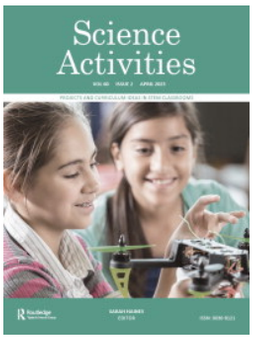

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RESEARCH ARTICLE

Discovering basic electricity through the "forty electronic challenges"

Patrice Potvin, Marie-Hélène Bruyère, Geneviève Allaire-Duquette, Emmanuel Ahr, Éric Durocher, Guillaume Cyr, Patrick Charland and Pierre Chastenay

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ABSTRACT
The "Forty Electronic Challenges" is a "discovery learning" and socio-constructivist science activity that has become rather popular in Canada. The article recalls its emergence and development. It discusses its theoretical underpinnings and how it fits into the existing literature. It then gives educators all the guidelines they need to use it autonomously, and presents observations derived from our extensive use of the activity over the years. Finally, a discussion of its promises, limitations, and possible extensions is presented.

KEYWORDS
Learning by discovery; socio-constructivism; electricity; misconceptions

Introduction

The "Forty electronic challenges" activity has a 30 year-long story. It was first developed in a secondary school by the first author. Since then, it has capitalized on the contribution of numerous colleagues, professors, scientists, and even students, who participated in the development and the optimal sequencing of many of the "challenges." When it first presented only a few problems, it was known as the "qualitative electronics" activity, but with its popularity rising, it was preferably identified as "the challenges." With its eventual and considerable development, it became the "Forty electronic challenges." The word "challenge" became central, and came with a certain philosophy, because it focuses on the positive connotation of the "problems." Students do not begin learning with the obligation to make up a deficit, but with the perspective of accumulating successes.

The activity is essentially a sequence of qualitative problems, ordered from the simplest to the more complex (and more difficult), and which must be resolved in the correct order by the construction of an electrical circuit, with the provided materials. The role of the teacher is to endorse successfully completed challenges (with integral respect to rules and conditions) by affixing his/her signature on the worksheet. The popularity of the activity is such that it has been used by thousands of students around the world, but mostly in Canada. It has also been used in- or inspired- scientific studies (Potvin et al. 2010, 2012, 2014).

Its initial goal was to provide students with an experiential basis for an introduction to the rather abstract core electricity ideas and concepts. In schools, the study of electricity was mostly based on paper-and-pencil exercises or relied on experiments that were essentially verificatory in nature. We wanted to provide a more cleverly scaffolded sequence that could allow minimally guided learning, discovery, essentially through raw trial-and-error manipulation. It was initially meant to support the acquisition of Québec's provincial program for 10th grade students, which included notions of basic electricity (conductivity; resistance; series, parallel, mixed circuits; current law, voltage law [Kirchhoff's circuit laws]). Eventually, we extended to capacitors and relays, mostly for extracurricular uses. The teaching of electricity is considered as profoundly important, due to the culturally rich history of the province with hydroelectricity, but it can also be related to the *Next Generation Science Standards* through the concepts of *Energy* and *Forces and interactions* (National-Research-Council 2013).

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However, even if it was designed for 10th grader, it was soon discovered that it was fun, engaging and academically very useful for any learner, at any age. Adults and elementary students enjoy it alike, the essential difference being the speed and maximum level learners can reach. While undergrads can autonomously go all the way to the last challenge in a few hours, 5th graders usually need teacher's assistance around challenge 18, and after many hours.

The "Forty electronic challenges" is usually used as an introduction to electricity with students with little or no formal exposure to the topic. It makes them progress very rapidly, while not necessarily giving them all it takes to deeply understand underlying phenomena. If needed or required, such understanding can be obtained with further activities, not described here. However, it was found that teachers who use the activity as an introduction, and then systematically refer to it through examples of previously taken up challenges while teaching in a more formal manner, greatly enhance the effectiveness of learning outcomes in their classroom.

