals. Several wires can be connected to one terminal. Instruments on the shelf cannot be wired to those on the desktop.



The wires in the Virtual Lab have minimal resistance and do not create magnetic phenomena.



Before making the connection, select the wire color by pressing button  on the control panel (see 5.4 “Selecting the color of connections”). By default, the wire color is set to black.

You can create a connection in two ways:

- Connection by click. Click on the start terminal, then click on the end terminal. The wire between the terminals will be created automatically.
- Connection by dragging. Hold the start terminal of the wire, draw the pointer to the end terminal, and drop it. When dragging the pointer, the location of the projected wire will be indicated by a line of points (Figure 32).

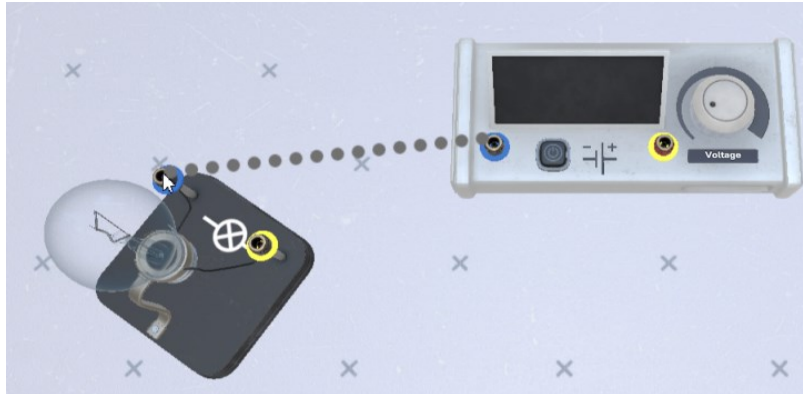


Figure 32 – Designation of the wire to be projected by a line from the points

In both cases, the terminal where the connection starts will be outlined in blue; all other instrument terminals on the desktop will be outlined in yellow (Figure 33).

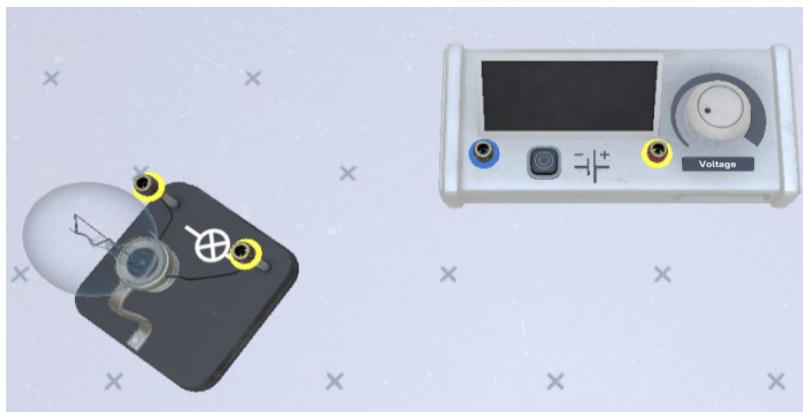


Figure 33 – Starting connection of instruments: outlining terminals in color

7.3 Moving objects

To move the instrument, hold it and drag it to the desired location on the desktop. Instruments on the desktop cannot overlap: when you move an instrument, it “bypasses” other objects on the desktop. If the instrument to be moved is wired to other instruments, the wires follow it; at the same time, the length of the wires is adjusted automatically.

7.4 Rotating objects

To rotate the instrument, point the pointer at it, press the left mouse button, and rotate the mouse wheel. The object will rotate around the pointer.

When using the touch screen, use two fingers to grip the instrument and rotate one finger around the other. The object will rotate around a fixed finger.

7.5 Removing objects

To remove an instrument, hold it, drag it into one of the removal zones at the top of the workspace until the instrument image turns red, and release (Figure 34).

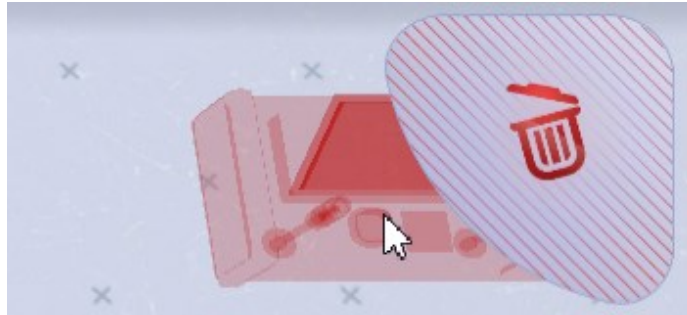


Figure 34 – Image of the instrument in the removal zone

Removing the instrument will remove all wires connected to it.

To remove a wire, hold it, drag the pointer to one of the removal zones at the top of the workspace, and release. The wire to be removed will be highlighted in red (Figure 35).

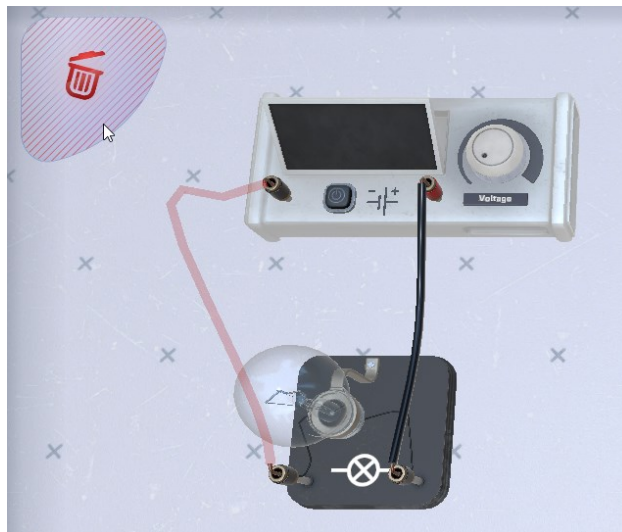


Figure 35 – Wire removal

To remove all objects in the scene, use the **Clear scene** button  on the scene control panel (see 5.1.2 “Clear scene button”).

7.6 Equipment failure

Some equipment may fail if the parameters allowed for that equipment are exceeded or if the connection is incorrect.

If the equipment fails, the simulation will stop, failure notifications will appear on the “failed” object

and in the center of the scene, and indicator  (Figure 36) will appear on the **Simulation reset** button.

To exit failure mode and continue working with the scene, press the **Simulation reset** button



. The simulation will be restarted and the power supplies will be turned off.

You can also use the desktop clear button to exit failure mode . In this case, all objects will be removed from the scene.



Figure 36 – Equipment failure

8 Describing the objects

8.1 Electrostatics

All objects in the **Electrostatics** category can only be placed on the shelf (7 in Figure). Instruments on the shelf cannot be wired to those on the desktop.

8.1.1 Electrometer

Electrometer is an instrument for determining the presence of electric charge in objects interacting with it. The deviation of the instrument arrow indicates a charge force value between 0 and 6 kW.

To set the size, shape, and type of the instrument conductor before placing it in the scene, click the object card on the **Equipment** tab (Figure 37) and set the required values in the constructor (see 6.1 “Object constructor”).

The default values are set when the instrument is created:

- conductor size: 5 cm;
- conductor shape: ball,
- conductor type: hollow.



Figure 37 – Electrometer card

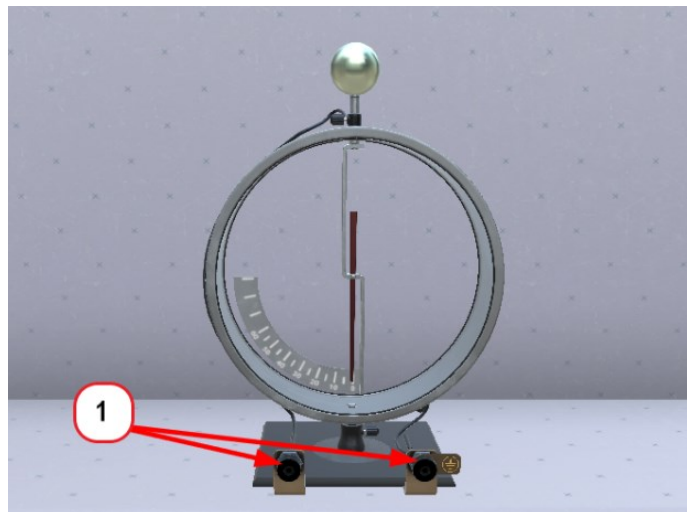


Figure 38 – Electrometer

Use the terminals (1 in 38) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.1.2 Induction machine

An induction machine is a high-voltage mechanical generator.

