

## **Charles dú Fay – Explorative Experiments: Describing and Explaining Electrical Phenomena**

### 1. Title and Key Words

Charles dú Fay – Describing and Explaining Electrical Phenomena  
(Episode 3 of the Series – a historical introduction to electricity)

Key Words: Static electricity, electrical repulsion, electrical attraction, Charles du Fay, Attraction-Transmission-Repulsion, Scientific Law, Scientific Theory

### 2. Authors and Institutions

Andreas Henke, University of Bremen, Germany

Dietmar Höttecke, University of Hamburg, Germany

### 3. Abstract

This case study of Charles Cisternay dú Fay's experiments on electrostatic attraction, repulsion, and on different kinds of electricity is the third episode in a series on the history of electricity. The main point of this stage is the reenactment of the experiemental findings of the French chemist and researcher. The episode can be used for teaching secondary school pupils (age 12 to 15).

The pupils plan and conduct research assignments and experiments based on original material from Dú Fay's findings.

Through his experiments Dú Fay expanded the theory of electrification on all kinds of materials and created the first general law of electricity. This law encompassed attraction, which was already known at the time, as well as electrostatic repulsion based on the work of Guericke.

Using the example of this scientific „Law“, pupils can experience how the natural sciences arrive at general statements about natural phenomena. Furthermore, du Fay found evidence for the existance of two different kinds of electricity. With this knowledge, a great variety of electrical phenomena could now be easily described. Thus, pupils can examine ‚Theories‘ and ‚Laws,‘ and differentiate between them based on simple criteria.

#### 4. Description of Case Study (and Suggested Plan of Action)

This stage begins with a short introduction to the most important moments in **research on electricity prior to dú Fay**. (see 5.1.1) including the use of glass as a good 'elektrikum'. Then dú Fay himself will be introduced (see 5.1.2, Fig 2), at which point it will be interesting and informative to explain that the botanical garden where du Fay was director was an important research center for scientists from all over the world.

The next step is the demonstration of **the main points of dú Fay's research**:

What materials can be electrified?  
What circumstances influence the attraction or repulsion of electrified bodies?

and the **type and scope of his experiments** (see 5.2.3)

### Dú Fay

#### Introduction

#### Dú Fay's Research

#### Du Fay's Results

#### Experimental Tasks



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1. He carried out hundreds of experiments, for example, changing to different rubbed materials whose electricity he was examining by rubbing. He searched for regularities which would help describe the observed phenomena and tried to explain the results with a theory about the character of electricity.

Subsequently, pupils will discover du Fay's two most important findings through the use of his original texts (see Material I and Material II):

Regularity: when electrified materials are brought in contact with non-electrified materials, electrical attraction first occurs, then the conducting of an amount of electricity. Finally, electrical repulsion occurs between the electrified materials.

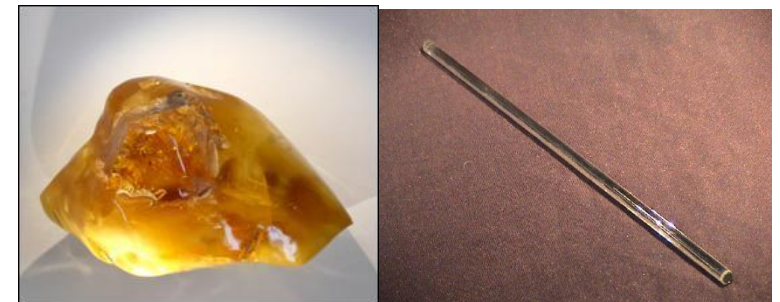
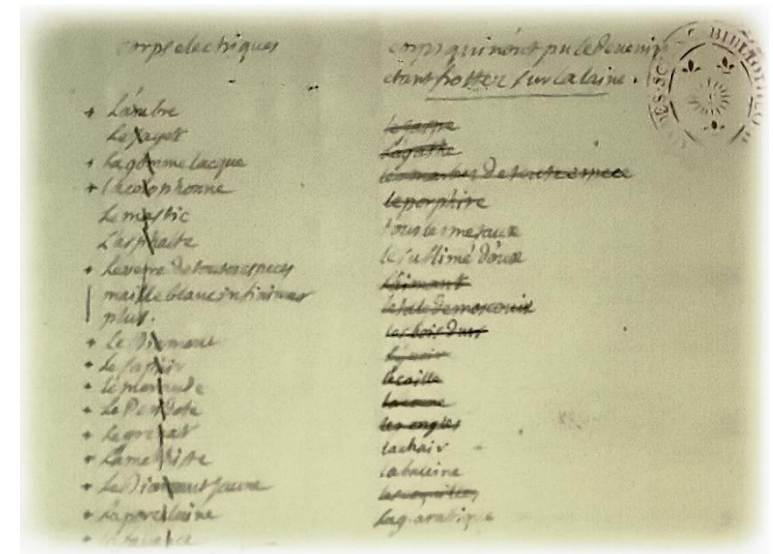
Theory on the Nature of Electricity: there are two kinds of electricity, one like that which occurs on rubbed glass, the second as it appears on rubbed resin. Therefore, differently electrified bodies are attracted to each other, and similarly electrified bodies repel each other.

