PHYWE

Student and Demonstration Experiments

TESS beginner PHYWE

Motion

13232-02

TESS beginner Student and Demonstration experiments

Motion

Order No. 13232-02

PHYWE series of publications
TESS beginner Student and Demonstration Experiments: Motion
Order No. 13232-02

Authors of experimental literature: Sabine Iwanek, Wiebke Kutzborski

1st edition

Preface

The PHYWE TESS beginner series offers completely drawn up groups of experiments on all themes which are relevant to the syllabus and assist in meeting the teaching and educating objectives of the basics of natural sciences.

A learning by doing approach to the natural sciences is used to address the natural inquisitiveness of students and convey the enjoyment of experimenting.

Particular attention was given during the choice of experiments to interdisciplinary aspects. For example, both physical and biological phenomena are to be found when dealing with movement. Basic principles of mechanics and physiological knowledge of one's own body can both be imparted in connection with this new theme. Distance, time and speed measurements, force comparisons and energy saving play just as much of a role as pulse, breathing and the physical load on bones and joints.

The descriptions of student experiments (S) and practical demonstrations (D) for the particular themes are carried out in a succession which matches the course of the lessons.

- Length, time, speed: S1, S2, S3
- Breathing and pulse: S4, S5, D1
- Force: S6, S7, S8, D2, S9, S10, D3, D4
- Bones and joints: S11, S12, S13, D5
- Particle migration: S14

The instructions for the experiments are designed not only to help the students carry out experiments on their own, but also to accustom them to record their results and evaluate them. Copies of the worksheets can be made for use by the students.

The teacher booklet contains information on the preparation required for an experiment, the experimental procedure, typical measurement results and solutions to questions asked.

The PHYWE "Natural sciences 5th/6th classes" series includes further groups of experiments on the themes "Heat", "Water", "Light, Air and Earth", "Senses" and "Electrical and magnetic phenomena".

Enjoy experimenting!

Contents

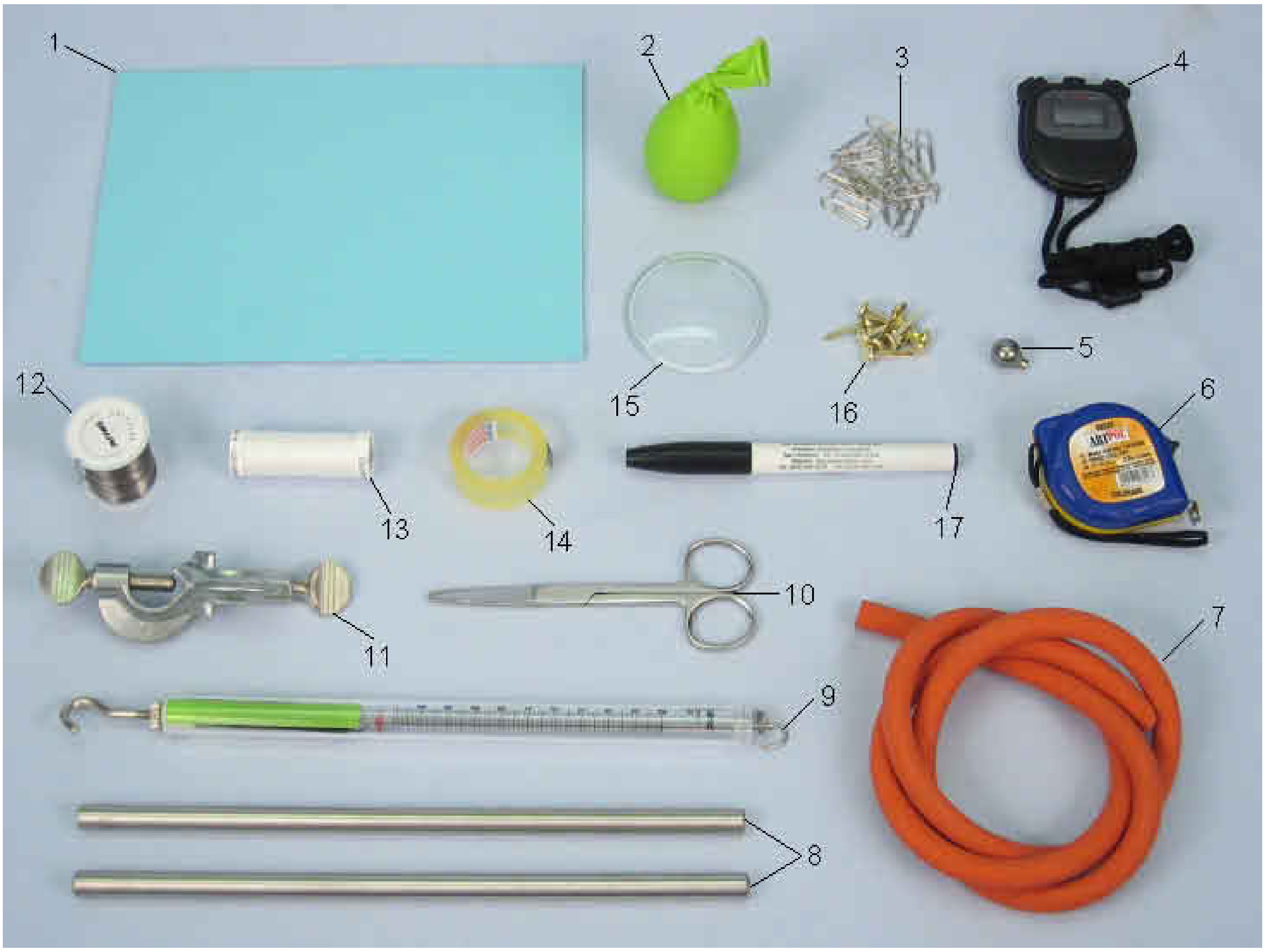
Student experiments:

Demonstration experiments:

Equipment and Storage

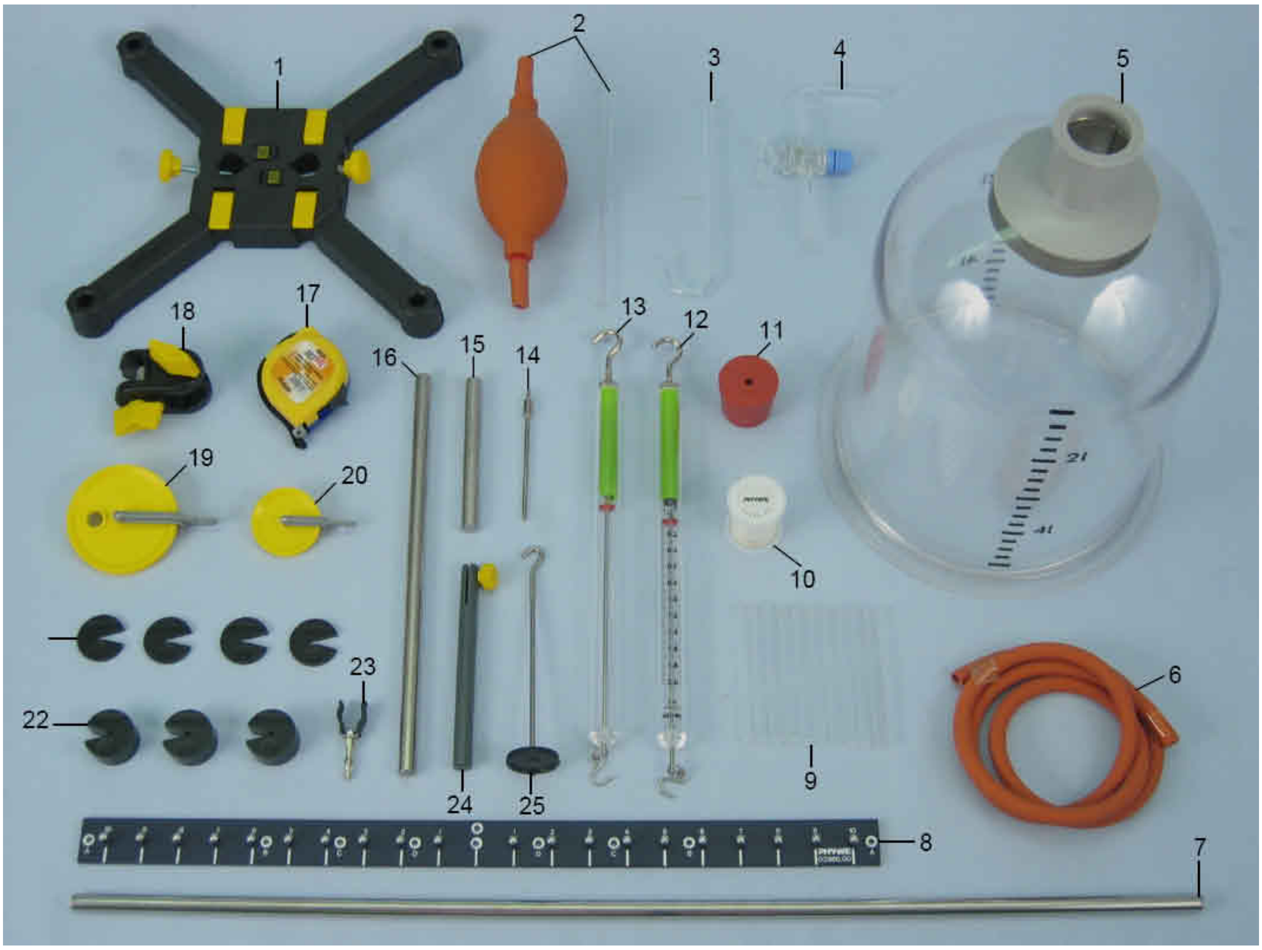
Student Set, Motion 13235-88

	Description	No.	Quantity
(1)	Foam rubber, 20 x 15 cm, 2 mm thick	13231-11	1
(2)	Sand bag, filled with sand	13231-20	1
(3)	Paperclips, 25 mm, copper-plated, 100/pkg	13231-30	1
(4)	Digital stop watch, 24 h, 1/100 s & 1 s	24025-00	1
(5)	Steel ball w.eyelet,d 12.7 mm	02464-01	1
(6)	Measuring tape, l = 2 m	09936-00	1
(7)	Rubber tubing, ID 7 mm	47526-00	1
(8)	Support rod, stainless steel, l=250 mm, d=10 mm	02031-00	2
(9)	Spring balance,transparent, 2 N	03065-03	1
(10)	Scissors, straight, l=125mm	46970-00	1
(11)	Right angle clamp	37697-00	1
(12)	Iron wire, d = 0.5 mm, l = 50 m	06105-00	1
(13)	Silk thread,200m	02412-00	1
(14)	Adhesive tape, 19 mm	170455	1
(15)	Watch glass, dia.60 mm	34570-00	1
(16)	Envelope clamps, brassed iron,	13231-41	10
(17)	Marker, black	46402-01	1