To set the size of conductors of the instrument before placing it in the scene, click the object card on the **Equipment** tab (Figure 39) and set the required value in the constructor (see 6.1 “Object constructor”).

By default, the size of the conductors is set to 5 cm when the device is created.



Figure 39 – Induction machine card

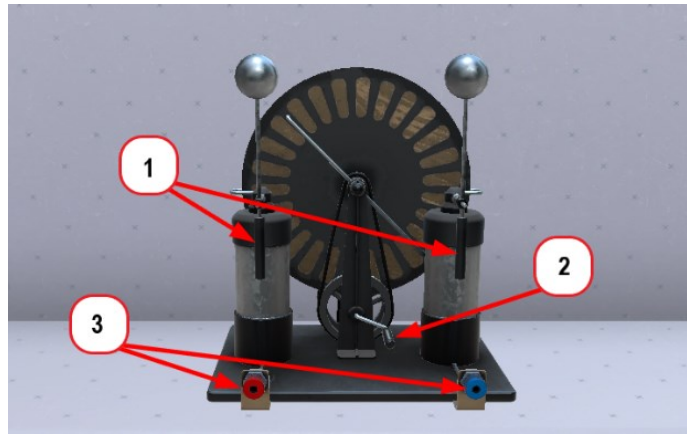


Figure 40 – Induction machine

To change the position of the conductor (Figure 40), hold its knob (1) and pull it to the right or left.

To spin the disks of the induction machine, hold and rotate the knob (2).

Use the terminals (3) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.1.3 Flat capacitor

A flat capacitor is a device for storing electrical charge.

To set the dielectric plate size, material, and height before placing the instrument in the scene, click the object card on the **Equipment** tab (Figure 41) and set the required values in the constructor (see 6.1 “Object constructor”).

The default values are set when the instrument is created:

- plate size: 12 cm;
- dielectric material: plexiglass;
- dielectric height: 12 cm.

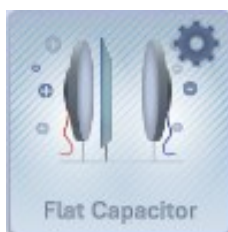


Figure 41 – Flat capacitor card

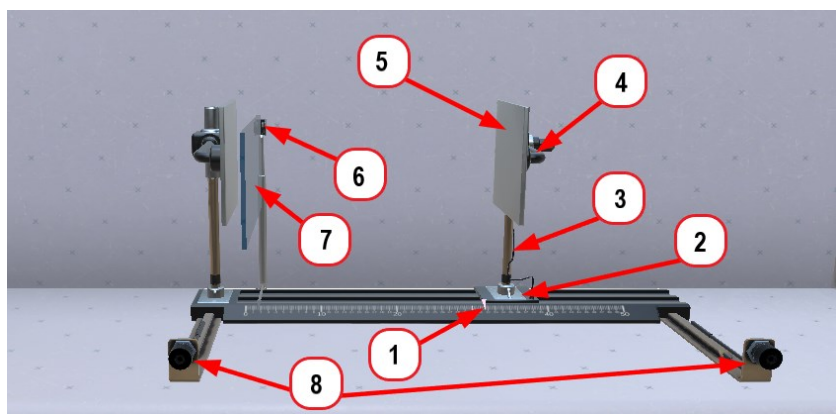


Figure 42 – Flat capacitor

The right condenser plate can be moved along the tripod. The arrow on the base of the right plate (1 in Figure 42) shows the distance between the plates.

To change the distance between the plates, hold the base (2) or stand (3) of the right plate and pull to the right or left.

To change the height of the right plate, hold the plate (5) or its knob (4) and pull up or down.

To change the dielectric height, hold the dielectric (7) or its knob (6) and pull up or down.

Use the terminals (8) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.1.4 Metal rod

Metal rod is an object made of metal with a dielectric handle.

The metal rod is placed above the shelf, the rod tripod (1 in Figure 44) is added to the scene automatically.

To move the metal rod, hold the pointer on its handle (2) and pull the rod to the desired location.



Figure 43 – Metal rod card

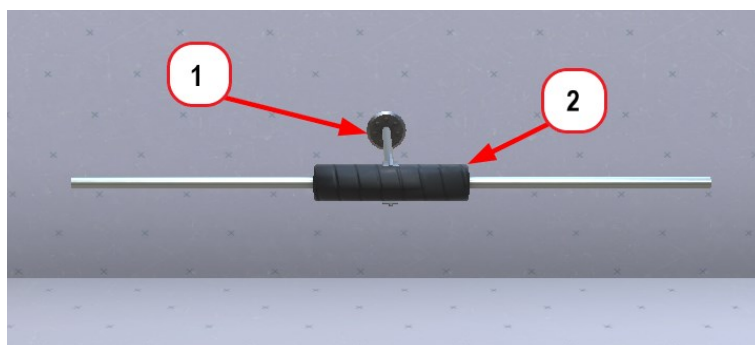


Figure 44 – Metal rod

8.1.5 Charging device

Charging device is a device for transferring negative, positive, or zero charges to a dielectric that has no charge of its own.



Figure 45 – Charging device card

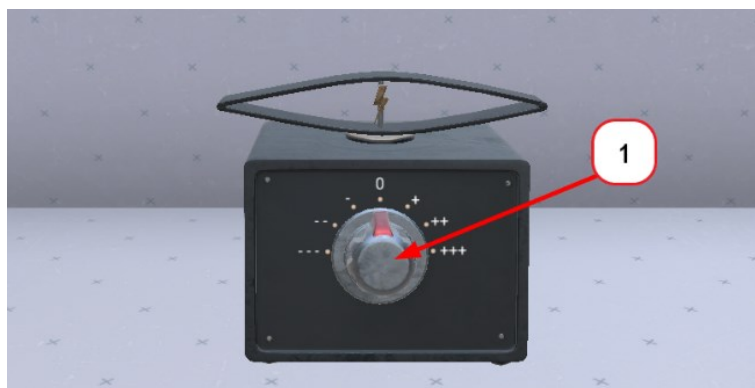


Figure 46 – Charging device

To select the sign and magnitude of the transferred charge, press and turn the knob (1 in Figure 46) to the right or left to the desired value.

8.1.6 Electrostatic rod

An electrostatic rod is a dielectric, can accept charge from a charger and transfer charge to conductors when touched.

The electrostatic rod is placed above the shelf, the tripod for the rod (1 in Figure 48) is added to the scene automatically.

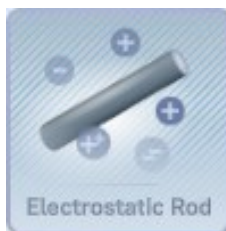


Figure 47 – Electrostatic rod card

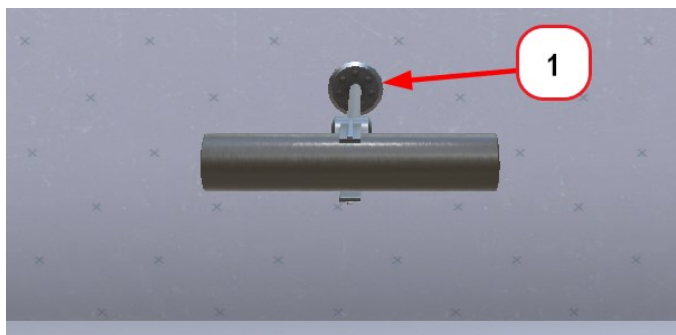


Figure 48 – Electrostatic rod

8.1.7 Grounding device

Grounding device is a zero-potential grounding device.

The grounding device is placed above the shelf, the tripod for it (1 in Figure 50) is added to the scene automatically.



Figure 49 – Grounding device card



Figure 50 – Grounding device

8.1.8 High-voltage source

High voltage source is a device for generating high voltage.



Figure 51 – High voltage source card



Figure 52 – High voltage source

Press the power button (1 in Figure 52) to turn the instrument on or off.

Use the terminals (2, 3, 4) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”). The high voltage source has 3 terminals: the positive terminal is marked in red (2), zero (3) in black, and negative (4) in blue.