Next, the pupils can reconstruct du Fay's

## Original Experiments

## Reflection Corner

## Correspondance withDú Fay

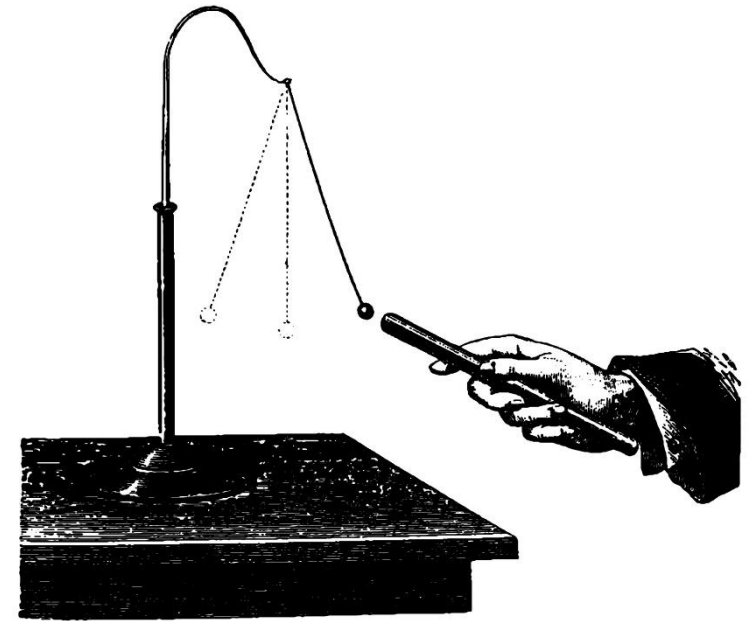


findings by using the recommended research tasks (Material I and Material II) or even develop and carry out their own related experiments.

Chapter 7.1 contains some suggestions for original experiments. They can either orient themselves towards dú Fay's more explorative approach or follow a reconstructed process based on the principle of **„Question-Hypothesize-Experiment-Analyze“** (see 5.2.3). In any case, the observations and conclusions should be carefully noted and the results of the students should be presented to the plenum. The difference between these two methods of the natural sciences can be discussed through questions such as:

How are our experiments different from those of dú Fay?  
How did dú Fay arrive at his results? Is that typical for a scientist? Can one also arrive at scientific knowledge through other means?

The results that dú Fay as well as the pupils, achieve through these experiments, offer a very



good opportunity to clear up widespread misconceptions about the meaning of the concept 'Law' and 'Theory' as types of knowledge. A full description of how these differ from one another and why Gilbert's findings are a good example of this kind of knowledge can be found in Chapter 5.2.2. Reflective questions for the discussion could be:

The two final results of dú Fay's research were: the Law of Attraction-Conductivity-Repulsion and the theory of two kinds of electricity. How do these two results differ?

There are different kinds of knowledge in the natural sciences. For example, there are laws and theories. Which kind of knowledge fits best to dú Fay's results?

The results of the reflection can be consolidated through a fictitious correspondence with dú Fay. (see Material III).

## 5. Background

### 5.1 History

#### 5.1.1 Research on Electricity in the years between Guericke and d'Arcy

Almost sixty years passed between the last experiments of Guericke (around 1670) and the start of d'Arcy's research (which were almost contemporary with those of Stephen Gray). During these sixty years, new research contributed to the theory of electric phenomena. Important work was done by (to name just a few): In 1694 Robert Boyle confirmed Guericke's notion that electrical energy must be able to function in a vacuum, and drew attention to the role of the characteristics of the surfaces of rubbed bodies.

Around 1700, a certain Dr. Wall reported on his painful experiences with electricity, and also classified electrical breakdown in electrical phenomena which had formerly been understood as an ignition of sulfuric or other vapors. He suspected electrical breakdown of occurring around phenomena such as lightning and thunder.

Simultaneously, glass was being tested as an excellent material for electrification – first by Newton, who had reported on this knowledge in 1675, then from Francis Hauksbee.

The latter is credited as the true inventor of the electrostatic machine, around 1700. Based on a rotating glass ball, it borrowed from Guericke's ideas, but provided much stronger results than sulfur had, as Hauksbee himself noted. This machine, however, was almost forgotten about, and had to wait almost 40 years before being reinvented. However, this reinvention was a great success –the friction-operated electrostatic machine, in all its possible variations, became a standard instrument of electrostatic research.

Newton and Leibniz made great advancements in mechanics and mathematics, and Denis Papin's invention of the steam engine in 1705, improved upon by Newcomen and Watt, made a lasting impact on the economy and society of the following century.

#### 5.1.2 Charles François de Cisternai Dufay (1698 –1739, Paris)

He was the son of a noble family and, after a short time in the military, pursued diverse academic ambitions. Probably through prominent advocacy, he gained an academic position as a chemist in 1723. His further career was as arduous as it was brief: in 1731 he became a full member of the Academy, in 1732, in addition to this, he became director of the Royal Botanical Gardens in Paris (Jardin du Roy). However, he could not perform this office for long: he died at the rather early age of 40, of smallpox.

