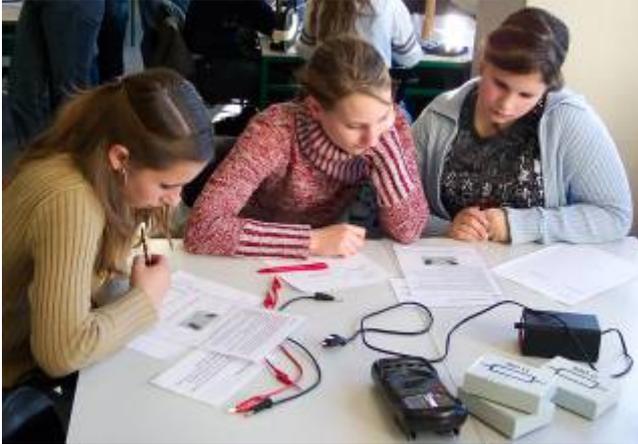


## Teaching Material

### Suggested Lesson Plan

Introduction	<p>The teacher introduces the lesson.          Possible topics: measuring errors, drawing the functional graph/ curves          -&gt; literature, resp. physical background</p>
Stations	<p>The experiments are offered in stations and are to be carried out independently and in their own responsibility (worksheets offer stimulation).</p> 
Final Session in Class	<p>Each group presents the results of their group work at the station.</p>

## Material needed and Experiments

### Station 1: *Experiment Tunnel*

Variables	Distance to light source and intensity of light
Interrelation	Approximately square reduction of light intensity with decrease from light source.
Material	Lux metre, Various cardboard tubes of same diameter Window at daylight (window pane serves as light source) 
Procedure	The cardboard tubes are held closely to the window pane. On the other side, the light sensor of the lux-metre is held tightly to the tube. The intensity of the light can be read on the display. 

<p>Cross-curricular Background</p>	<p>A lightsource (sun, lamp etc.) sends light of a special quantity. A recipient (eye, photo-diode etc.) “feels” a special brightness. The lux-meter measures the brightness in lux. Lux-meters “feel” similar like the human eye. They don’t measure the energy of the light; they measure how bright the lighting seems to be to an eye. Light of same energy but different colours seem to have not the same brightness.</p> <p>The measurement is realized by silicium-diodes, which are connected in locking direction. Action of light causes an electric current, which is a measure for the brightness. The brightness or intensity of lighting is the ratio between light current on a plane and area of the plane. 680 lux relates to an area of 1 m<sup>2</sup> lightened by monochromatic yellow-green light (550 nm) of 1 Watt. 0,1 Lux relates to red light (750 nm) under the same conditions.</p> <p>Examples of light intensities:</p> <ul style="list-style-type: none"> <li>- sunny summer day outside: about 100000 lux</li> <li>- covered sky in summer: about 20000 lux</li> <li>- dimmed winter day: about 3000 lux</li> <li>- good street lamp: about 40 lux</li> <li>- night with full moon: about 0,25 lux.</li> </ul> <p>Good lightening helps to avoid accidents. For work there are regulations which demands 100 to 250 lux and 1000 lux for precision work.</p> <p>The brightness/ intensity of light depend also on the distance of the light source. The intensity decreases quadratically with the distance.</p>
<p>Relation to Reality</p>	<p>Ride into a tunnel (without seeing the end), distance to a lamp (street light, desk lamp)</p>

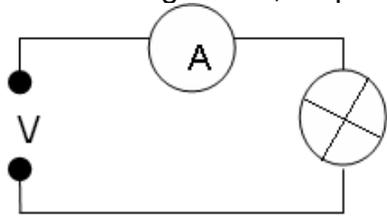
**Station 2:**  
**Experiment: *Aeroplane wing***

Variables	Angle of attack of a wing/surface and lift	
Interrelation	Partially cubic connection can be approached.	
Material	<p>A moveable wing.                  This can be realized with a simple wooden frame covered with card board (see photograph). A protractor to measure the set angle.                  A hair drier to produce the air stream, scales.</p>	
Procedure	<p>The wing is set at a given angle and that angle is measured with the help of a protractor. A hair dryer blows air horizontally (always from the same position) in the direction of the wing (card board). The difference in mass is indicated on the scales.</p>	