Demo Set, Motion 13232-88

	Description	No.	Quantity
(1)	Support base variable	02001-00	1
(2)	Rubber bulb, with glass tube	64170-00	1
(3)	Glass tube,hooked, 160x30, 10p	36701-54	1
(4)	Stopcock,1-way,r.-angled, glass	36705-01	1
(5)	Bell jar, 5 l	64156-00	1
(6)	Rubber tubing, i.d. 6 mm	39282-00	1
(7)	Support rod, stainless steel, l=600 mm, d=10 mm	02037-00	1
(8)	Lever	03960-00	1
(9)	Glass tube, straight, l=80 mm, 10/pkg.	36701-65	1
(10)	Fishing line, l. 20m	02089-00	1
(11)	Rubber stopper,d=35/29mm, 1 hole	39259-01	1
(12)	Spring balance,transparent, 2 N	03065-03	1
(13)	Spring balance,transp.,2N,non-adj	03065-09	1
(14)	Holding pin	03949-00	1
(15)	Support rod with hole, stainless steel, 10 cm	02036-01	1
(16)	Support rod, stainless steel, l=250 mm, d=10 mm	02031-00	1
(17)	Measuring tape, l = 2 m	09936-00	1
(18)	Boss head	02043-00	1
(19)	Pulley,movable,dia.65mm,w.hook	02262-00	1
(20)	Pulley,movable,dia.40mm,w.hook	03970-00	1
(21)	Slotted weight, 10 g, black	02205-01	4
(22)	Slotted weight, 50 g, black	02206-01	3
(23)	Spring balance holder	03065-20	1
(24)	Rod for pulley	02263-00	1
(25)	Weight holder for slotted weights	02204-00	1
	Storage tray		



Which distance must a spider at a corner of your classroom cover to visit all relatives, one at each other corner?

Task

Measure the distance from corner to corner of your classroom. Also measure the distance to friends of the spider which have spun their webs underneath your chairs and desks.

Material

1 Measuring tape

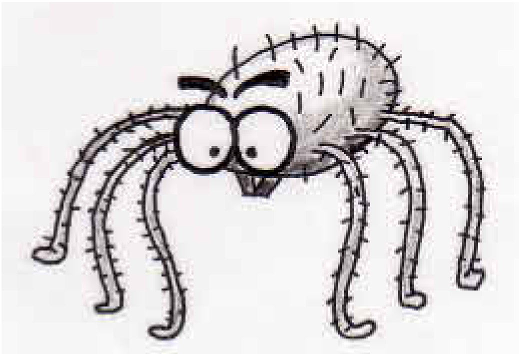


Fig. 1

Set-up and procedure

- Examine the tape measure and find the meanings of the various marks on the tape.
- Look for the 1 metre mark.
- Practice using the tape measure by measuring out a 1 metre 12 centimetres 6 millimetres distance.
- Start measuring the lengths of the individual stretches at one corner of the classroom and record each measurement as in this example: 1 m 12 cm 6 mm.

Observations

1.

Distance from ... to ...	Length of the stretch

Evaluation

1. Which marks have you found on the tape measure and what do they mean?

   ....

   ....

   ....

2. Which path did the spider take to visit each relative one after the other?

   ....

   ....

   ....

3. And when the spider visited friends?

   ....

   ....

   ....

(Which distance must a spider at a corner of your classroom cover to visit all relatives, one at each other corner?)

Notes on set-up and procedure

Although the student would no doubt enjoy crawling about in the classroom to make measurements as described in this experiment, it could be that you prefer to talk over the subject matter of the experiments with the class.

Evaluation

1. Black numbers from 1 to 9 stand for centimetres. Red numbers from 10 to 200 are given every 10 centimetres and stand for tens of centimetres. Small black secondary graduation lines are spaced 1 millimetre apart. Large black secondary graduation lines are spaced 5 millimetres apart for better orientation.

2. and 3.

The sums of the individual measurements of lengths and heights of the paths are to be entered here.

Room for notes

How quickly does a pendulum swing?

Task

Measure the time it takes for pendulums of different lengths to each carry out ten oscillations.