In the seven years of his directorship, he made the Gardens once more into one of the most important research centers of Europe, with considerable resources and a distinctive research and lecture enterprise.



### 5.1.3 Dú Fay's Research

A summary of Dú Fay's results:

- *All* bodies can be electrified through rubbing. The exceptions are metal and soft or liquid materials ([1], p. 28 top, 29 bottom)
- *All* bodies, including metal, can be electrified through contact. ([1], p. 29, para. 3)
- *There* are two states of electrification, one vitreous and one resinous. ([1], p. 31f)
- Vitreous electrified bodies attract resinous electrified bodies, and repel those which are also electrified with vitreous electricity. ([1], p. 31f)
- Electricity that has been conducted onto a body is of the same kind as that belonging to the body from which it originally came ([1], p. 32, para. 2)
- Glas is as good an insulator as silk cord.
- *Damp* cords conduct electricity better than dry ones. ([1], p. 29, para. 6)

*The previous three points are direct additions or responses to experiments Stephen Gray had carried out just prior to du Fay.*

Dú Fay asked himself the question, **when exactly attraction arises, and when repulsion, and which circumstances are responsible for which process.** Du Fay's strategy was to vary the different parameters: what kind of electrification of the bodies (rubbing, electricity transmission), the level of electrification, the size of electrified bodies, their materials and the composition of the underlying surface. In hundreds of experiments, he varied the distance between bodies and studied the influence of other bodies that were nearby. In spite of the wide scope of his experiments, the problem was indeed much more difficult to solve than the previous ones. The results remained perplexing and did not help create a consistent regularity.

#### An Initial Regularity: 'Attraction-Conduction-Repulsion'

In very particular constellations of electrification a rule became apparent: when an electrified body attracted a non-electrified body, and the non-electrified body moved close enough that it itself became electrified through a transfer, the attraction reverted to repulsion, and the body that had initially been attracted moved away again. This rule was clearly very generally valid and could make many effects comprehensible. At the same time, however, this rule was also explicitly limited to pairs of bodies within which one body became electrified through the other. For all other cases, the circumstances continued to appear confusing and apparently random.

#### The Critical Experiment:

In the course of his further experimentation with these methods of variation some key evidence arose for du Fay. He suspended a piece of gold leaf over his glass tube and then brought a third, electrified body towards the gold leaf. When this third body was made of glass, then the gold leaf was repelled by it, but when the third body was of copal resin, the gold leaf was attracted to it! This result fully confused du Fay, but indicated strong evidence that the kind of material was important, and du Fay followed this lead at length. The results were more and more astounding – they demonstrated a very clear dichotomous dependence on the kind of materials used.

### The Conclusion:

In the end, this led Du Fay to a radical proposal: *instead of electricity in general, one should speak of two electricities. Thereby the rule applies that an electrified body repels all those bodies which have the same electricity, but at the same time it will also attract those bodies which have the the other kind of electricity. Moreover, as the experiments showed, both electricities also retained their character when transferred to other bodies.*

Du Fay's results showed that the kind of electricity a body takes on when it is rubbed depends on the material of which this body is made. Thus the differentiation of two electricities also led to a division of all materials into two groups, and the electricities could be named after the important materials in each group. Du Fay thus spoke of vitreous or resinous electricity. With these new terms, as he declared, du Fay could now understand not only his own extensive experiments on electrical attraction and repulsion, but also those of other researchers.

His findings were a radical proposal with implications on many levels. Du Fay could not only ask if his classification of materials was a sign for more fundamental properties of matter but, also, more directly, that the field of electricity had now a totally different outlook, at least for Du Fay. [see 3]

### A Theory:

Even if dú Fay did not seem fond of referring to theoretical entities, he developed a theory to explain this behavior where there existed two different electrical fluids – not visually perceptible or of any weight. Neutrally charged objects would have equal amounts of both fluids which would neutralize each other. When rubbed, an object would lose one of these fluids and leave an excess of the other. He developed a theory to explain this behavior where there existed two different fluids. Neutrally charged objects would have equal amounts of both fluids which would neutralize each other. When rubbed, an object would lose one of these fluids and leave an excess of the other.



## 5.2 Learning About the Nature of Science

### 5.2.1 The Law of Attraction-Conductivity-Repulsion

In the course of his research, du Fay conducted a great deal of similar experiments on electrical attraction, in which he only varied a few parameters (weight, strength of electrification, distance etc.) Only thus could he determine the Law of Attraction-Conductivity-Repulsion as the lowest common denominator of his experiments.