<p>Cross-curricular background</p>	<p>The three basic laws of mechanics are Newton's axioms (Axiom: a law that is considered true – until it is disproved):</p> <ul style="list-style-type: none"> <li>- The first states that a body is either in a static condition or it moves uniformly (at a constant speed) in a straight line, as long as no external forces affect it.</li> <li>- The second states that, in a body of the mass <math>m</math>, the force <math>F</math> effects an acceleration <math>a</math> by <math>F = ma</math>.</li> </ul> <p>In connection with this experiment, Newton's third axiom is of special interest, because it states that any force is counteracted by a counter force of the same value and in the opposite direction (rule of thumb: <i>actio = reactio</i>). This makes us understand why a plane flies. Through the special form and angle of the wings, a force acts upon the air stream. It is deflected downwards; the counterforce acts on the wings upwards (Cf. simplified presentation in the graph). The form and the position of the wing (marked by the angle of attack (<math>\alpha</math>), are, next to the speed of the aeroplane, decisive for the "dynamic uplift force" effecting the movement of the aeroplane.</p> <div data-bbox="689 699 1164 922" data-label="Image"> </div> <p>The uplift force in the experiment: In the experiment, the wing is reproduced in an idealized fashion by a straight piece of card-board (if one wants to do without the aerodynamic experimental wings offered in shops). The wing is positioned on the scales and its mass is measured. The air stream (simulated here by a hair dryer) reduces the mass. Newton's second law illustrates that the difference in mass is a measure of the uplift (Cf. above).</p>
<p>Relation to Reality</p>	<p>Flying, gliding, paragliding, aeroplane</p>

(To Experiment: *Aeroplane wing*)

**Station 3:**  
**Experiment *Electric Bulb***

Variables	Voltage and amperage	
Interrelation	Amperage increases with voltage, however, the relation is not proportional. The relation depends on the respective switched components (electric bulb etc.). As the case may be, a root relation can be established.	
Material	Power supply with variable voltage (up to 12 V). Multi-metre, 3 cables, Electric bulb with socket	
Procedure	<p>The components are switched in an electric circuit (see photo). The voltage is varied and the respective amperage is measured. The difference in brightness, respectively, heat is observed.</p> 	

<p>Cross-curricular Background</p>	<p>The electric voltage is a measure of the difference in the distribution of the charge induced. At the “negative pole”, there is a lack of electrons compared with the surplus of electrons at the “positive pole”.</p> <p>If the circuit is closed, a current flows to equalize the charge (In order to avoid a short circuit, a consuming component, such as an electric bulb, has to be switched in between). If the current flows, the bulb lights up. With greater amperage, the bulb glows brighter.</p> <p>The individual resistance R of components in the electric circuit can be determined through the quotient of voltage U and amperage I: <math>R = \frac{U}{I}</math></p> <p>For certain components (e.g. a “Constantan” wire or an iron wire, kept at a constant temperature) <b>Ohm’s law</b> applies. It states that the resistance is constant, i.e. that amperage and voltage are mutually proportional.</p> <p>Ohm’s law does not apply to an electric bulb switched in the circuit. (In an electric bulb, the electric energy/current is transformed to radiation energy. The metal wires inside glow, i.e. the metal atoms are stimulated). With an increase in voltage, resistance increases. It is because of the increase of temperature, which means an increase in the movement of the particles in the bulb.</p>
<p>Relation to Reality</p>	<p>Electric appliances in the home and in industry etc.</p>

(To Experiment: *electric bulb*)