The most important feature of the activity is that formal teaching of electricity is not required and not encouraged. The rigorous scaffolding favors the fact that every new problem poses a reasonable challenge, not too difficult for a large majority. However, those for whom some challenges are too easy simply progress more rapidly until they hit an adjusted challenge a few minutes later. There is almost no idleness nor boredom. The "challenging" philosophy allows the learners to rapidly accumulate a certain number of confidence-boosting successes. At the end of the first hour, everyone is exhausted, but happy to have reached achievements. We would like to warn teachers: this activity is very demanding, because it requires to run all around and very rapidly assess the qualities of numerous circuits. However, it is also very rewarding as well as stimulating, because the teacher's role is not to provide feedback nor to correct (nature does the work for them), but to commend, sometimes several times a minute. The atmosphere can thus become overwhelmingly positive, while also sometimes a bit exhausting.

The absence of direct teaching makes the challenges a *learning-by-discovery* pedagogy activity. However, through its studied sequencing and the necessity of making real-world electrical circuits work, it avoids the pitfalls of poorly guided activities (Kirschner, Sweller, and Clark 2006; Clark 2009). With students working in dyads and the discussions that necessarily arise, through constraint to make the bulbs light (and other problems) and to adapt the strategies to available materials, the "Forty electronic challenges" activity could certainly be labeled as socio constructivist. However, it does not provide all the time needed to achieve deep learning, or sufficient institutionalization of knowledge. Indeed, students are often more motivated to take up the next challenge than to really infer useful or formalize laws and principles. However, we believe that encouraging students to slow down and reflect more deeply is a task typical of any teaching. Students are always in tension between learning and succeeding.

The activity helps to overcome certain identified popular misconceptions about electricity, while not addressing them directly. Instead, students can rapidly put one or two hypotheses or solutions that are based on these misconceptions, witness their incapacity to resolve the challenges, and then proceed to "plan B," or initiate discussions with their partner to find possible alternatives. They can also engage in dialogues (or negotiations) with other teams for possible solutions, especially if they know that these teams have already succeeded. It should not be forbidden to proceed as such. Usually, their pride and desire to overtake other teams or to progress faster appear as sufficient brakes not to abuse this strategy.

Among the misconceptions that sometimes motivate students' solutions (and for which the activity may create a cognitive conflict), we can find "one wire is sufficient to make a light bulb light" (Periago and Bohigas 2005; Çepni and Keleş 2006); "only metals are conductors" (Thouin 2015); "high resistance bulbs glow brighter" (Toppr 2023); the "clashing current," lessening current," and "shared current" models (Andre and Ding 1991); "equal division of current in parallel parts" (Chang, Liu, and Chen 1998); etc. However, the activity does not necessarily make them apparent, since students rapidly move to other

options for resolution and do not have incentives to make their failures explicit. We, however, do not believe this to be a problem, since recent models of conceptual change do not necessarily require such highlighting of misconceptions (Potvin et al. 2020).

This article will pursue the objective of reporting on the proper use of the activity and will describe the observations that have emerged over the years as a result of its extensive use with learners from primary school to university. Based on these observations, we will discuss its didactic, pedagogical and motivational virtues, as well as its functional limitations.

Materials and methods

Participants

Participants can be students of any age beginning at 4th grade, but preferably of 10th, in classes not too crowded. They are put preferably freely formed dyads; each roughly separated from others. Single-gender teams may be more frequent; it is not a problem. There are no safety issues whatsoever with this activity.

Materials

Each dyad has a 12 V DC power source, preferably a "battery eliminator," but any source (sets of batteries) can do. Other materials are available on a table at the front or at the center of the classroom. Students can borrow material elements without limit other than the needs of their classmates. If material elements (parts) are available only in small numbers, the following limits can be imposed. For each team:

- Plenty of alligator wire (at least 10 per team);
- 3 12V bulbs;
- 3 spring-loaded push-button switches (push in ["ON"], release ["OFF"]); and
- 4 weak resistors (20 or 25 Ohms) and 4 strong resistors (40 or 50 Ohms)—These resistors are only allowed from challenge #16 onwards.