Compared with the principle of of Attraction-Conductivity-Repulsion he described his decision about there being two kinds of electricity as being ,even more general and even more curious.’ (Material C, page 31 lower third). With the gold leaf experiment alone (see dú Fay’s research) dú Fay would not have recognized this need. He needed all his previous experiments in order to test whether attraction and repulsion were dependent on the material being tested. This *Theory* could first prove itself by describing all formerly-known and actually-researched phenomena. If dú Fay had not already carried out such a multiplicity of research, he might not have deemed this theory as being meaningful. The search for regularity and similarity is one (but not the only!) basic method in the natural sciences, which aims to make *general statements* about related processes. A rule, a principle, or a law is such a statement. Furthermore, with this knowledge, predictions can be made about natural processes which fall within the scope of these statements.

In the process of development and proving of scientific statements such as laws or theories, the simplicity of the principle, (see Material A), the scope of its application, as well as its productive function in the course of research play decisive roles. Of equal value are social factors, such as level of popularity among scientists, credibility of its supporter(s), and recognition of du Fay and his research.

### 5.2.2. On the Differentiation Between Laws and Theories

Most pupils use these terms in an intuitive or colloquial manner, which is not consistent with their meaning within the natural sciences, and which can lead to a wide range of problems in understanding. A simple method for distinguishing between these two forms of knowledge is the below table:

Laws	Theories
<p>DESCRIBE</p> <p>Processes in Nature (HOW) (sometimes in a mathematical way)</p> <p><i>Example: The law of attraction-conductivity-repulsion describes what happens when electrified bodies come in contact with one another.</i></p> <p>Are often written as 'IF....THEN'</p> <p><i>Example: 'If an electrified body touches another, then...'</i></p>	<p>EXPLAIN</p> <p>Processes in Nature (WHY)</p> <p><i>Example: The theory of two electricities explains why electrified bodies attract some other electrified bodies but repel others.</i></p> <p><i>Example: The theory of two electricities explains why attraction and repulsion depend on the materials being rubbed.</i></p> <p>Are often written as '...happens, because...'</p> <p><i>Example: 'Bodies electrified by glass attract bodies electrified through resin, BECAUSE there are most likely two different electricities.'</i></p>
<p>NEITHER are direct observations or data, but are rather established by scientists through the interpretation of observations and data.</p> <p>Represent REGULARITY in observations and in data</p> <p><i>Example: attraction-transmission-repulsion occurred in many of dú Fay's experiments</i></p>	
<p>Make predictions possible for procedures where they apply</p> <p><i>Example: the law of attraction-transmission-repulsion allows for prediction about what happens when one electrified body touches another.</i></p>	<p>Allow for many and widespread predictions, which can then be tested through experimentation.</p> <p><i>Example: the theory of two kinds of electricity also explain observations made by other scientists in very different experiments.</i></p>

Require much hard work and good powers of observation from scientists, since they must find regularities in many different observed phenomena.

*Example: dú Fay carried out hundreds of experiments before he could determine the law of attraction-transmission-repulsion as a commonality between certain experiments.*

Require a great deal of CREATIVITY on the part of the scientists, given that a good explanation does not exist in the observations themselves. Scientists must be able to come up with explanations that fit their observations.

*Example: the assumption that there could be two kinds of electricity cannot be drawn directly from dú Fay's observations during his experiments. He had to interpret them and come up with a possible explanation.*

They have only LIMITED application for particular phenomena or situations.

*Example: the law of attraction-transmission-repulsion is not valid for magnets (although they also demonstrate attraction and repulsion).*

*Example: the law of attraction-transmission-repulsion cannot be applied to gases but only to solids.*

Are often INCOMPLETE, because they explain certain phenomena and not others

*Example: the theory of two electricities explains why attraction and repulsion are dependent on the kind of materials being rubbed, but not why charged bodies sometimes remain stuck to each other (induction).*

Are PROVISIONAL and NOT CONCLUSIVELY PROVABLE.

They simply fit the observations or they do not, or make predictions which occur or do not.

Thus it is clear that:

- A Theory is NOT an as-yet unproved Law
- Theories DO NOT become Laws; Laws DO NOT become Theories
- Nature (and scientists!) are not categorically restricted by once established scientific laws and there are no penalties for not following these laws.
- Laws do not have to be valid all the time or in every situation or everywhere in the universe (testing for that would apparently mean an infinite amount of work).

- Laws and Theories are based on data, but require a scientist's interpretation

### 5.2.3 Dú Fay's Approach and Experiments for Schools

The application of this case study for science instruction can be dramatically different from the way in which dú Fay approached his experiments. In hundreds of experiments, dú Fay varied the distance between bodies and studied the influence of third bodies which were nearby. Naturally, pupils will not be doing the same, but will plan experiments for testing particular assumptions. BOTH methods are valid scientific methods - this case can be used to contrast them effectively and demonstrate, that either one can lead to valid scientific knowledge.

Dú Fay undertook **explorative (enquiry-based) experimenting**:

Many experiments that differ only slightly from one another are employed within a very **open line of questioning**, so that, as far as possible, no effect will be overlooked and most effects can be directly attributed to experimental circumstances.

#### **Research Question**

What influences the force between electrified bodies?

The pupils conduct **hypothesis-driven (testing) experimenting**:

Following rather **closed types of questions** the pupils will conduct single/simple experiments that are designed to test the hypothesis in question.