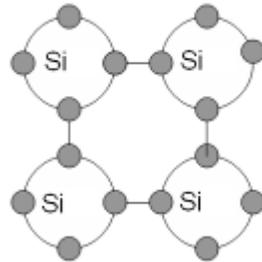
**Station 4: Experiment *Dimming***

Variables	Light intensity and resistance	
Interrelation	Resistance decreases with greater light intensity	
Material	<p>A darkened room (classroom with blinds or thick curtains),          Photoconductive cell and resistor meter, Lux-metre</p> 	
Procedure	<p>The room is darkened in different degrees. The light intensity is recorded by a lux-metre. Then, the individual resistance of a photoconductive cell is measured.          (lux-metre and resistor have to be aligned in the same direction)</p>	
Cross-curricular Background	<p>(as regards the term light intensity, cf. tunnel experiment above)</p> <p>A photoconductive cell consists of semi-conductors.          In the following, the model of a semi-conductor and what effect light has on it, is briefly and graphically explained.</p>	

*Semi-conductor.*

Semi-conductors are materials with high resistance. When light falls on them, the resistance is reduced. This can be used to measure light intensity.

The solid bondage is the result of the number of bonding electrons in semi-conductors, i.e. 4 (Cf. graph: each electron finds a partner: the bonding is stable in a so-called bridge bondage). The typical semi-conductor materials are silicon (Si) and germanium (Ge).

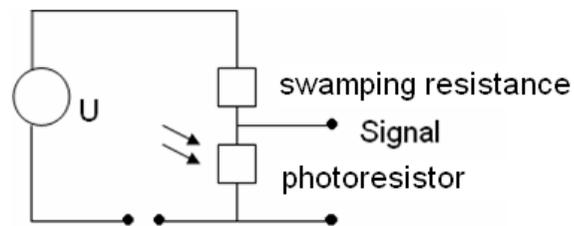


Structure of a Si-crystal

Each of the four outer electrons finds a partner (solid bridge bondage)

*Photo-resistance:*

Effect of light on semi-conductors. A photo-resistor consists of semi-conductor material. If exposed to light, electrons are extracted from the bondage, so that the resistance is reduced and a current can flow, if voltage is applied.



Light falling on the photo-resistor affects a reduction of the resistance. The amount of resistance depends on the intensity of the light.

Relation to reality

Photo-resistors are, e.g., used to turn on lamps at dusk. For this, a set resistor value is fixed as a measure for the light intensity.

## Worksheets

The investigation of the functional relationships, resp. the formation of hypotheses, should be stimulated, e.g. through an impulse taken from every-day life. In this context, the natural science background should be repeated and/or worked out. Furthermore, a discussion on the material presented should take place before the start of the experiment.

What can be changed?

Which values vary, if a certain value is changed?

What is, in your opinion, the connection?

Each experiment is, on principle, headed by a general task:

Describe the connection between value ....and value.....  
Check: Does the connection confirm your assumption?  
Give a description of the special characteristics of the connection.

You will find worksheets to design yourself and, for selected stations, some in the E-book "Experimente zum Funktionsbegriffserwerb" by Astrid Beckmann, published by Aulis-Verlag, Cologne 2006.

The following impulses were also taken from this book.

## Impulses for the Stations

### Impulse

### Tunnel

Imagine you are going or driving through a long tunnel. You can't see the end of it.

How does the brightness change (light intensity) without considering the car lights?



