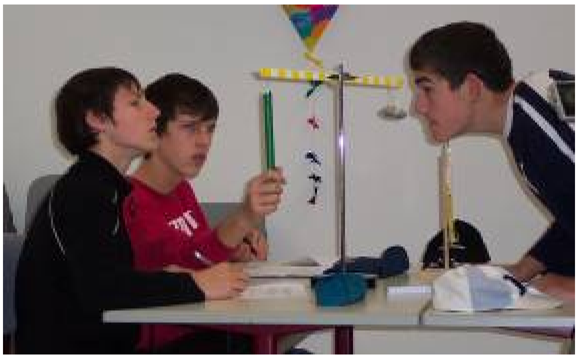
# Teaching Material

There are numerous experiments for proportional contexts (see German literature of the ScienceMath-project: Beckmann 2006). The choice can be made in different manners according to class or to level of performance or even according to experimental possibilities. The following examples refer to younger students of secondary schools and to an implementation that can be realized within normal school day. The experiments are simple physics experiments. To some of them the physics background should be discussed.[1]

## Teaching material

### Possible course

| | |
|---|---|
| Introduction | Teacher introduces into the work,<br>Possible themes: measuring errors,<br>drawing the line of best fit etc. → Literature |
| Station work | The experiments are arranged in stations.<br>The students´ work should be self-dependent (e.g. use worksheets)<br> |
| Plenary session | Every group presents the results received during the work at one station. Important is the reflection about the extra-mathematical meaning of the proportional factors in the experiments. |

## Needed Equipment and Experiments (see following pages)

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[1] The here mentioned suggestions for experiments are a possible selection.. It is quoted partly from the e-Book of Astrid Beckmann, published 2006 by Aulis, Köln/ Germany (Experimente zum Funktionsbegriffserwerb), where many suggestions can be found. More simple experiments you can find under "The ScienceMath-project: Proportional factor 1".

Idea: Astrid Beckmann,
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## Station 1:
## Experiment *Electric Car*

| | |
|---|---|
| Dependent dimensions | Distance and time |
| Dependence | proportional |
| Material | Electric car, measuring cord (at least 2 m), stop watches  |
| Performance | Measuring time for certain distances of the car |
| Proportional factor | The quotient of distance and time is constant. The constant is the velocity. If the velocity is higher res. lower, the proportionality factor is bigger res. smaller. |
| Interdisciplinary background | The car moves straight on with constant velocity. This linear constant movement has the following property: In equal times equal distances are covered, which means that distance and time are proportional: $\frac{s}{t}$ = constant. The constant value describes the here unchanged size, the velocity v. The unit for velocity is $\frac{m}{s}$ (meter per seconds). |
| Reference to reality | Car ride |

## Station 2: Experiment *Spring*

| | | |
|---|---|---|
| Dependent dimensions | force and mass | |
| Dependence | proportional | |
| Material | force meter,<br>slit weights (mass pieces),<br>weight holder |  |
| Performance | The weight holder is supplied with a mass piece and hung to the force meter. The acting force is measured in dependence of the mass. | |
| Proportional factor | The quotient of force and mass is constant. The constant is the acceleration due to gravity acceleration g = 9,81 m/s² ~ 10 m/s². | |
| Interdisciplinary background | Hanging up the mass causes deflection of the spring in the force meter. The force of the mass (gravity) is working (including the mass of the weight holder).<br>The force F is proportional to mass m: $\frac{F}{m} = const$, concrete: $\frac{F}{m} = g$ with g = 9,81 $\frac{m}{s^2}$ (acceleration due to gravity, i.e. acceleration with which any mass is accelerated towards earth). The unit for the force is Newton ($1N = 1\frac{kg \cdot m}{s^2}$). | |
| Reference to reality | Bungee-jumping, bar exercises with persons of different masses | |