To change the voltage value on the terminals use the controllers: red controller (6) for the positive terminal, blue controller (5) for the negative terminal. To set the voltage value, hold the controller and turn it to the desired value. The values set for each terminal are displayed on the screen (7) in the corresponding colors.

The range of the instrument generated voltage:

- for the positive terminal from 0 to +50 kW;
- for the negative terminal from -50 kW to 0.

8.2 Magnetism

8.2.1 Magnetic field detector

A magnetic field detector is an instrument that shows the direction of magnetic field strength vectors.

By default, the detector arrows are oriented toward the Earth's magnetic field.

To move the instrument, hold the pointer on the frame or corner of the detector and drag to the desired location.



Figure 53 – Magnetic field detector card

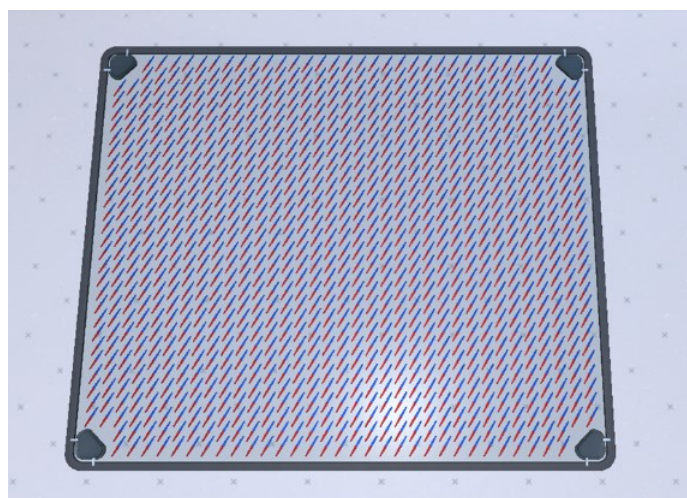


Figure 54 – Magnetic field detector

8.2.2 Strip magnet

Strip magnet is a source of constant magnetic field in the form of a bar with two poles.

To set the magnetization direction before placing the magnet in the scene, click the object card on the **Equipment** tab (Figure 55) and set the required value in the constructor (see 6.1 “Object constructor”).

The default setting is transverse magnetization.



Figure 55 – Strip magnet card



Figure 56 – Strip magnet

8.2.3 Horseshoe magnet

Horseshoe magnet is a source of a constant magnetic field in the form of a horseshoe with two poles.

To set the location of the poles of the magnet before placing it in the scene, click the object card on the **Equipment** tab (Figure 57) and set the required value in the constructor (see 6.1 “Object constructor”).

By default, north is on the left.



Figure 57 – Horseshoe magnet card

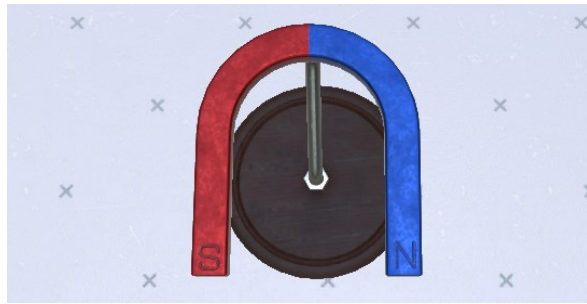


Figure 58 – Horseshoe magnet

8.2.4 Frame

Frame is a frame of conductor attached to an electrical machine. The electric machine converts electrical energy into mechanical energy.

To lock or unlock the free movement of the frame (Figure 60), hold one of the stops (1) and pull inward or outward.



Figure 59 – Frame card

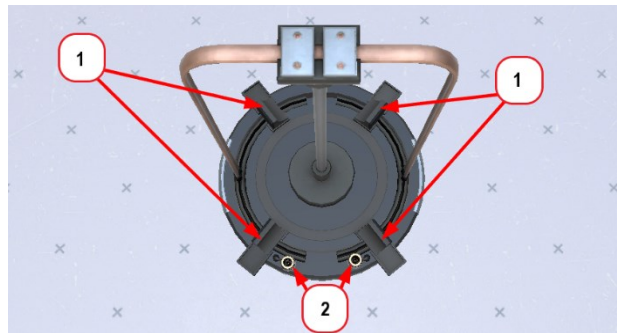


Figure 60 – Frame

Use the terminals (2) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.2.5 Magnetic arrow

A magnetic arrow is a horizontal magnet on a vertical stand that has its own permanent magnetic field.

When magnetic fields are absent or weak, the arrow is oriented to the Earth's magnetic field.



Figure 61 – Magnetic arrow card

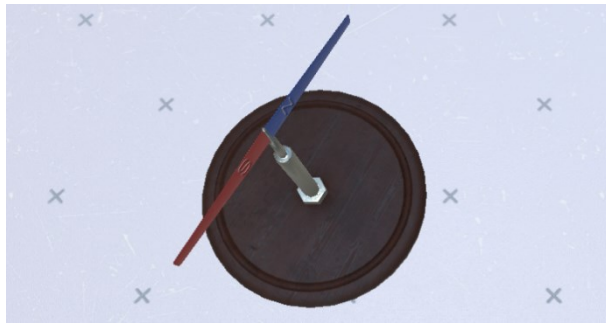


Figure 62 – Magnetic arrow

8.2.6 Coil with core

A coil with core is a helical coil made of coiled insulated conductor that has significant inductance with relatively low capacitance and low active resistance.

To set the number of turns, coil diameter, and length, select the core material and diameter, and enable deceleration compensation before placing the instrument in the scene, click the object card on the **Equipment** tab (Figure 63) and set the desired values in the constructor (see 6.1 “Object constructor”).

The default values are set when the instrument is created:

- number of turns: 1000 pcs.;
- coil diameter: 5 cm;
- coil length: 10 cm;
- core: magnetic;
- core diameter: 2 cm;
- deceleration compensation: active.



Figure 63 – Coil with core card

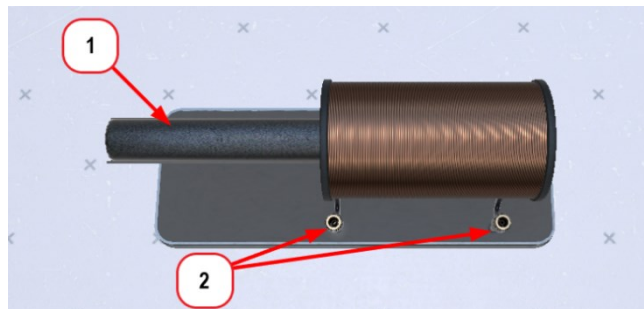


Figure 64 – Coil with core

To adjust the position of the core (1 in 64), hold it in place and pull it to the right or left.

Use the terminals (2) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.2.7 U-shaped electromagnetic stand

U-shaped electromagnetic stand is a stand with an electromagnetic conductor in the shape of the letter U.

To set the type of the conductor before placing the instrument in the scene, click the object card on the **Equipment** tab (Figure 65) and set the required value in the constructor (see 6.1 “Object constructor”).

By default, a single conductor will be created.



Figure 65 – U-shaped electromagnetic stand card

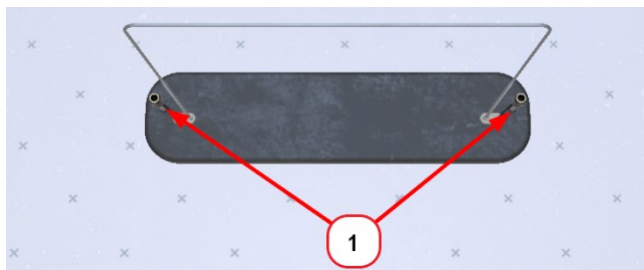


Figure 66 – U-shaped electromagnetic stand

Use the terminals (1) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.2.8 Solenoid electromagnetic stand

Solenoid electromagnetic stand is a conductor shaped like a coil of inductance.

To set the number of turns, their diameter, and distance between them before placing the instrument in the scene, click the object card on the **Equipment** tab (Figure 67) and set the required values in the constructor (see 6.1 “Object constructor”).

The default values are set when the instrument is created:

- number of turns: 1;
- diameter of turns: 10 cm;
- distance between rings: 1 cm.