#### **Research Questions**

- Are there different kinds of electricity?
- Is there a regularity in the processes that happen when charged bodies are brought near each other?

## 6. Target Audience, Curricular Benefits and Didactical Considerations

The case study on Charles dú Fay's experiments on electrical processes is the fourth episode in a series on the history of electricity. This episode is suitable for pupils between the ages of 12 and 15. Teaching about electricity plays a large role in physics and in physics instruction. The most important concepts and ideas can be introduced and consolidated through the treatment of electrostatics. This minimizes later misconceptions and learning difficulties in teaching about

electricity. (This is also important in vocational training.) An informed treatment of fundamental theoretical concepts in science such as ‚Law‘ and ‚Theory‘ is a recognized need for teaching the natural sciences.

## 6.1 Learning Goals and Skills

### Content Knowledge

- Attraction and Repulsion as equivalent phenomena of electrification
- The term ‚charge‘ for ‚that which is exchanged.‘
- The basic development for exchanges of electrical charge as ‚attraction-transmission-repulsion‘
- Differentiation of two kinds of electricity based on the ways they are produced.
- Quantity  $Q$  for an amount of charge (and its unit ‚Coulomb‘)

### The Nature of Science

- Knowledge within the natural sciences can arise as descriptions or explanations of observations from a great number of experiments
- „Law“ and „Theory“ are two different kinds of knowledge in the natural sciences and do not ever merge with one another
- „Law“ and „Theory“ can be differentiated from one another through very particular properties (description vs. explanation, etc.).
- „Law“ and „Theory“ are similar in very particular ways (provisional nature, based on data)

## 7. Teaching and Learning Resources

### 7.1 Dú Fay’s Experiments on the Regularity of Electrical Processes and on Two Possible Kinds of Electricity

#### 7.1.1 Required Material

- Silk thread, small pieces of cork, a pendulum electroscope
- Amber, rods of sealing wax, glass rods, PVC rods, pieces of (real) straw, wooden rods, steel rods (for example those from laboratory equipment)
- Materials for rubbing: wool, cotton, and silk scarves, cat fur
- lightweight bodies: cotton thread, scraps of paper, brass filings (byproducts of metal work), iron filings or powder.

#### 7.1.2 Experiments and Advice

The experiments here serve to help illustrate and validate dú Fay’s hypotheses, he himself used them for the same purpose. However, he did not obtain these hypotheses (attraction-transmission-repulsion and two electricities) through these experiments, but only after conducting hundreds of experiments on electrical attraction and repulsion. Pupils can undertake these experiments

themselves with different materials for rubbing, different substances being rubbed, different bodies to be attracted or repelled, as an introduction to the subject. When possible, size, distance, and strength of electrification should be varied.

### **Experiment 1: The Principle of Attraction-Transmission-Repulsion**

- A silk thread is touched with an electrified body: first it is attracted, and after a short time the repulsion effect suddenly appears. If the silk thread is touched to a grounded object, the attempt can be repeated.
- The electrified body is brought near to lightweight materials such as feathers, paper scraps etc on a grounded background, and the lightweight bodies are alternately attracted and repulsed.

#### Advice for Experiment 1:

1. Altogether this leads one to sense that indeed SOMETHING is being transmitted and not just that a transfer of state happened. After all the supply of the electrified body seems to run low. This can also be seen very clearly in Experiment 3.
2. In order to demonstrate the sensitivity of the silk thread to air currents, and to diminish this sensitivity, a ball of elder pith, a very small piece of cork, or a piece of loosely rolled aluminum foil can be attached to the end of the thread.
3. To disengage the paper scraps or feathers, the rod must sometimes be lightly shaken (as with Guericke's ball of sulfur).
4. The rod should be only weakly electrified, so that the lightweight bodies can be easily detached.

### **Experiment 2: Different Electricities**

Two silk threads are electrified through a glass rod, and two further silk threads are electrified through a rubbed sealing wax rod or through amber. First, the principle of attraction-transmission-repulsion can be seen: through transmission, the threads are repelled by the respective rods (and also repel each other). However, if a vitreously-electrified and a resinously-electrified thread are brought together, they attract each other. Therefore, there must be two kinds of electricity, because otherwise one would expect to see repulsion here, too.

### **Experiment 3: Attraction-Transmission-Repulsion with Thread and/or Pendulum Electroscope**

Most of the experiments can be carried out very well with the pendulum electroscope (see Fig. 1). The principle of attraction-transmission-repulsion is



implied in Material D but the experiment can be extended when a differently charged second rod is brought to the other side of the little ball, opposite to the first rod. The ball will now periodically swing back and forth between the two rods. This effect does not last for very long when the second rod is not electrified, but it is even shorter when the second rod is electrified with the same kind of charge.

#### **Experiment 4: Resin-Glass-Electricity Indicator**

Resinous or vitreous electricity is transmitted to a silk thread. Now it is possible to test a variety of differently electrified bodies for resin or glass electricity: repulsion means they are charged with the same kind of electricity as the silk thread. Attraction means they are charged with the other kind of electricity.