For the whole class (if needed; usually for secondary students and higher):

- 10 12V relays (from challenge #21 and following); and
- Several large cylindrical capacitors of various capacities (starting with challenge #32)

Protocol

Along with the power source, the "Forty electronic challenges" paper document (Appendix 1) is also distributed. The six rules of the activity are read out loud (and questions can be answered):

1. You may not move on to a subsequent challenge until you have obtained homologation for the challenge immediately preceding it;
2. To obtain homologation, all team members must be present (i.e., close to the circuit, ready to defend their choices and discuss with the teacher);
3. Short circuits are strictly forbidden. (This rule can come with a short explanation of what it is. This explanation is also the opportunity to name parts) If a short circuit is found, which directly connects the positive terminal to the negative one, this circuit cannot be approved. A push-button switch does not prevent short circuits;
4. There can be only one wire attached to each terminal of the power source;
5. (If needed) During the activity, you may not have parts on your table that you do not wish to use within a reasonable time; and
6. Carefully collect and file each part (in specific bins) at the end.

The teacher then gives the signal to begin. As soon as they see students with their hands up, he/she comes and eventually confirms the conformity of Challenge #1 by putting his/her signature in the provided space. Then when a second team is ready, he/she goes to eventually congratulate them with his/her signature, and so on. Homologations (signatures) can be obtained only in the correct order (challenge #2 after challenge #1, etc.). There is no correction grid. Only conformity of the circuit with

the challenge statement and its constraints is necessary. Teachers are not encouraged to provide too many hints. Rather they can encourage students to look at how other teams have taken up the challenges. If teachers can obtain help from a colleague to provide signatures, we encourage them to do so, especially in the beginning of the activity, because the first four challenges are met very rapidly, and they can be quickly overwhelmed.

After a while, teachers like to require from students that they draw their circuits (in addition to having them function properly) in order to obtain homologation. It helps them slow down the process and start making students reflect. Some of them also pause the activity for a few minutes, showing them how to correctly draw wires (vertical, horizontal, at 90°, etc.), light bulbs, resistors, etc., according to standards, or to class-wide standards. When things slow down and the frequency of homologations decreases, some teachers appreciate having longer conversations with students about their circuits, requiring them to use the terms *resistors*, *resistance*, *in parallel*, *in series*, etc., in a correct fashion.

The activity stops when the teacher has reached his or her pedagogical goals, or by exhaustion. However, the activity can also lead to a deeper collective discussion, or to openings to future activities.

Results

In the last 30 years, we have used the "Forty electronic challenges" activity with thousands of science students at all levels, including in higher education. Many school boards, and hundreds of pedagogical counselors and teachers have tested it and used it in their institutional settings. Some of them have developed sub-products or sub-versions of it, in all sorts of shapes and themes. It has been widely used in science clubs, to enrich extracurricular activities. It has been presented many times in professional conferences and in-service training initiatives. It is commonly used in pre-service teacher training in universities in Canada.

It reveals itself as a demanding but engaging activity that generates a lot of motivation. We have seen students begin the activity with a fear of getting electrocuted, and ending it with a deep sense of understanding and mastery. Some students express the desire to pursue beyond following breaks, or to come back after school to continue resolving the challenges. Although we do not explicitly encourage competition, many students, especially boys, take pride in advancing quickly and outperforming other teams. It was also observed that girls seem to respond better to encouragements to push themselves, rather than to simply beat others. We also saw loud expressions of joy when a team finally managed to solve one of the more difficult problems. Usually, the atmosphere is excellent, and the learning is there.

We also believe the activity to be motivating because it makes students directly learn about real-life phenomena. Interacting directly with nature through circuits, instead of through *modelisation*, allows them to better understand the objective value of the activity. Even if we never invoked the links between this academic activity and real-life phenomena (electric circuits in a house, Christmas decorations [lights], etc.) students never asked the infamous questions "Why are we learning this?"