Figure 67 – Solenoid electromagnetic stand card

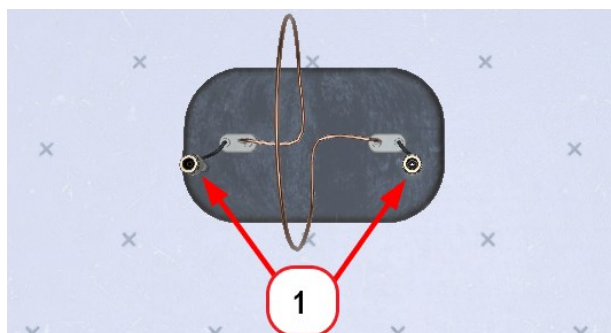


Figure 68 – Solenoid electromagnetic stand

Use the terminals (1 in 68) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.3 Power supplies

8.3.1 Real voltage source

A real voltage source is a source of direct electric current power that has an internal resistance.

To set the internal resistance of the instrument before placing it in the scene, click the object card on the **Equipment** tab (Figure 69) and set the required value in the constructor (see 6.1 “Object constructor”). The default internal resistance value is set to 1 ohm.



Figure 69 – Real voltage source

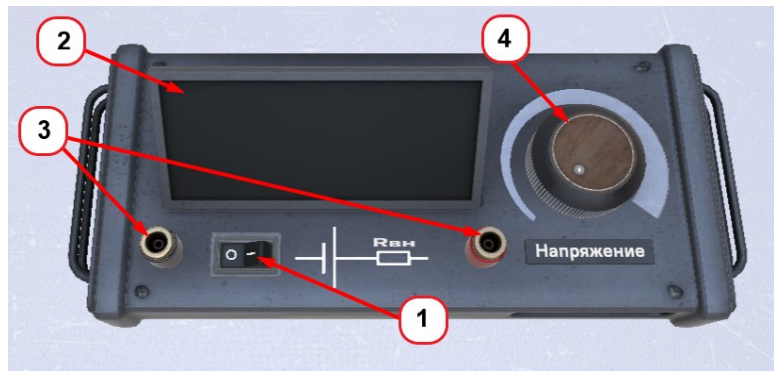


Figure 70 – Real voltage source

Press the power button (1) to turn the instrument on or off (Figure 70).

To change the voltage, hold the knob (4) and turn it to the desired value: clockwise to increase the voltage, counterclockwise to decrease it. The set value is displayed on the screen (2).

Use the terminals (3) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.3.2 Real functional generator

A real function generator is a source of alternating voltage to produce an electrical signal of sinusoidal, rectangular, sawtooth and triangular shape, having an internal resistance.

To set the internal resistance of the instrument before placing it in the scene, click the object card on the **Equipment** tab (Figure 71) and set the required value in the constructor (see 6.1 “Object constructor”).

The default values are set when the instrument is created:

- signal amplitude: 5 V;
- frequency: 40 Hz;
- waveform: sinusoidal;
- internal resistance: 1 ohm.



Figure 71 – Real functional generator card

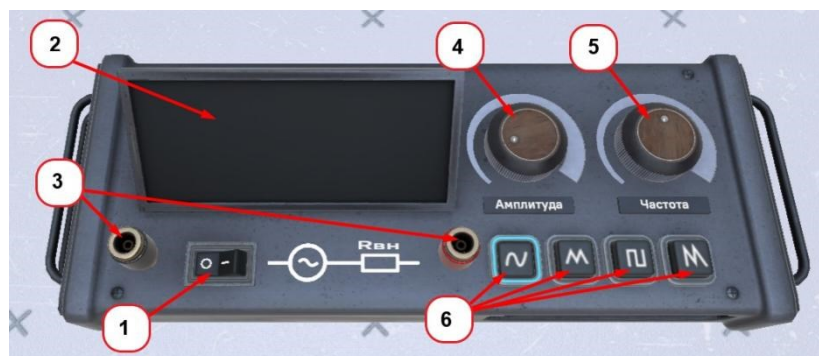


Figure 72 – Real functional generator

Press the power button (1) to turn the instrument on or off (Figure 72).

To change the signal amplitude, hold the knob (4) and turn it to the desired value: clockwise to increase the signal amplitude, counterclockwise to decrease it.

To change the signal frequency, hold the knob (5) and turn it to the desired value: clockwise to increase the signal frequency, counterclockwise to decrease it.

To select the waveform, press the corresponding button (6). The button of the selected waveform is outlined in blue.

The set values of the signal amplitude and frequency and the selected waveform are displayed on the screen (2).

Use the terminals (3) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.4 Passive elements

8.4.1 Real resistor

A real resistor is a passive element of electrical circuits that possesses resistance.

Use the terminals (1 in Figure 74) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).



Figure 73 – Real resistor card

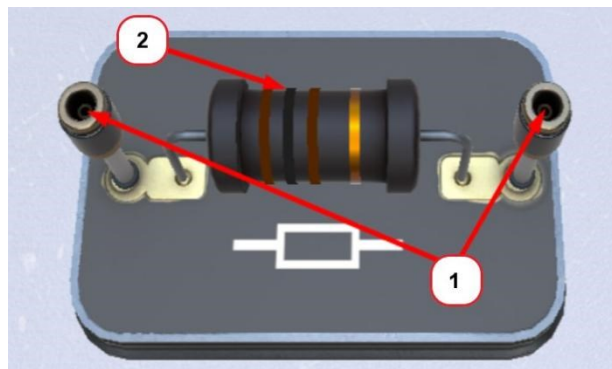


Figure 74 – Real resistor

The color marking on the resistor (2) indicates its rated resistance and permissible error.

The default values when creating a real resistor are set to:

- resistance: 100 ohm;
- permissible error: $\pm 5\%$;
- rated power: 1 W.

To set the rated resistance, permissible error, and rated power of the instrument before placing it in the scene, click]the object card in the **Equipment** tab (Figure 73) and set the required values in the constructor (see 6.1 “Object constructor”).



Figure 75 – Selecting the number of tens in the value of the resistance rating

The resistance of a four-band resistor can be found by the formula $R=(10A+B)10^C$, where:

R — resistor resistance, Ohm;

A — number of tens in the resistance value, indicated by the color of the first band;

B — number of tens in the resistance value, indicated by the color of the second band;

C — the multiplier as a power of ten, by which the resistance value is multiplied, is indicated by the color of the third band.

The color of the fourth color band indicates the value of the permissible error — percentage deviation from the rated value (**D**).

To set the values **A**, **B**, **C**, and **D**, click the appropriate button on the constructor panel and select a value from the list (Figure 75). The color marking on the instrument housing after it has been created corresponds to the selected values (Figure 76).

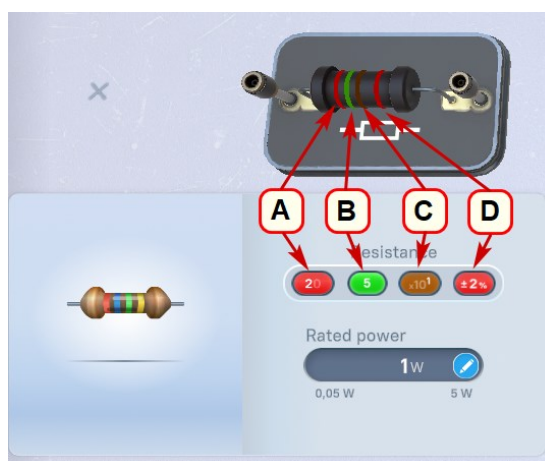


Figure 76 – Displaying the selected values on the object constructor panel and on the body of the created instrument

For example, to create a resistor with a resistance of 450 ohms and a permissible error of $\pm 10\%$, set the values in the constructor as in Figure 77.



Figure 77 – Values A, B, C, D when creating a real resistor

8.4.2 Rheostat

A rheostat is a variable resistor with a movable tap-off contact (slider). The position of the slider determines the resistance value of the rheostat as a fraction of its rating.

To set the resistance of the instrument before placing it in the scene, click the object card on the **Equipment** tab (Figure 78) and set the required value in the constructor (see 6.1 “Object constructor”). The default setting when the instrument is created is 1000 ohm.