##### Advice for Experiment 4:

Dú Fay noticed, without having a clear explanation, that similar electrified bodies where one has a weak charge and the other a strong one nevertheless attract each other. His opinion was that they should have repelled each other. (This effect is due to induction). To avoid these problems he stated in his instructions that one should charge every tested body as much as possible.

#### **Experiment 5: The Strength of Repulsion**

A pair of threads of different material but of the same weight are suspended from a metal rod so that they are near to each other. The metal rod should be isolated, for example by hanging it with silk threads. The threads repel each other more or less depending on how much they are charged.

##### References for Experiment 5

Here the principle of a thread-electroscope, which shows the power of the charge, is used to test the ability of different materials to be electrified. One assumes that the charge is distributed evenly over the metal rod. The problem is that both threads have to have similar weight per length to allow a comparison between the different amounts of repulsion.

## 7.2 Material for Pupils

### Material 1: Research Task "Two Electricities"

#### **Charles dú Fay writes:**

*And so it is certain that bodies which become electrified through contact repel those bodies from which they have been electrified. Is it also true that they will be repelled by all other electrified bodies, regardless of which kind? And is it true that bodies which have become electrified are only different from each other in the strength of their electrification? Investigating these questions led me to a discovery which I had not at all expected and of which I believe no one has yet had the slightest notion.*

*We see that there are two very different kinds of electricity, and that these are those of the clear, hard bodies, such as glass or crystal, etc., as well as tar or resin-like bodies such as amber, resin lacquer, sealing wax, etc. All these bodies repel each body whose electricity is of the same kind, and attract all those which are of the opposite kind.*

*Bodies which themselves are not electrified can obtain both kinds of electricity. Then their properties are the same as the body from which they have been electrified.*

#### **Assignments**

Read what dú Fay has written about his research and answer the following question: What „investigations“ did dú Fay undertake and why did he bother with this at all?

**With the materials provided, conduct your own experiment with which you can demonstrate what dú Fay discovered. (You must think it through yourselves; the result is not in the text):**

- Pose a clear research question which you will try to answer through an investigation
- Think about experiments which will help you answer the question
- Note your observations while conducting the experiment
- Interpret your observations: can you answer the question with them, or do you have to carry out further experiments?
- Present your investigation (research question, experiments, observations, results) to the class.

Text from dú Fay on the Theory of Two Electricities and related tasks, as well as research assignments.

Dú Fay Text from: Philosophical Transactions, Vol.38 (1735), p. 263ff, Dufay, adapted translation

**Charles dú Fay writes:**

*And so it is certain that bodies which become electrified through contact repel those bodies from which they have been electrified. Is it also true that they will be repelled by all other electrified bodies, regardless of which kind? And is it true that bodies which have become electrified are only different from each other in the strength of their electrification? Investigating these questions led me to a discovery which I had not at all expected and of which I believe no one has yet had the slightest notion. I discovered a very simple principle which can explain a great deal of the irregularities that seem to accompany most experiments in electricity. This principle states that electrified bodies attract all those bodies which are not electrified. These then become electrified through contact or from being very near to electrified bodies. Now that both bodies are electrified, they repel one another. If this principle is applied to different experiments in electricity, one is astonished at the number of irregular and mysterious phenomena which can be explained through it!*

**Assignments:**

Read what dú Fay has written about his investigations and answer the following questions:

1. What „investigations“ did dú Fay undertake and why did he bother with this at all?
2. What are dú Fay’s results?

With the materials provided, conduct your own investigation with which you can demonstrate what dú Fay discovered. (You must think it through yourselves; the result is not in the text):

- Pose a clear research question which you will try to answer through an investigation
- Think about experiments which will help you answer the question
- Note your observations while conducting the experiment
- Interpret your observations: can you answer the question with them, or do you have to carry out further experiments?
- Present your investigation (research question, experiments, observations, results) to the class.

Text from dú Fay on the Law of Attraction-Transmission-Repulsion and related materials as well as research assignments

Dú Fay Text from: Philosophical Transactions, Vol.38 (1735), S. 263f, Dufay, adapted translation

Material III: Writing Task – dú Fay Needs Help

**Imagine you receive the following letter from dú Fay:**

*My dearly esteemed colleague ,*

*I am sure you have heard of the astounding results I have arrived at through many experiments.*

*Nevertheless I will summarize:*

- 1. My observations of electrified bodies can be very well described through the general Law of Attraction-Transmission-Repulsion.*
- 2. I am certain that all my observations can be explained through the existence of two kinds of electricity.*

*Perhaps, I may kindly ask for your assistance:*

*A short time ago it was suggested that there are different kinds of knowledge in the natural sciences. I find this a marvellous idea! However, I am not sure how I should identify the above results. Which is more of a law, which more of a theory? And how should I justify this claim? I fear if I publish something that is incorrect it will damage my reputation, and therefore I would be eternally grateful, if you were to help me to correctly classify my results.*

*Yours, with my kindest regards,  
Charles dú Fay*

**Your response could begin like this:**

*Dear Friend and Colleague,*

*It is with great interest that I have observed your research. In everyday speech, the terms ‘Law’ and ‘Theory’ are often understood in a very different way than what they mean in the natural sciences. But your results can be very easily classified, because there are certain things which apply for scientific laws and things which apply for scientific theories. I will try to classify your results ...*

Creative writing task for the consolidation of the idea of the difference between theories and laws.