It happens however that some work teams get stuck on one challenge or another for a rather long time. Discouragement and demotivation then threaten them, especially when other teams are performing well or moving quickly. Our experience leads us to recommend that teachers let students decant and reflect for a while before giving them clues. Indeed, providing them with concepts, remarks, solutions, tools, or ideas too quickly does not allow them to perceive their added value. It is therefore preferable to create *a need* for these clues, which can only come from a rather clear perception of what is missing. Providing only small, incomplete, yet crucial cues also allow students to retain the credit that comes with the eventual success, and at least retain the impression that they are making progress through their own efforts.

As mentioned earlier, the activity is also enjoyable for the teacher as much as it is for the students, because its role is essentially positive: to confirm and comment successes. We encourage teachers to even "add a layer" and to double down their expressions of enthusiasm for fertile solutions. In keeping with the usual recommendations (Killian 2017), we have always found it preferable to provide reinforcement for students' propositions or solutions, rather than for their individual qualities.

On the other hand, these reinforcements should never come at the expense of lower expectations of

compliance between the proposed solutions and the wording of each of the challenges. Each of the 40 statements has been carefully thought through and tested (and translated to the best of our knowledge). It is therefore important to respect each word, as each subtlety is likely to be essential to secure the development of the expected knowledge.

Finally, another observation we have made during our years of experimentation concerns the differences between the attitudes of boys and girls in conducting the activity. In general, the boys' teams start off very strong and outpace the girls quickly. The girls seem to be less competitive and more reflective at the beginning. They more often feel the spontaneous need for mutual understanding and shared representation of solutions (often through drawings). This initially seems to be to their disadvantage. However, our observations reveal that these attitudes eventually turn to their advantage, and the delays they seem to have accumulated before the first 15 or 16 challenges are quickly regained once they reach around challenge 20. Their reflexive and communicative attitudes then appear to pay off in the context of more complex challenges. They often surpass the boys, who sometimes struggle to develop reflexive attitudes and the need for real cooperation. Therefore, the initial slowness of the girls' teams should not worry the teachers. We can however observe that most of the time, the mixed girl+boy teams did not necessarily appear to be the best combination, even though we sometimes find recommendations in favor of mixed teams (Miller, Kestin, and Miller 2022). We unfortunately fall short of understanding why their differences in explorational attitude (fast/reflective) could not often be turned into a productive dynamic. We merely observe that often appears to be the case with, of course, exceptions. A systematic exploration of this problem through research could enlighten this particularly interesting difficulty.

Discussion

The "Forty electronic challenges" is a very successful and popular activity. One of the reasons is that it was developed by teachers for teachers. Over the years, colleagues have tested it and participated to its development, through sharing their experience, proposing new challenges, or different formulations or sequencings. Even the students, highly motivated by the activity, proposed new challenges, commented, and thus contributed. We are indebted to them.

The activity can thus be used in teacher training as an example not only of a materialization of socioconstructivist views or as a prototypical example of *discovery pedagogy*, but also as an example of collective professional development. Even if direct teaching of electricity is presented as almost completely absent from the sequence, it nevertheless is present, through the choice, the precise formulation, and the carefully elaborated ordering of the challenges. An entire collective of teachers, a considerable load of pedagogical engineering, hides behind this set of problems.

However, it would be unwise, though tempting, to assume that the "Forty Electronic Challenges" are sufficient to develop a complete understanding of basic electrical concepts. The activity, while motivating, does not necessarily allow the student to secure explicit formulation, institutionalization, or sufficient automation in the use of such concepts. School formalism remains useful and necessary. But perhaps this time, if it is based on an authentic attachment to reality, it could appear to the pupils as a little more sensible and in echo to the reality of natural phenomena, necessarily intrinsically interesting.