Figure 78 – Rheostat card

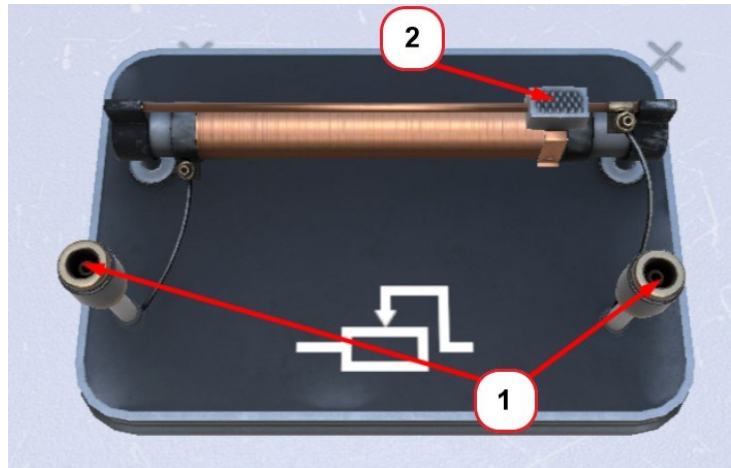


Figure 79 – Rheostat

To change the resistance of the rheostat (Figure 79) already placed in the scene, hold down the slider (2) and move the pointer along the wire spiral. Move the slider to the left to decrease resistance and to the right to increase resistance.

Use the terminals (1) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.4.3 Potentiometer

A potentiometer is an adjustable electrical voltage divider with a tap-off contact. Can be used as a variable resistance resistor.

To set the resistance of the instrument before placing it in the scene, click the object card on the **Equipment** tab (Figure 80) and set the required value in the constructor (see 6.1 “Object constructor”). The default setting when the instrument is created is 1000 ohm.



Figure 80 – Potentiometer card

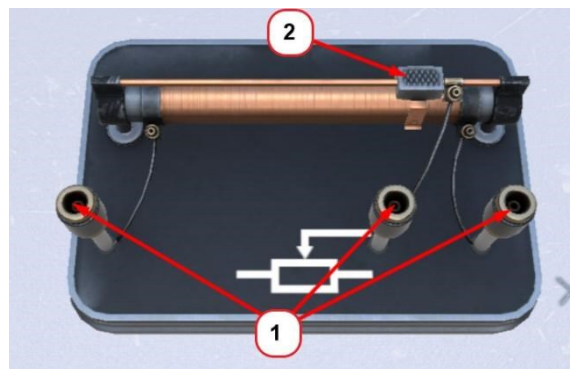


Figure 81 – Potentiometer

To change the resistance of the potentiometer (Figure 81) already placed in the scene, hold down the slider (2) and move the pointer along the wire spiral. Move the slider to the right or left to change the resistance at the tap-off (center) terminal.

Use the terminals (1) to connect the instrument with other circuit elements (see 8.4 “Connecting instruments with wires”). Connect a potentiometer through the center terminal to adjust the resistance. When connected across the end terminals, the full potential of the resistance will be utilized.

8.4.4 Real inductor

A real inductor is an inductor made of a coiled insulated conductor that has a significant inductance with a relatively small capacitance and a small active resistance. When alternating electric current flows through the inductor, its significant inertia is observed.

To set the inductance of the instrument before placing it in the scene, click the object card on the **Equipment** tab (Figure 82) and set the required value in the constructor (see 6.1 “Object constructor”). The default setting when the instrument is created is 1 H.



Figure 82 – Real inductor card

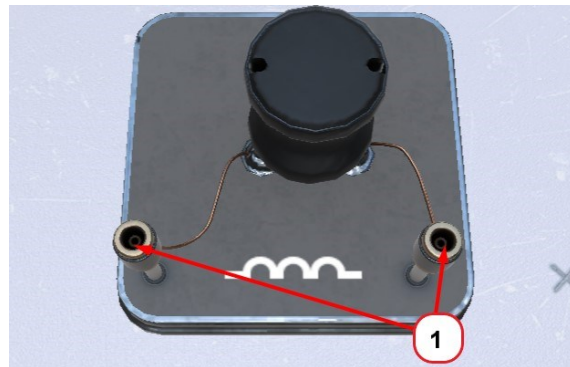


Figure 83 – Real inductor

Use the terminals (1 in Figure 83) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.4.5 Transformer

A transformer is an electromagnetic device for changing the voltage of an alternating current at the same frequency.

To adjust the inductance of the first inductor and set the transformation coefficient before placing the instrument in the scene, click the object card on the **Equipment** tab (Figure 84) and set the required values in the constructor (see 6.1 “Object constructor”).

The default values are set when the instrument is created:

- inductance: 5 H;
- transformation coefficient: 1.



Figure 84 – Transformer card

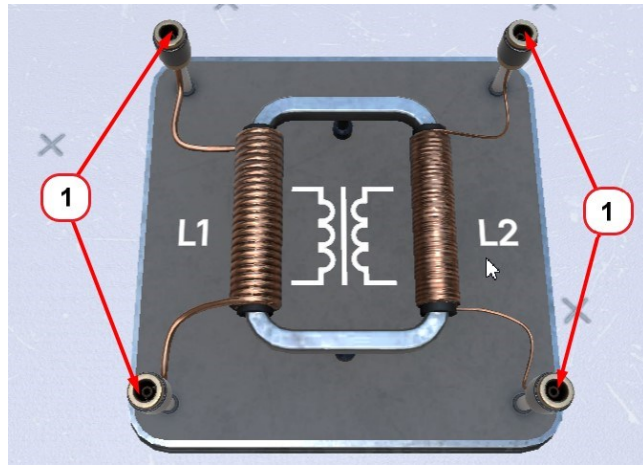


Figure 85 – Transformer

Use the terminals (1 in Figure 85) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.4.6 Real electrolytic capacitor

A real electrolytic capacitor is a type of capacitor in which the dielectric between the liners is a film of metal oxide. The anode is made of metal and the cathode is a solid, liquid, or gel electrolyte, with the lead being the metal body of the capacitor.



Observe the polarity when connecting the instrument:

- right red terminal “+”,
- left black terminal “-”.

To set the capacitance, operating voltage, and rating error before placing the instrument in the scene, click the object card on the **Equipment** tab (Figure 86) and set the required values in the constructor (see 6.1 “Object constructor”).

The default values are set when the instrument is created:

- capacitance: 100 μF ;
- operating voltage: 10 V;
- error: 5 %.

Use the terminals (1 in Figure 87) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).



Figure 86 – Real electrolytic capacitor card

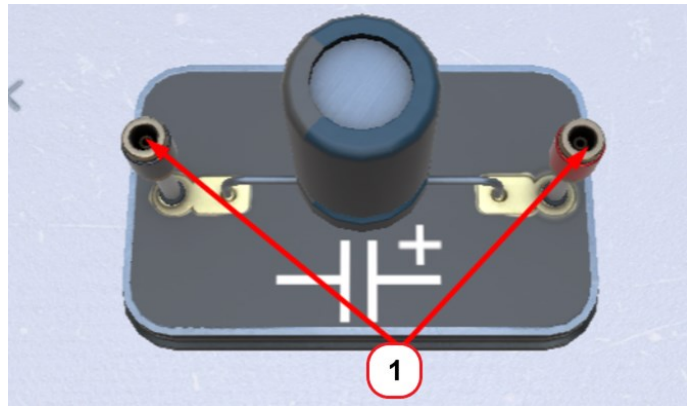


Figure 87 – Real electrolytic capacitor

8.4.7 Adjustable capacitor

A adjustable capacitor is a capacitor that changes its capacitance when a movable element is rotated relative to a fixed element. Typically used in oscillating circuits to change the resonant frequency.

To set the rated capacitance, adjustment range and rating error before placing the instrument in the scene, click the object card on the **Equipment** tab (Figure 88) and set the required values in the constructor (see 6.1 “Object constructor”).

The default values are set when the instrument is created:

- rated capacitance: 100 μF ;
- adjustment range: 20 %;
- rating error: 5 %.



Figure 88 – Adjustable capacitor card

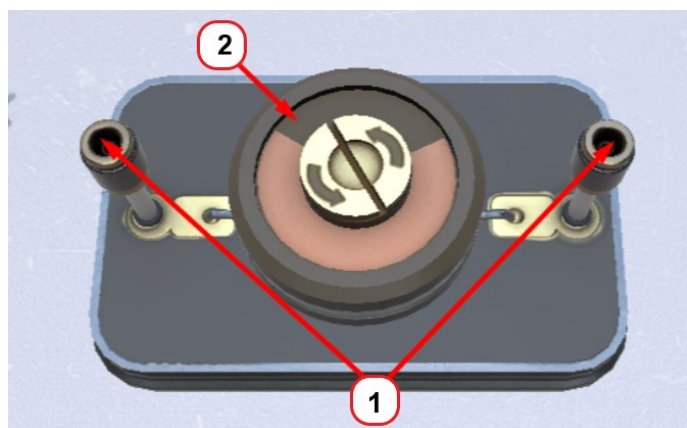


Figure 89 – Adjustable capacitor

To change the capacitance of the capacitor (Figure 89), hold down the knob (2) and turn it to the desired value.

