Designing Electrical Circuits

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Recommended year	*Grade 8-10*
Time framework	*ca. 2 hours*
Thematic block	*Technical creation*
Objectives and development of competences	*The aim of this thematic block is for the students to learn how to determine potential specifications theoretically using electric circuits and subsequently verify them in experiments.*
Interdisciplinary (cross-curricular) relations	*Relations between physics and mathematics / logic*

Circuits and their Potentials

Students receive task A:

They have to connect three lamps (with equal set points – 2.5 V/0.1A) in series to an electric energy source (9V battery block). Subsequently, they will discuss which potential values they expect for each cable section.

They have to apply the potential color-blocking rule and verify – task B – their assumptions in an experiment.

In the following teamwork phase – task C – the students work on more complex circuits, which can be answered by applying the previously acquired skills.

The Methodical Part

- In previous lessons, the class discussed electrical potentials.
- Why the zero potential has to be defined in an electric potential.
- That one has complete freedom in defining the electric potential. It is smart however to set the lowest potential value as the zero potential to avoid having to deal with negative potentials.
- How to smartly apply the potential color-blocking rule, i.e. coloring the galvanic connections within the circuit in the same color and presuming the potential along a sufficiently thick lab cable to stay the same, since the resistance in the lab cable is negligible compared to the other ohmic resistance. Additionally, it is assumed that a bulb without an electric current (i.e., a bulb that is switched off) has the same potential on both ends.
- This process trains "scientific work", i.e. predictions are deducted from a theory and have to be substantiated with experiments. If the projections are confirmed, the underlying theory becomes more likely. If the experiment contradicts the predictions action is needed (reviewing the experiment, discussion potential errors, discarding the underlying theory … or restricting the theory to "smaller areas of application"
- Theoretic predictions of potentials are verified with a voltmeter.
- Subsequently, the knowledge gained in this simple experiment are transferred to more complex circuits.

ALTERNATIVES

ACTIVITY, IDEA 1

One option is to recreat the circuit with real compartments. It is subsequently tested with a "real voltmeter."

ACTIVITY, IDEA 2

Another option is constructing the circuit with a simulator – e.g. the Yenka-simulator (http://www.yenka.com/de/Home/). However, the students learn that the simulator can not replace scientific works.

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Didactic notes for teachers

- **It is of particular importance for the physics teacher to request predictions before the students create the circuit.**
- **AND teamwork is an important part of the project. The physics teacher should stay out of the student's work as much as possible.**
- **It is important that the physics teacher does not create any "time pressure" and allows the students to make false predictions, too. One of the most important learning experiences are learning to falsify potential predictions with individual experiments – AND NOT by being corrected by the physics teacher!**

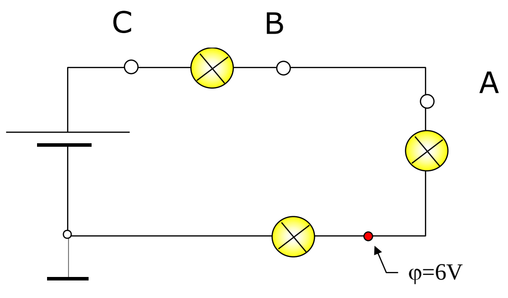
Worksheets for step 2

See annex

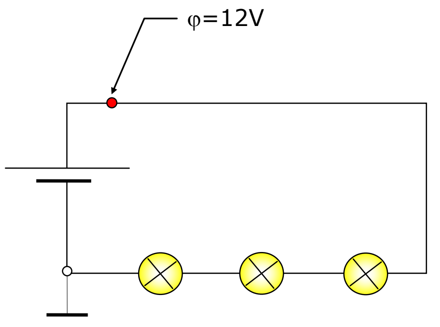
Team task C – Tasks on Electric Potential

After completing the last task on potentials we will apply our knowledge to the following, more complex circuits. The task is to predict the potential for different spots and to verify or falsify the predictions in an experiment.