Through close observation of the students' first attempts to solve each of the challenges, one can commonly recognize attempts based on the misconceptions (described above) that had been identified by the researchers and anticipated when the activity was designed. However, through their evidently collective efforts, teams very quickly come up with alternative solutions that they fall back on and that quickly allow them to succeed. Thus, even if the students do not go through systematic introspection, it appears that their erroneous conceptions are quickly corrected, as they hardly reappear in subsequent attempts. It is therefore not unreasonable to assert that the activity quickly produces conceptual changes that seem to be sustained, possibly through concerted effort and strong motivation to resolve the cognitive conflicts that reality imposes, for example, when circuits do not behave as anticipated.

Last, let us notice that the mere idea of "challenges" has seduced teachers, as some of them have extended it to other objects of knowledge. Entire sequences of numerous challenges have

indeed been developed over the years, mostly for secondary school students, for *volume and mass*, for *forces* and *movement transmission*, for *dilution* problems, and for *technology* (i.e., engineering -with Lego™ bricks), etc. (see the acknowledgements). These activities, while less widespread, have recorded great success with students, and also with teachers, provided that they be accompanied by more formal activities. Some teachers have also felt the need to add to the electronic challenges enrichment problem-based activities, like the construction of a model house, with lighting, and a realist circuit that behaves accordingly to a design brief. Others have requested that students develop electric quiz games, etc. There are all sorts of enrichment possibilities.

In summary, our main observations about the "Forty electronic challenges" activity are the following:

- The activity has a strong potential to motivate both learners and teachers, possibly because of its experiential nature, which allows the concrete study of phenomena;
- It can be used at almost any level, provided adaptations are made;
- In general, boys start fast, the girls catch up quickly;
- Many misconceptions seem to be rapidly challenged and corrected, possibly through socio-cognitive conflicts that are quickly resolved (successes) through confrontation with real events;
- The activity itself is probably not sufficient to produce learning that is sufficiently formalized for the needs of regular schooling.

Conclusion

In conclusion, the "Forty electronic challenges" appears to be a successful constructivist activity, based on the principles of *learning by discovery*, while avoiding some of the usual pitfalls of such ideology. It has come to be very popular, possibly through its attachment to the reality of natural phenomena, and through a clever sequence of short problems (scaffolding) that distributes difficulty evenly, over a progressive continuum of complexity. Also, because it concentrates on successes, instead of on errors.

The document of the activity is available in the appendix. But if readers wish to obtain a copy (in Word™ format) for use, modification and adaptation, on to eventually contribute to further developments, feel free to contact the first author at potvin.patrice@uqam.ca. Have fun!

Acknowledgements

We would like to warmly thank all the teachers, pedagogic counsellors, scientists, technicians, and of course the hundreds of learners who have contributed to the development of the activity over the years. It is impossible to name them all, but we can however identify these persons, who have been particularly helpful: Jean-Philippe Bolduc, Luc Chamberland, the Laval-Laurentides-Lanaudière regional group, Louis-René Levac, Olivier Laforest, Robin St-Pierre, Geneviève Morin, and HsingChi von Bergman. We would also thank the Association pour l'enseignement de la science et de la technologie au Québec (AESTQ) for the recognition of excellence through the 2000 "APSQ/Merck-Frosst" prize.

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Appendix 1

40 electronic challenges

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AUTHOR@uqam.ca

Rules

1. It is forbidden to move on to a higher challenge before obtaining certification of the challenge immediately preceding it;
2. All team members must be present (i.e., close to the circuit, ready to defend their choices and discuss with the teacher) in order to obtain homologation (signature);
3. Short circuits are strictly forbidden. If a short circuit is found in the circuit, which directly connects the positive terminal to the negative terminal, this circuit cannot be approved. A switch does not prevent a short circuit;
4. There can be only one wire attached to each terminal of the power source;
5. During the activity, you may not have parts on your table that you do not wish to use within a reasonable time; and
6. Carefully collect and file each part (in specific bins) at the end.