Use the terminals (1) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.4.8 Incandescent lamp

An incandescent lamp is an electric light source in which the filament body (tungsten coil) is heated to a high temperature by an electric current and emits visible light.

To set the wattage, voltage rating and rating error before placing the instrument in the scene, click the object card on the **Equipment** tab (Figure 90) and set the required values in the constructor (see 6.1 “Object constructor”).

The default values are set when the instrument is created:

- rated power: 100 W;
- rated voltage: 5 V;
- rating error: 5 %.

Incandescent lamps vary in size according to their wattage rating (Figure 91):

- 1) large lamp: 60 to 100 W;
- 2) medium lamp: 12 to 60 W;
- 3) small lamp: 1 to 12 W.



Figure 90 – Incandescent lamp card

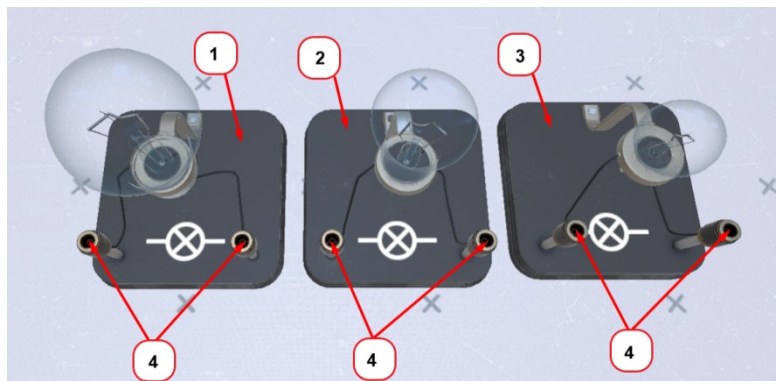


Figure 91 – Incandescent lamp

Use terminals (4) to connect the lamp with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.5 Semiconductors

8.5.1 Real (Shockley) diode

A real (Shockley) diode is an electronic component that conducts current predominantly in one direction. Consists of PNP semiconductor sections.

Use the terminals (1 in Figure 93) to connect the real diode with other circuit elements (see 7.2 “Connecting instruments with wires”).



Figure 92 – Real (Shockley) diode card

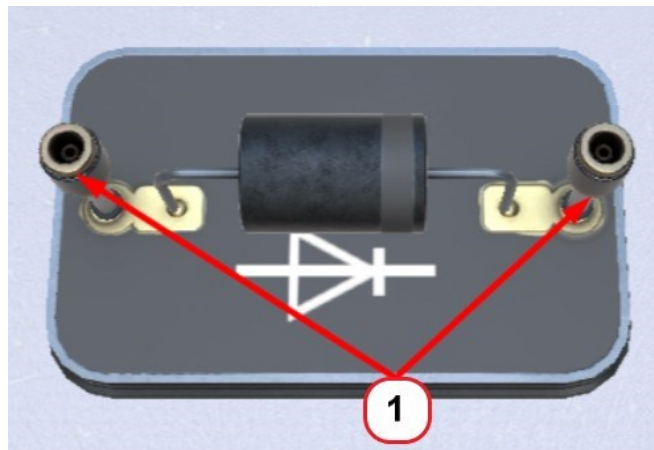


Figure 93 – Real (Shockley) diode

8.5.2 LED

LED is a semiconductor element with an electron-hole transition that produces optical radiation when an electric current is passed through it in the forward direction.

To set the LED color before placing the instrument in the scene, click the object card on the **Equipment** tab (Figure 94) and set the required color in the constructor (see 6.1 “Object constructor”). By default, the LED color is set to red.

Different colors have different operating voltages:

- red — 1.63 to 2.03 V;
- green — 1.9 to 4 V;
- blue — 2.48 to 3.7 V;
- white — about 3.5 V.

Use the terminals (1 in Figure 95) to connect the instrument with other circuit elements (see 7.2 “Connecting instruments with wires”).

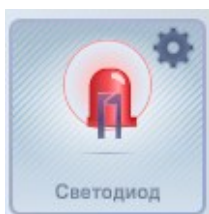


Figure 94 – LED card

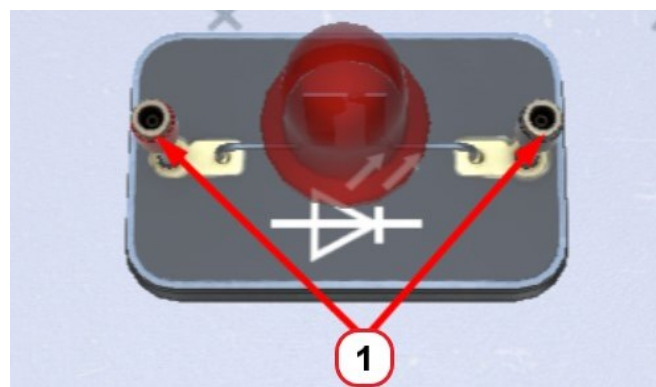


Figure 95 – LED

8.5.3 PNP and NPN transistors

PNP and NPN transistors are semiconductor elements categorized as active electronic components (Figures 96, 97).

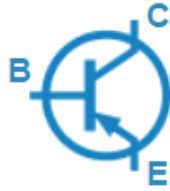


Figure 96 – PNP transistor schematics symbol

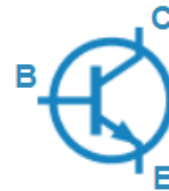


Figure 97 – NPN transistor schematics symbol

PNP (Figure 99) and NPN (Figure 101) transistors are available in the Virtual Lab. PNP transistor is forward, NPN transistor is reverse.



Figure 98 – PNP transistor card

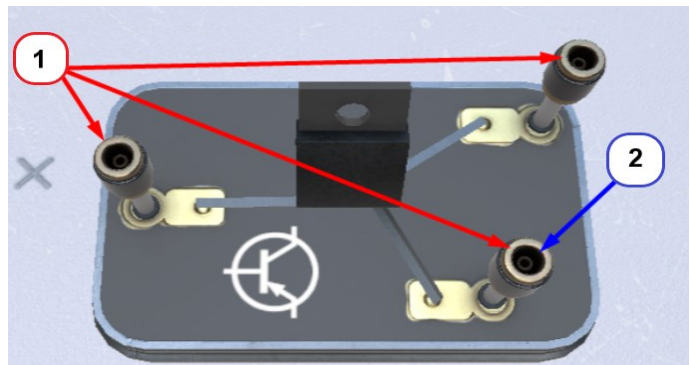


Figure 99 – PNP transistor



Figure 100 – NPN transistor card

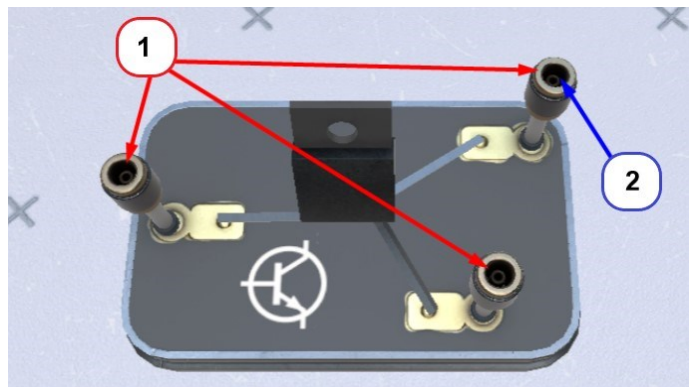


Figure 101 – NPN transistor

Use the terminals (1 in Figures 99 and 101) to connect the transistors with other circuit elements (see 7.2 “Connecting instruments with wires”).

8.6 Meters

8.6.1 Simplified oscilloscope

Simplified oscilloscope is a simplified model of an instrument for displaying and studying amplitude and time parameters of an incoming electrical signal.

Use the terminals (1 in Figure 103) to connect the simplified oscilloscope with other circuit elements (see 7.2 “Connecting instruments with wires”).