The pupils should use the information in Table 5.2.2.

### 7.3 Graphic Materials

Fig. 1: A Simple Pendulum Electroscope

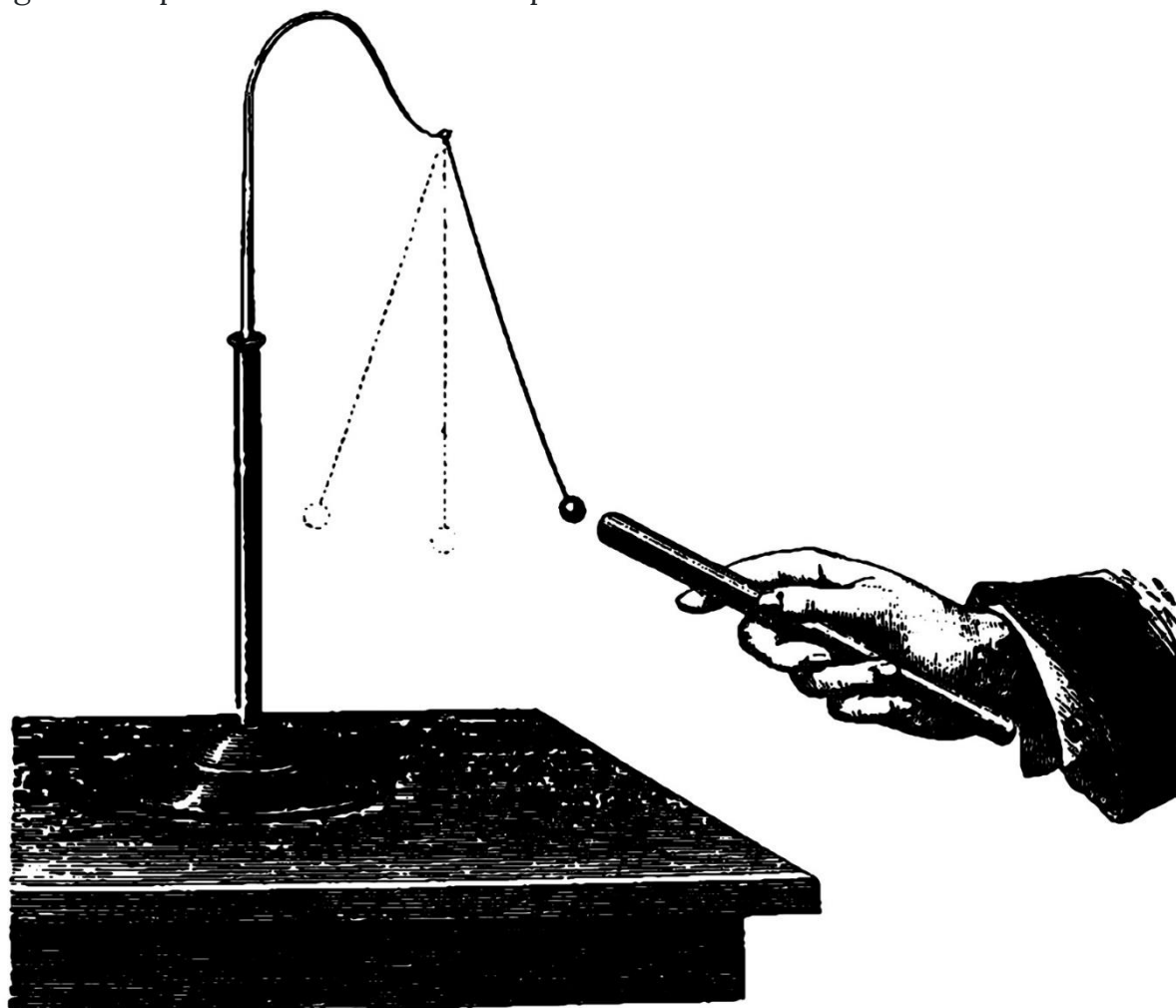


Fig. 2: Glass Rod and Piece of Resin (Copal)