Materials

For each team:

- 1 12V power source;
- Plenty of alligator wire (at least 10 per team);
- 3 12V light bulbs;
- 3 spring-loaded push-button switches (push in ["ON"], release ["OFF"]); and
- 4 weak resistors (20 or 25 Ohms) and 4 strong resistors (40 or 50 Ohms). These resistors are only allowed from challenge #16 onwards

For the whole class:

- 10 12V relays (from challenge #21)
- Several large cylindrical capacitors of various capacities (starting with challenge #32)

Good Luck !

(Even if luck has little to do with it...)

Owner(s) of the document: 1) _____
2) _____

Challenge #1

Light up a bulb.

Homologation: _____ Date: _____

Challenge #2

Light two bulbs.

Homologation: _____ Date: _____

Challenge #3

When the switch is pressed, a bulb lights up. When you release the switch, the bulb goes out.

Homologation: _____ Date: _____

Challenge #4

When the switch is pressed, a bulb lights up. When you release the switch, the bulb goes out. However, the current must have passed through four different objects of your choice. (Any object; a fork, a pencil, a zipper, etc. however not the ones in the materials list.)

Homologation: _____ Date: _____

Challenge #5

When the switch is pressed, two bulbs light up. When you release the switch, the bulbs go out.

Homologation: _____ Date: _____

Challenge #6

Switch A turns on bulb 1. Switch B turns on bulb 2.

Homologation: _____ Date: _____

Challenge #7

You have to press either of the two switches to make the bulb light up. When both are pressed at the same time, the bulb lights up as well.

Homologation: _____ Date: _____

Challenge #8
It is necessary to press both switches at the same time to make the bulb light up. Homologation: _____ Date: _____

Challenge #9
Turn on two bulbs quite brightly. (As bright as if you only had one bulb). Homologation: _____ Date: _____

Challenge #10
When you press the switch, three bulbs light up quite strongly. (As bright as if you only had one bulb). Homologation: _____ Date: _____

Challenge #11
When the switch is pressed, three bulbs light up dimly. (More dimly than in the previous challenge). Homologation: _____ Date: _____

Challenge #12
When the switch is pressed, three bulbs light up. One of them lights up strongly and the other two more dimly. Homologation: _____ Date: _____

Challenge #13
Without pressing the switch, a bulb is lit. When you press the switch, a new bulb lights up. It must light as much as the first one. Homologation: _____ Date: _____

Challenge #14
Without pressing the switch, a bulb is lit. When the switch is pressed, two new bulbs are lit. All three bulbs must light up equally. Homologation: _____ Date: _____

Challenge #15

Without pressing the switch, a bulb is lit. When the switch is pressed, two new bulbs are lit. These two new bulbs are not as bright as the first one.

Homologation: _____ Date: _____

Challenge #16

When the switch is pressed, two identical bulbs are lit at the same time. One of the two lights up brighter than the other. Use a resistor.

Homologation: _____ Date: _____

Challenge #17

When the switch is pressed, three identical bulbs are lit at the same time. The first one is the one that lights up the most, the second one lights up a little less and the third one even less.

Homologation: _____ Date: _____

Challenge #18

A bulb lights up dimly. When the switch is held down, the bulb becomes brighter. When the switch is released, the bulb dims back to its original intensity.

Homologation: _____ Date: _____

Challenge #19

A bulb lights up dimly. When switch A is held down, the bulb lights up more strongly. When switch B is held down, the bulb lights up even more strongly. Use 2 resistors of unequal value.

Homologation: _____ Date: _____

Challenge #20

A bulb lights up dimly. When switch A is held down, the bulb lights up more strongly. When switch B is held down, the bulb lights up even more strongly. Use three resistors [no more, no less than three] of equal value.

Homologation: _____ Date: _____

Challenge #21

A bulb lights up dimly. When switch A is held down, the bulb lights up more strongly. When switch B is held down, the bulb lights up even more strongly. Use only 2 resistors of equal value.

Homologation: _____ Date: _____

Challenge #22

At the beginning, no bulb lights up. When switch A is pressed, bulb 1 lights up strongly and bulb 2 lights up weakly. When switch B is pressed, it is the opposite. Caution: neither bulb should remain at the same intensity when pressing A as when pressing B.