Figure 102 – Simplified oscilloscope card

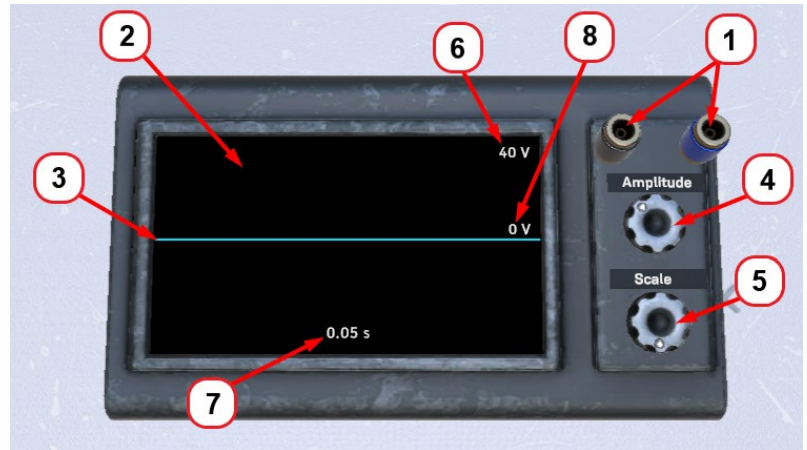


Figure 103 – Simplified oscilloscope

If only one wire is connected to the oscilloscope (Figure 103) or no wires are connected, the zero voltage line (3) is displayed on the screen (2). The digit “0” (8) is always at the zero voltage level. When voltage is applied to the instrument, the line displays the received signal on the screen.

To change the range of the displayed voltage, hold the knob (4) and turn it to the desired value: clockwise to increase the range, counterclockwise to decrease it. The set value is displayed on the screen in the upper right corner (6).

To change the range of the displayed time interval (in seconds), hold the knob (5) and turn it to the desired value: clockwise to increase the range, counterclockwise to decrease it. The set value is displayed at the bottom of the screen (7).

8.6.2 Oscilloscope

Oscilloscope is a device for displaying and studying amplitude and time parameters of an incoming electrical signal. The incoming signal is clearly displayed on the instrument screen (Figure 105): horizontally (X-axis) — time, vertically (Y-axis) — voltage.

The oscilloscope has two connection channels: **channel 1** and **channel 2**. The yellow frame in Figure 105 shows the connection and setting panel of channel 1, the blue frame shows the connection and setting panel of channel 2.

Channel settings are displayed on the panel at the bottom of the screen (2): in the upper line in yellow color — channel 1 settings, in the lower line in blue color — channel 2 settings. To turn the channel 2 signal display on or off, press the switch (7).



Figure 104 – Oscilloscope card

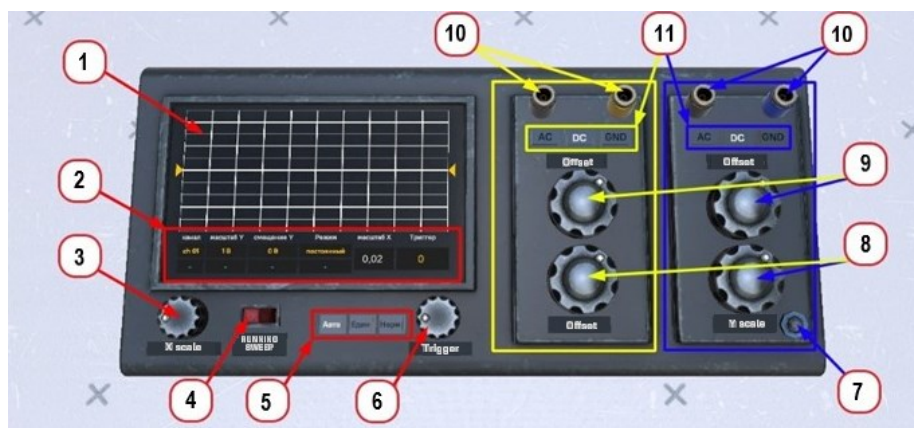


Figure 105 – Oscilloscope

To change the X-axis scale value (seconds/division), turn the **X Scale** knob (3) to the desired value and release. The X-axis scale is adjusted for two channels at the same time.

Press the **Running sweep** switch (4) to toggle between running signal mode and trigger signal synchronization mode.

In the trigger signal synchronization mode, the **buttons for selecting the type of signal drawing** (5) are active. Press one of the buttons (5) to select the desired drawing type:

- **Auto** — the instrument constantly redraws the graph even if the trigger conditions are not met. This mode is set by default.
- **Once** — the instrument redraws the graph once from the moment of triggering.
- **Norm** — the instrument redraws the graph every time the trigger is activated.

To set the condition for drawing graphs in **Normal** and **Once** modes, turn the **Trigger** knob (6) to the desired voltage value.

To change the Y-axis scale value (volts/division), turn the **Y Scale** knob (8) to the desired voltage value and release. Y-axis scale is adjusted separately for each channel.

To conveniently position the image on the screen, turn the **Offset** knob (9) to the desired position of the graph along the Y-axis. Adjusted separately for each channel.

Use the **terminals** to connect the oscilloscope (10) (see 7.2 “Connecting instruments with wires”). Each channel can be connected to a different part of the circuit or to different circuits.

To set the **input operation mode** for each channel, press the corresponding button under the terminals (11):

- **AC** — AC mode.
- **DC** — DC mode. Set by default.
- **GND** — incoming signal grounding mode. The signal is displayed on the screen as a straight line.

8.6.3 Digital ammeter

Digital ammeter is an instrument for measuring the strength of electric current in an electric circuit (in amperes). Connect a digital ammeter in series on the section of the circuit where the measurement is to be made.

Use the terminals (1 in Figure 107) to connect the digital ammeter with other circuit elements (see 7.2 “Connecting instruments with wires”).



Figure 106 – Digital ammeter card



Figure 107 – Digital ammeter

The screen (2) shows the value of the current flowing through the instrument. To change the type of current (AC/DC) with which the instrument operates, press the switch (3).

8.6.4 Analog ammeter

Analog ammeter is an instrument for measuring the strength of electric current in an electric circuit (in amperes). Connect an analog ammeter in series on the section of the circuit where the measurement is to be made.

Use the terminals (1 in Figure 109) to connect the analog ammeter with other circuit elements (see 7.2 “Connecting instruments with wires”).

To set the range of scale values and the instrument operation mode before placing it in the scene, click the object card on the **Equipment** tab (Figure 108) and set the values in the constructor (see 6.1 “Object constructor”). The default values are set when the instrument is created:

- scale: 0 to 2 A;
- operating mode: direct current.

The operating mode designation is displayed in the lower part of the body (2 in Figure 109).



Figure 108 – Analog ammeter card

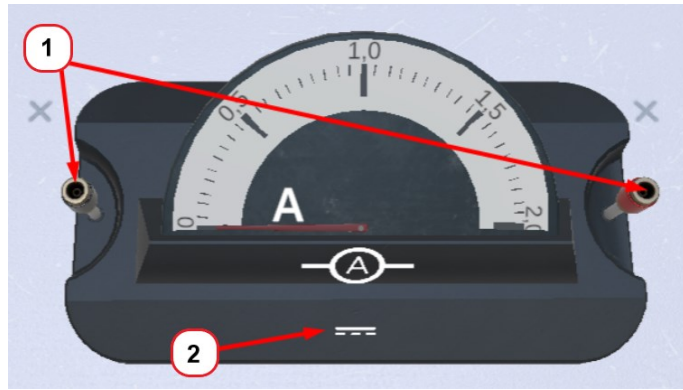


Figure 109 – Analog ammeter

8.6.5 Digital voltmeter

Digital voltmeter is an instrument for measuring voltage or electromotive force in electrical circuits (in volts). Connect the instrument in parallel with a load or electrical power source to make measurements.

Use the terminals (1 in Figure 111 to connect the digital voltmeter with other circuit elements (see 7.2 “Connecting instruments with wires”).



Figure 110 – Digital voltmeter card



Figure 111 – Digital voltmeter

The display (2) shows the voltage value in the circuit (Figure 111). To change the type of current (AC/DC) with which the instrument operates, press the switch (3).

8.6.6 Analog voltmeter

Analog voltmeter is an instrument for measuring voltage or electromotive force in electrical circuits (in volts). Connect the instrument in parallel with a load or electrical power source to make measurements.

Use the terminals (1 in Figure 113 to connect the analog voltmeter with other circuit elements (see 7.2 “Connecting instruments with wires”). To set the range of scale values and the instrument operation mode before placing it in the scene, click the object card on the **Equipment** tab (Figure 112) and set the values in the constructor (see 6.1 “Object constructor”).