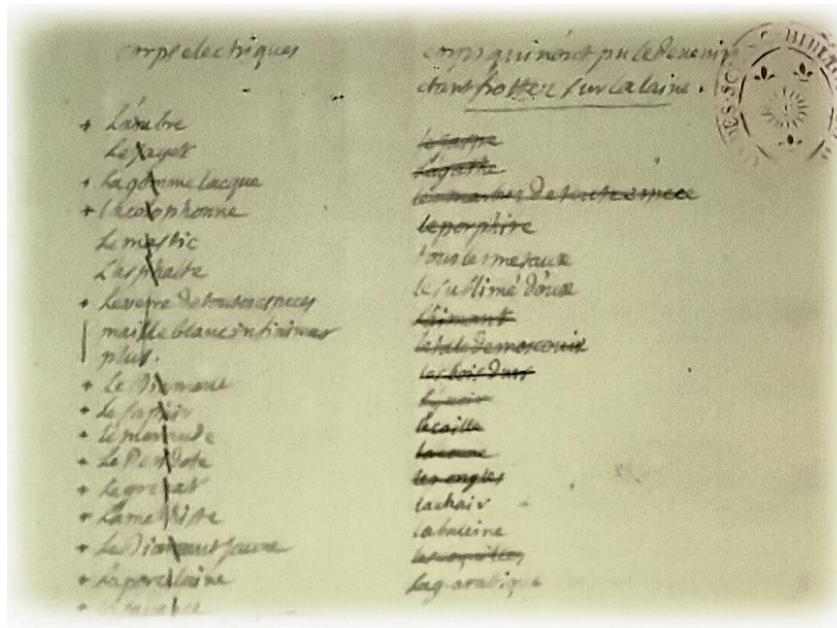


Fig 3: Charles François de Cisternai Dufay (\*1698 – †1739, Paris)





Fig. 4: Excerpt from du Fay's Laboratory Journal



Left the list of electrifiable materials, right the non-electrifiable materials.

The more experiments du Fay carried out, the more materials he had to cross out on the right hand list and move to the list on the left. Source: (3)

Fig. 5: A View of the Experiment Room of the Botanical Gardens in Paris (Jardin du Roi)



Du Fay's work in the Botanical Gardens was responsible for the fact that, even many years after his death, famous scientists came to do research and hold public lectures there. Source: (3)

Fig 6: Amphitheater of the Botanical Gardens



Source gallica.bnf.fr / Bibliothèque nationale de France

Lectures in the natural sciences were also held here.

Source:<http://gallica.bnf.fr/ark:/12148/btv1b7744334r>

## 8. Obstacles to Teaching and Learning

### 8.1 Different types of research

Many pupils often demonstrate typical gaps in their knowledge of the theoretical foundations of science, including lacking knowledge about different kinds of research – in this case made clear through their lack of knowledge about the difference between exploratory and hypothesis-driven experimentation. It can be brought up in this case study that researchers approach their work differently depending on the goals they are pursuing (Discovery or Testing).

Furthermore, pupils usually start with an idea of concepts such as theory and law that is based on colloquial language and has nothing to do with their real meaning in the natural sciences. This often leads to inappropriate ideas about the development and validity of scientific knowledge. In paragraph 5.2.2 simple properties and typical mistakes in thinking will be presented so that within the context of explicit reflection appropriate ideas can be developed.

8.2 The “Reflection Corner“ – a method for addressing the nature of science explicitly and reflectively

**The “reflection corner“ is a method which facilitates and structures the students’ reflections about role, function, conditions and properties of science, scientific knowledge, and its production towards general insights about the nature of science.**

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## 9. Methodical and Didactical References

### 9.1 On the experimental phase

Depending on the amount of knowledge and experience the pupils have, the teacher should consider stepping in to guide or check the learning process. The teacher should make certain that all groups have a clear line of questioning, possessing a type of research question, which they intend to answer. Here, the original quotations and the research tasks (Material I and II) will be useful for inspiration. The situation can be made still more open ended by giving the pupils only "attraction-transmission-repulsion" or the unexpected attraction of a differently charged body as phenomena to research, then allowing them to develop their own line of questioning, hypotheses, experiments, and explanations.

### 9.2 Fine-tuning guidance

- Distribute the research tasks together with Figure 1 or Figures 1 and 2.
- Demonstrate dú Fay’s critical experiment (see 5.1.3) on two kinds of electricity.
- Either suggest or construct several of the experiments (Experiments 1-4).

### 9.3 Reflection task: the difference between theories and laws

In a trial of this case study, reflection was initiated through a task based on the table in 5.2.2. The task structure is as follows:

1. The pupils drew a table with the column headings "Theories" and "Laws"
2. Next the pupils sorted the general characteristics of theories and laws into the correct columns based on their own assessment. One method would be to distribute cards to the pupils with one characteristic on each card.
3. Then the pupils looked for the appropriate examples from the table in Section 5.2.2 and arranged the general characteristics of laws and theories accordingly They received the examples as individual cards with one example on each.



4. In groups, the pupils create one table based on putting together all their individual results.
5. The groups present their tables and discuss the differences between them with the teacher. The teacher's task is to guide the discussion and to only intervene with questions when there are serious mistakes in understanding.

This way one can make sure all pupils share their ideas on the two types of knowledge while giving enough support for it not being frustrating or too demanding. Also, all theoretically relevant criteria have to be judged individually and paired with a corresponding example from Du Fays research.

## 10. Results of Research and Evaluation

See 9.3.

## 11. Further user professional development

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12. Sources

**Attachments**

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