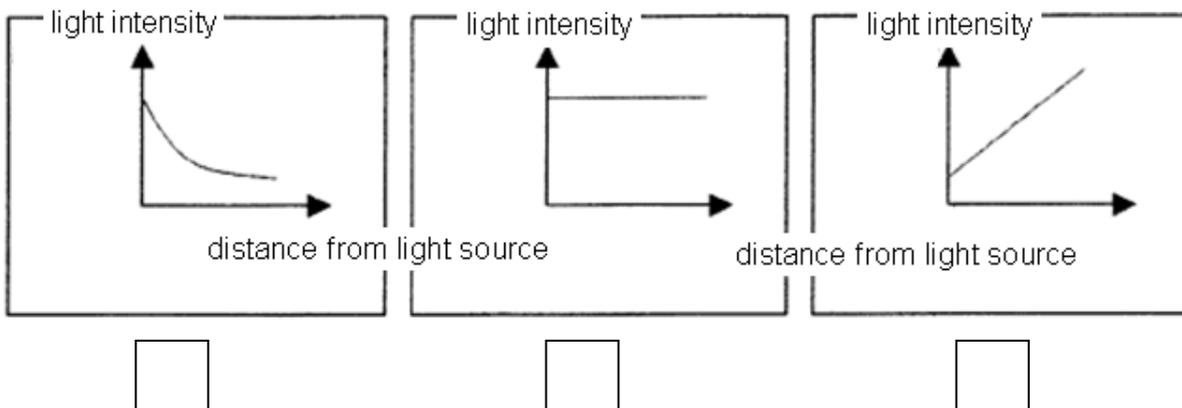
Talk about it in the group.

Take a cardboard tube. Hold it against the car window (the window represents the light source – sunlight). Observe the brightness. Take another cardboard tube of a different length and hold it against the window. Observe the brightness. Compare.

Talk about it in the group.

Which diagram is the most fitting?

Mark it with a cross and check, after the completion of the experiment, whether your assumption was correct.



### General Task

Describe the connection between the distance to the light source and the intensity of the light. Check: Does the connection confirm your answer to the question above? Describe the special qualities of the connection.

## Impulses

## Aeroplane Wing

Have you noticed that the wings of an aeroplane are set at an angle?

There is a good reason for it:

When an aeroplane is in flight, there is a constant air stream directed at the wings. Through the angle, the air stream is pressed downwards in direction of the earth. For every force there is a counter- force. Here, the counter force is directed upwards. One speaks of lift. The lift has the effect of making the plane fly.



(Photo Airbus 380)  
(source: [www.pixelquelle.de](http://www.pixelquelle.de), ID 92677, photo:Spibo)

The lift depends on the form and the position/angle of the wings, as well as on the speed of the aeroplane.



Position A



Position B



Position C

Guess: Which wing position produces the greatest uplift?

Discuss the wing positions presented above, as well as other wing positions, in your group. Give reasons for each assumption.

For your information: The angle between the horizontal line and the wing is called the angle of attack.

### General Task:

Describe the connection between the angle of attack of the wing and the uplift.

Check: Does the connection confirm your assumptions?

Describe the special characteristics of this connection.

## Impulses

## The Electric Bulb

We all use a number of electric appliances as a matter of course (see photos)



We need electricity to run them.

Information:

By electric current, we understand the flow of charges. The strength of the current/amperage depends on the number of the flowing charges per time. The strength of the current is abbreviated by  $I$ . Electric currents are produced by electric sources. Such electric sources are labelled/marked by an electric voltage  $U$  (corresponding to a difference in the charge). The difference in charge is equalized by closing the electric circuit. A current flows. The strength of the current depends on the electric source, but also on the appliance connected to it.

Plugging in an iron, a computer or an electric bulb at your home, results in a difference in amperage, although the same voltage of 230 V is applied in each case.

On the other hand: If you change the electric source (or the voltage at the source), the amperage changes, even if it is always the same electrical appliance that is connected.

In an experiment you can simulate the second situation.

Get familiar with the components (the power supply unit as a variable electric source, an electric bulb as the constant appliance and a measuring unit to measure the strength of the current).

Ask yourself: How does the amperage change, if you change the voltage?

### General Task:

Describe the connection between the electric voltage and the amperage with a constant resistor switched.

Check: Does the connection confirm your assumption?

Describe the special characteristics of this connection.

## Impulses

## Dimming

Street lights or lamps at the entrances to houses switch on themselves, if it starts to get dark. The “information” on the degree of brightness comes from a photo resistor.

At low resistance, a current flows  
(see information).

What is the connection between the degree of brightness and the resistance?

Discuss this in your group.



### General Task:

Describe the connection between the degree of brightness and the resistance.

Check: Does the connection confirm your assumption above?

Describe the special characteristics of the connection.