The default values are set when the instrument is created:

- scale: 0 to 40 V;
- operating mode: direct current.

The operating mode designation is displayed in the lower part of the body (2 in Figure 113).



Figure 112 – Analog voltmeter card

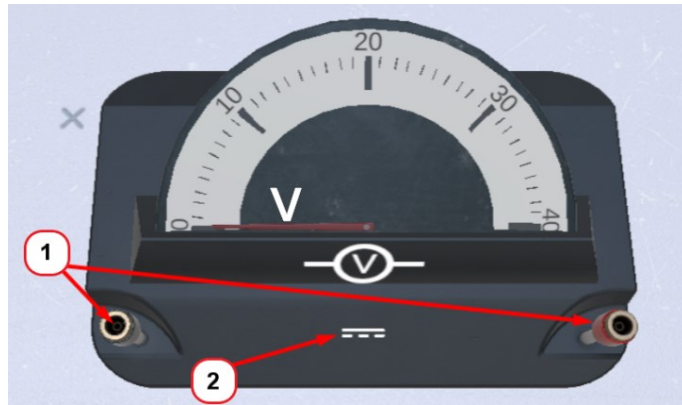


Figure 113 – Analog voltmeter

8.6.7 Digital ohmmeter

A digital ohmmeter is an instrument for measuring electrical active (ohmic) resistances.

Use the terminals (1 in Figure 115) to connect the digital ohmmeter with other circuit elements (see 7.2 “Connecting instruments with wires”).

To turn the ohmmeter (Figure 115) on or off, press the button (2) at the bottom of the body. The resistance value in the electrical circuit is displayed on the instrument screen (3).



Figure 114 – Digital ohmmeter card

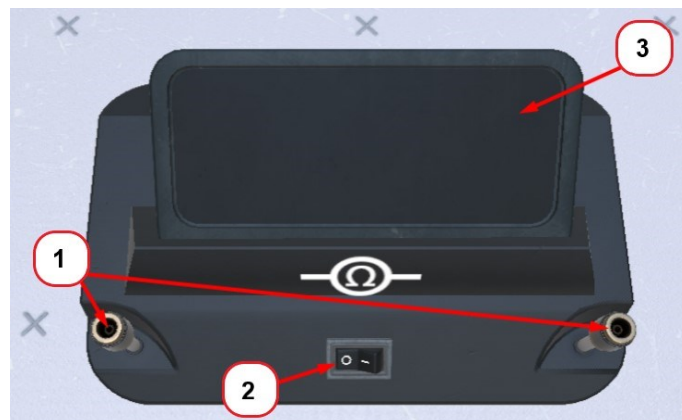


Figure 115 – Digital ohmmeter

8.6.8 Analog galvanometer

An analog galvanometer is a highly sensitive instrument for measuring the strength of small direct electric currents.

To set the range of instrument scale values before placing it in the scene, click the object card on the **Equipment** tab (Figure 116) and set the required value in the constructor (see 6.1 “Object constructor”). By default, when the instrument is created, the scale is set from $-20 \mu\text{A}$ to $20 \mu\text{A}$.

Use the terminals (1 in Figure 117) to connect the analog galvanometer with other circuit elements (see 7.2 “Connecting instruments with wires”).

The lower part of the scale shows the value of the internal resistance of the instrument (2 in Figure 117).



Figure 116 – Analog galvanometer card

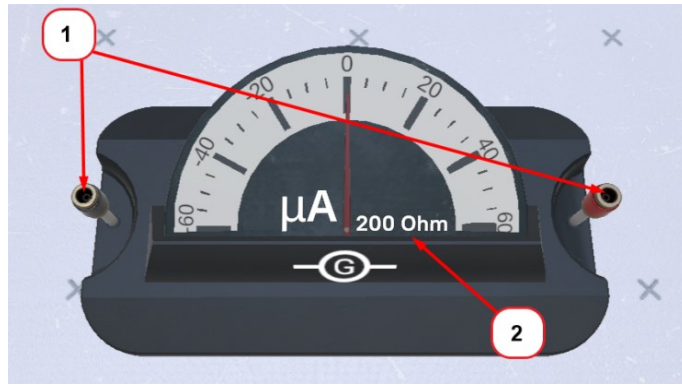


Figure 117 – Analog galvanometer

8.7 Switching

8.7.1 Key

A keyswitch is an instrument for closing and opening an electrical circuit.

Use the terminals (1 in Figure 119) to connect the keyswitch with other circuit elements (see 7.2 “Connecting instruments with wires”).

To close or open the circuit, hold the keyswitch knob (3 in Figure 119) and pull up or down. In the upper position of the knob (1), the keyswitch is open and the circuit is open. In the lower position of the knob (2), the keyswitch is closed and the circuit is closed.



Figure 118 – Keyswitch card

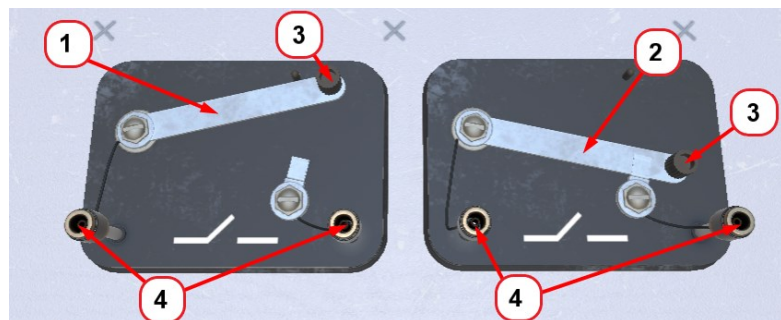


Figure 119 – Keyswitch

8.7.2 Three-position switch

The three-position switch is a transfer switch with three terminals for switching electrical circuits.

Use the terminals (1, 2, and 3 in Figure 121) to connect the three-position switch to other circuit elements (see 7.2 “Connecting instruments with wires”).



Figure 120 – Three-position switch card

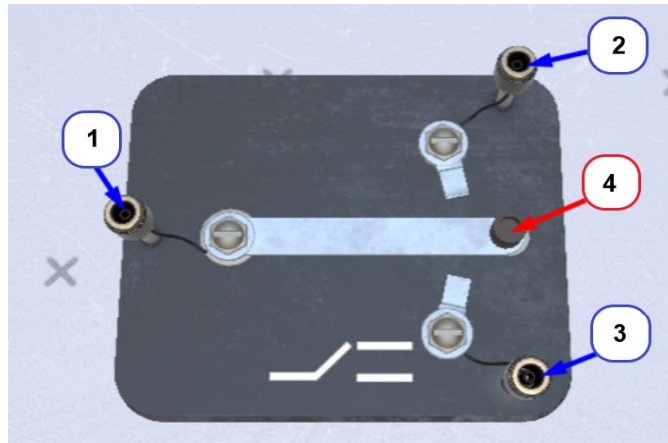


Figure 121 – Three-position switch (switch knob in middle position)

To close or open the circuit, hold the switch knob (4) and pull up or down.

The switch knob can be set in 3 positions:

- 1) In the upper knob position, the circuit between terminals (1) and (2) is closed, the circuit between terminals (1) and (3) is open.
- 2) In the middle position of the knob, both circuits are open (as shown in Figure 121).
- 3) In the lower handle position, the circuit between terminals (1) and (2) is open, the circuit between terminals (1) and (3) is closed.

8.7.3 Connecting bus

A connecting bus is a device for connecting wires at a single point. The connecting bus has one terminal (1 in Figure 123) to which several wires can be connected for easy arrangement of the circuit (see 7.2 “Connecting instruments with wires”).



Figure 122 – Connecting bus card

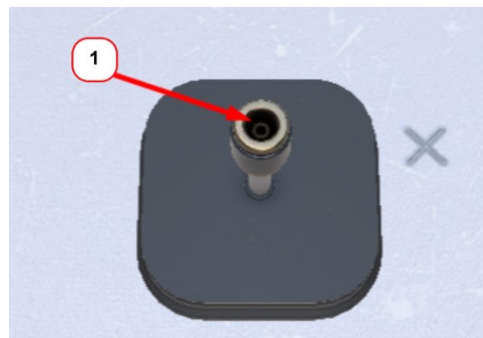


Figure 123 – Connecting bus