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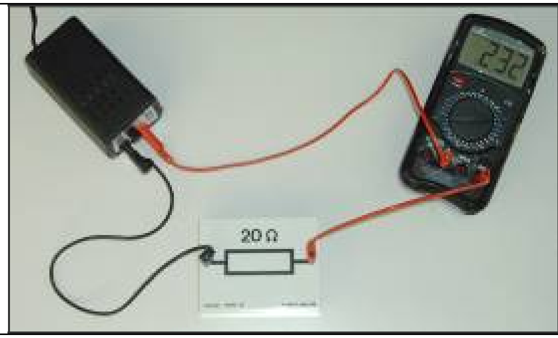
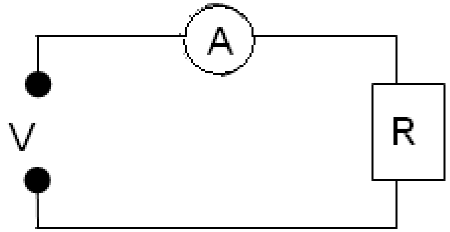
## Station 3:
## Experiment *Electricity*

| | | |
|---|---|---|
| Dependent dimensions | Amperage and voltage | |
| Dependence | proportional | |
| Material | Power supply unit with variable tensions (to 12 V),<br>Multimeter,<br>Resistor (20 Ω, 50 Ω or 100 Ω),<br>3 cables (probably bulb with fitting) |   |
| Performance | The materials are assembled to a circuit: Resistance is varied and voltage is measured by the multimeter. |   |
| Proportional factor | The quotient of the amperage and voltage is constant. The constant is the *Ohm resistance* R, measured in Ohm (Ω = V/A). | |
| Interdisciplinary background | Voltage is a measure for the difference of charging allocation. At “minus” there is – in comparison to “plus” - a surplus of electrons. If the circuit is closed a current flows. (To avoid a short we need a resistor in between). Current I is proportional to voltage U: $\frac{U}{I} = const$. The constant is the electric resistance R (Ohm´s resistance).<br>The units are Ampere (A) for the current, Volt (V) for the voltage, Ohm (Ω) for the resistance. | |
| Reference to reality | Electric devices in households and every-day-life, energy resources, current supply | |

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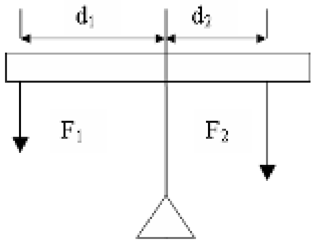
**Station 4: Experiment *Lever 1***

| | | |
|---|---|---|
| Dependent dimensions | Force and weight arm |  |
| Dependence | proportional | |
| Material | Stand with lever bar,<br>Force mete (max. 10 N),<br>Hanging mass, e.g. a stone or a mass piece 100 g | |
| Performance | The force is mounted to a certain place at the lever bar, where it remains during entire experiment duration (force arm therefore is constant). The weight arm (distance between weight and spin axis of the lever) is changed by hanging the weight to different places of the lever bar. The force that is needed to hold the lever in balance is measured in dependence from the force arm. | |
| Proportional factor | The quotient of force and weight arm is constant (in balance with unchanging force arm and weight). The constant corresponds to the quotient of weight and force arm. | |
| Interdisciplinary Background<br> | A lever can be imagined as beam with a rotation axis. On both sides of the rotation axis forces may act. The distance d between rotation axis and force F is called lever arm (according to picture).<br>Remark: If we distinct between force on one side and weight on the other side we talk about force arm and weight arm.<br><br>A lever is exactly in balance if the products of the amount of the force and lever arm are equal on both sides of the rotation axis. $F_1 \cdot d_1 = F_2 \cdot d_2$ (force by force arm = weight by weight arm).<br>The following functional coherences may be deduced from the balance condition.<br>*Proportionality* between force and weight arm $\frac{F_1}{d_2} = const$ (force arm and weight are constant).<br>*Antiproportionality* between force and force arm $F_1 \cdot d_1 = const.$.<br>A constant weight $F_2$ is mounted to the lever in a certain distance $d_2$. | |
| Reference to reality | Seesaw on the playground, lever at a crane, claw, bicycle etc.,<br>Transport of heavy subjects, sticks and hiking stick of the travelling journeymen | |