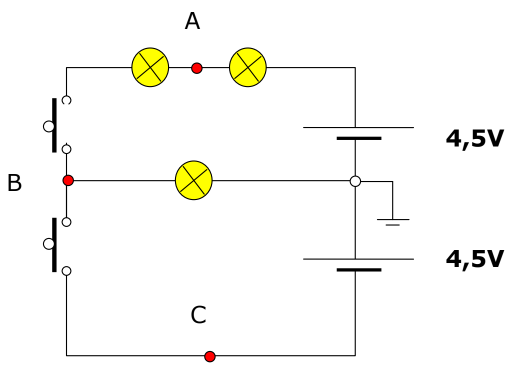
Determine the potentials at the spots in the circuit marked with a letter with your group. Assume the bulbs used in the circuit to be identical, if no additional information for the bulbs are included in the circuit.



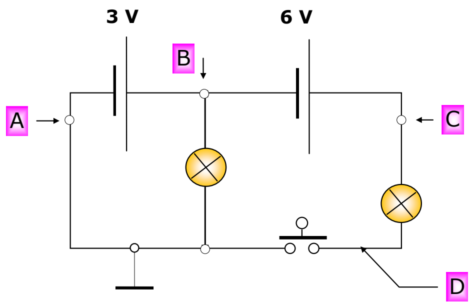
Task 1



Task 2

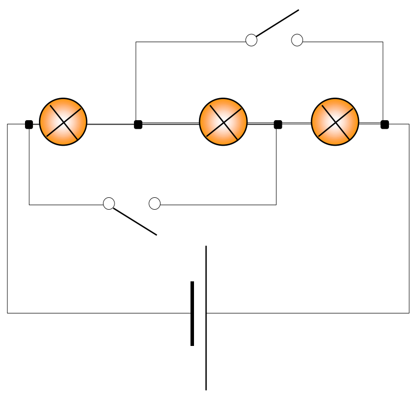


Task 3



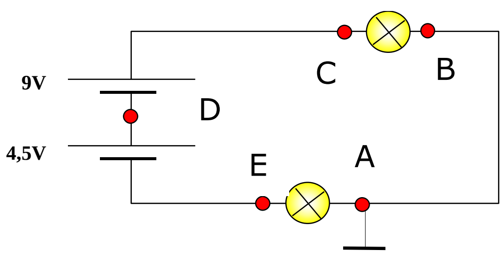
The bulbs have different operating data. Which potential difference applies to each bulb?

Task 4



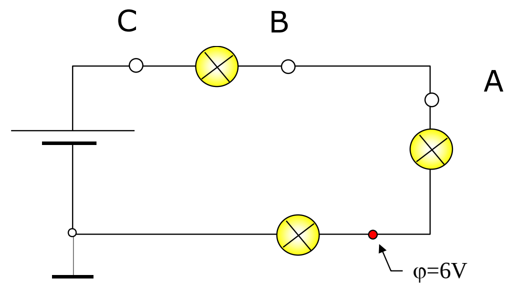
Which bulbs are lit up in which setup?

Task 5



Task 6

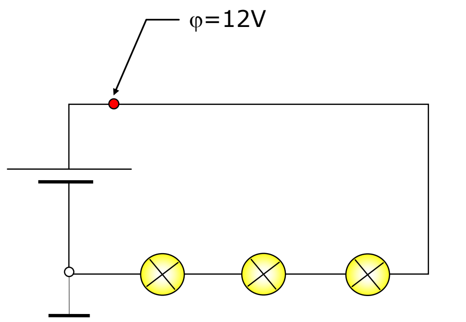
Answers



Task 1

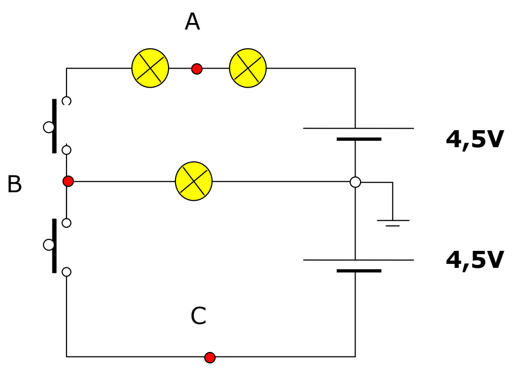
When the lamps are identical and connected in line, each bulb has the same potential difference.