	Bulb 1	Bulb 2
Switch A	**Strong**	**Weak**
Switch B	**Weak**	**Strong**

You can use a maximum of two resistors.

Homologation: _____ Date: _____

Challenge #23

Same challenge as challenge 22, but with only one (1) resistor.

Homologation: _____ Date: _____

Challenge #24

You must build a circuit that will behave according to this table:

	Bulb 1	Bulb 2	Bulb 3
Switch A	**Weak**	**Medium**	**Strong**
Switch B	**Medium**	**Strong**	**Medium**
Switch C	**Strong**	**Medium**	**Weak**

You can only use two similar resistors to make this circuit.

Homologation: _____ Date: _____

Challenge #25

When the switch is pressed, a light bulb dims without going out.

Homologation: _____ Date: _____

Challenge #26

When the switch is pressed, a relay is triggered. When you release the switch, the relay stops. You know the relay is working when you hear a slight click inside. You know it's stopping when you hear another soft click. (When getting certification for this challenge, ask the facilitator for a short “relay lesson”)

Homologation: _____ Date: _____

Challenge #27

When the switch is pressed, a bulb goes out. When the switch is not pressed, the bulb lights up. The use of a relay is mandatory. Short-circuits to be watched.

Homologation: _____ Date: _____

Challenge #28

When you press the switch, a bulb A lights up and a bulb B goes out, when you don't press it, it's the opposite.

Homologation: _____ Date: _____

Challenge #29

A light bulb is on. When the switch is pressed, this bulb dims. When the switch is released, it returns to its initial intensity.

Homologation: _____ Date: _____

Challenge #30

Two switches must be pressed at the same time for a bulb to go out.

Homologation: _____ Date: _____

Challenge #31

When you press one of the two switches, the bulb goes out. When both are pressed at the same time, it lights up. When nothing is pressed, it stays on. Tip: use two relays.

Homologation: _____ Date: _____

Challenge #32

When the switch is pressed, it triggers a relay that triggers a second one that turns off a bulb.

Homologation: _____ Date: _____

Challenge #33

A first relay triggers a second relay which triggers a third relay which extinguishes the first relay which extinguishes the second relay which extinguishes the third relay which revives the first relay which triggers the second relay which triggers the third relay which extinguishes the first relay which extinguishes the second relay which extinguishes the third relay which revives the first relay which triggers a second which triggers a third which extinguishes the first which has the effect of extinguishing the second which has the effect of extinguishing the third which has the effect of reviving the first which triggers a second which triggers a third which extinguishes the first which has the effect of extinguishing the second which has the effect of extinguishing the third which has the effect of reviving the first which. ... And so on *ad infinitum*.

Homologation: _____ Date: _____

Challenge #34

When the switch is pressed, a relay makes a continuous noise (a kind of buzzing) of tripping and interrupting, when not pressed, this noise stops. Beware of short circuits!

Homologation: _____ Date: _____

Challenge #35

When the switch is pressed, a relay is triggered and no matter how much you let go of the switch, the relay always stays on. The only way to interrupt it is to disconnect it from the source.

Homologation: _____ Date: _____

Challenge #36

When you press the switch, a light bulb comes on. When you don't press it, it stays on, no matter what happens afterwards. However, if the power is cut off at the source, it goes out again.

Homologation: _____ Date: _____

Challenge #37

When you press the switch, a light bulb comes on. When the switch is released, the bulb slowly goes out. Use a capacitor.

Homologation: _____ Date: _____

Challenge #38

When a switch is pressed, a bulb lights up. When the switch is released, a delay of more than one second passes and then the bulb suddenly goes out.

Homologation: _____ Date: _____

Challenge #39

When the switch is pressed, two bulbs turn on and off alternately very quickly. Use a relay.

Homologation: _____ Date: _____

Challenge #40

When the switch is pressed, a bulb turns on and off at a very slow rate. Use a capacitor and a relay.

Homologation: _____ Date: _____