## Station 5: Experiment ***Block***

| | |
|---|---|
| Dependent dimensions | Sliding friction force and weight force |
| Dependence | proportional |
| Material | Wooden block with pull rope,<br>Various mass pieces for laying onto the wooden block,<br>Force meter,<br>Glass plate for slipping or very smooth surface,<br>weight<br> |
| Performance | The wooden block is weighed and weight is calculated through mass ( F = mg with g = 9,81 m/s²). Mass pieces are put on the wooden block and pulled across the glass plate. The sliding friction force is measured at the force meter for different masses (different mass pieces on the wooden block). |
| Proportional factor | The quotient of sliding fiction force and weight (actually normal force) is constant. The constant indicates the frictional force per weight unit (N) and is called sliding friction number $\mu_G$. This number is also dependent on the material. |
| Interdisciplinary background | Friction forces develop by interaction of molecules of surfaces that get into touch and may be described as “interlocking” of the surfaces. The wooden block that lies on the glass plate sticks at first (static friction). If the wooden block is pulled across the glass plate it undergoes sliding friction. There has to act a force that has the same size and the different direction to the sliding friction force. The size of the sliding friction force depends on the interacting material and the normal force that acts vertically to the pad. (If the pad is horizontal the normal force corresponds to the weight $F_g$ = mg with g = 9,81 m/s². The unit of force is Newton, $1N = 1\frac{kg \cdot m}{s^2}$). Sliding friction force and normal force are proportional: $F_G = \mu_G \cdot F_N$.<br>Proportional factor $\mu_G$ is called sliding friction number and depends also on the interacting material. E.g.: 0,03 (steel-steel) and 0,14 (steel-ice). |
| Reference to reality | Displacing of articles on different material, move on carpet or laminate. |

## Impulses

The experiments should show that the proportionality factor results from the basic proportional relation. The functional correspondence between the regarded quantities is proportional. The analysis of the functional correspondence res. the framing of hypothesis should be initiated possibly by an impulse out of every-day-life (see below, next pages)

Furthermore there should be an examination of the provided material before starting the experiment:

What may be changed?
Which size will change if a certain size is changed?
What correlation do you presume?

In principle there is the general task above every experiment

| |
|---|
| Describe the correlation between quantity … and quantity …. <br> Verify: Does the correlation confirm your presumption? <br> Describe the special features of the correlation. |

Since in all cases proportional correlations are concerned the following question may also be asked:

| |
|---|
| Determine the proportional factor <br> (Do not forget the units!). <br> What is its relevance? |

Impulses to copy – next pages

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## Impulse

**Electric Car**

Imagine you sit in this car. The car

1. starts at a traffic light.
2. drives around a corner.
3. keeps going straight on a long highway.

Describe the different movements of the car.

*Talk about it in your group.*

## Impulse

**Spring**

Surely you saw bungee-jumping on TV. Or did you even try it by yourself?
Describe what happens. What happens with the rope?

*Talk about it in your group.*

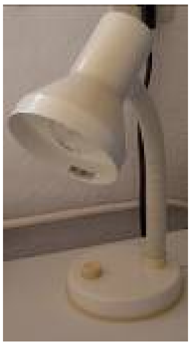
Is there a difference between a light and a heavy bungee-jumper? If so, which?

Check your assumption using the elastic lying on the table.
Hang things of different weight on it or draw with different force.

www.pixelquelle.de ID83026, Fotograf: uppa

## Impulse

**Electricity**



We all use electric equipment. To use it we need electric current.
Information: Electric current could be understood as the flow of charge. Its size is called amperage. Electric voltage describes the difference in charge between two points.
The amperage depends on the source but also on the connected equipment. By changing the source resp. the voltage the amperage changes in dependence.
Describe the relation.

## Impulse — Lever 1

At building sites there is often a crane, which helps to lift heavy objects.
To keep this crane in balance a certain power is necessary. Which case requires the bigger power?

a) The load is near to the crane mast?
b) The load is far from the crane mast?

*Discuss it in your group. Use a pencil to try.*

## Impulse — Block

Surely you arranged furniture in your room before. Did you notice the difference between moving a wardrobe on a carpet or on laminate?

Normally you cannot change the floor. But: what could you change to make the work easier?

*Talk about all the questions in your group.*

On the table there is some equipment to re-enact the situation with the wardrobe. For a smooth and level surface you can use the glass. How could you re-enact the different filled wardrobe?

*Discuss it in your group and plan the experiment.*

The force you need for drawing is called slide friction force.

Describe the relation between slide friction force and mass.