For A, this results in a potential of φ(A) = 12 V. Since B is directly linked to A and the lab cables are assumed to be thick enough to maintain equal potentials everywhere, we conclude a potential of φ(B) = 12 V. At point C, a potential of φ(C) = 18 V arises. We therefore have a battery voltage of 18 V.



Task 2

12 V are distributed among three identical bulbs. Each bulb receives 4V.



Task 3

We have to distinguish four alternatives in this circuit:

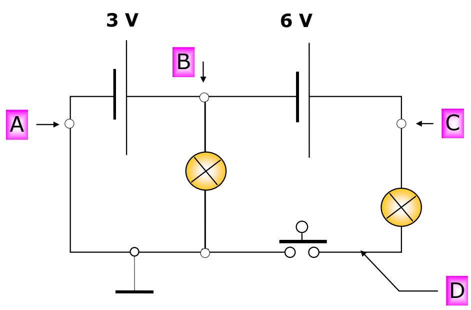
In all four situations applies: -4.5V

Both switches off: φ(B) = -4.5V / φ(A) = 0 V

Both switches on: φ(B) = 0V / φ(A) = 4.5 V

Only upper switch off: φ(B) = 1.5V / φ(A) = 3 V

Only lower switch off: φ(B) = -4.5V / φ(A) = 4.5 V



The bulbs have different operating data. Which potential difference applies to each bulb?

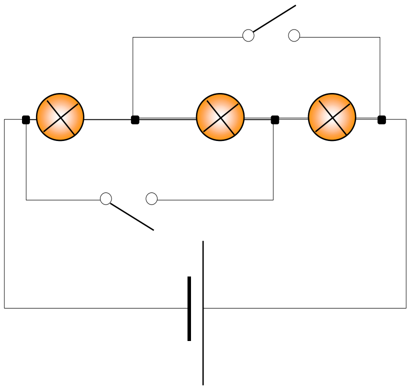
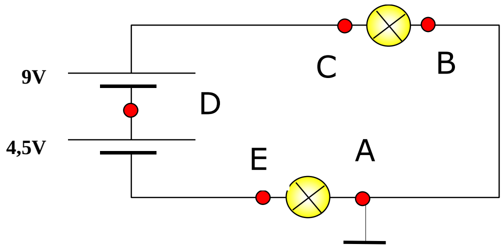
Task 4

We have to distinguish two alternatives in this circuit:

In all situations is φ(A) = 0V / φ(B) = 3V / φ(C) = 9 V and the potential difference (voltage) left bulb = 3V

Switch on: φ(D) = 9 V and the voltage right bulb = 0V bulb is off

Switch off: φ(D) = 0 V and the voltage left bulb = 9V bulb is on.

 Which bulbs are lit up in which setup? **Task 5** We have to distinguish four scenarios: **Both switches on**: we have a series connection of three bulbs. Each bulb receives 1/3 of the battery voltage. **Both switches off:** we have a parallel connection of three lamps. Can be easily shown using the potential color-blocking rule. **Lower switch on, upper switch off**: only the lamp on the far left is lit. **Upper switch on, lower switch off**: only the lamp on the far right is lit.	 **Task 6** φ(A) = 0 V and φ(B) = 0 V Both battery voltages are connected in series and supply a total of 13.5V. These 13.5V are distributed among two identical bulbs – each bulb receives 13.5V/2=6.75V We therefore have φ(E) = 6,75V and φ(C) = 6,75V and the spot D is 9V „lower" than C We therefore have at D: φ(D) = 6.75V – 9V = -2.25 V