Material

1 Stopwatch
1 Measuring tape
2 Support rods
1 Right angle clamp
1 Ball with eyelet
Silk thread

Storage box

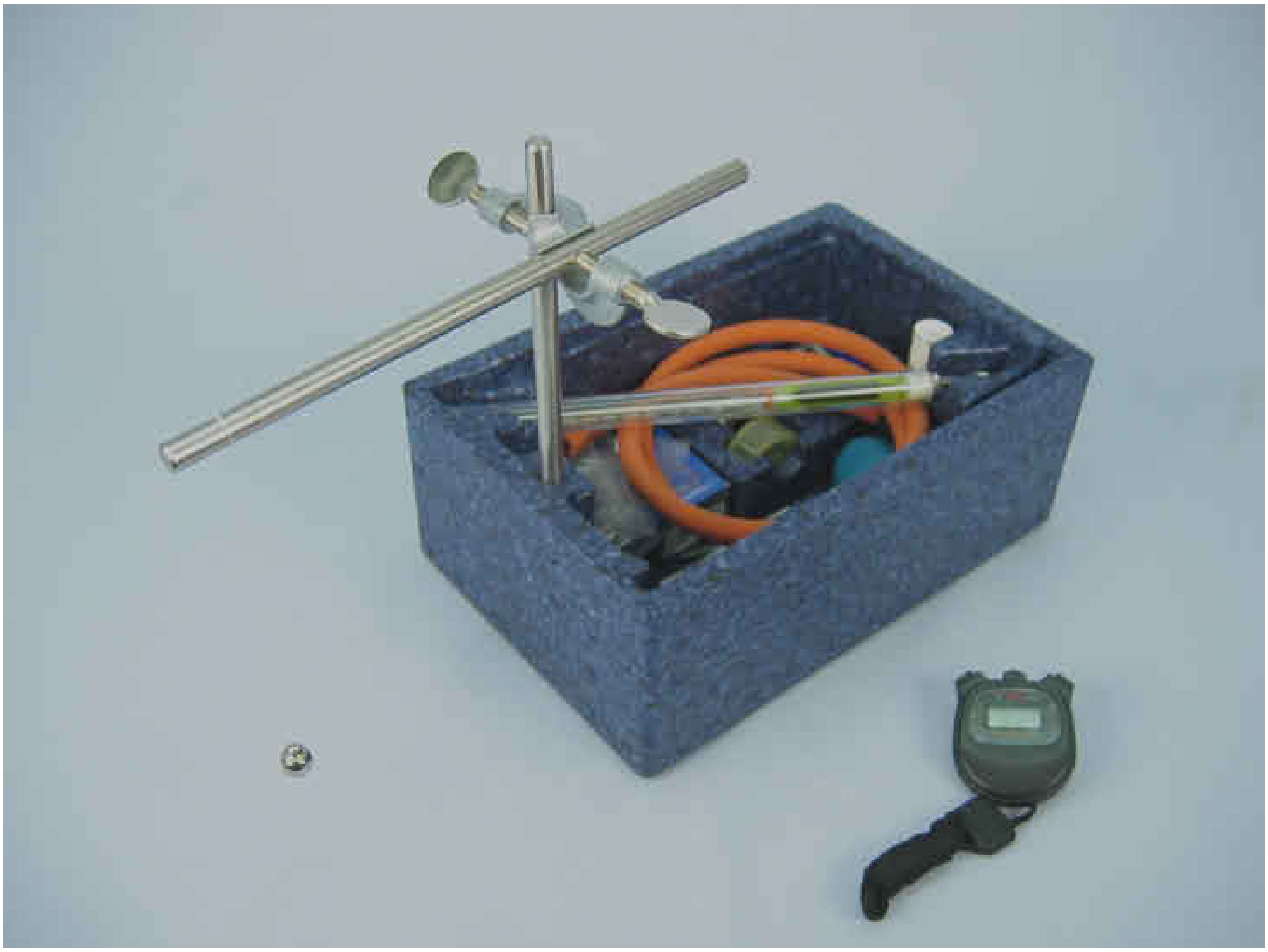


Fig. 1

Set-up and procedure

- Take a good look at the stopwatch and practice how you can measure a period of time with it (start, stop and back to “zero”).
- Consider what the following display means: 2:1245.
- Now set the experiment up as shown in Fig. 1.
- Tie the piece of thread to the eyelet of the ball and hang the ball to the support rod to give a thread length of 80 cm.
- Push the storage box to the edge of the table so that the pendulum can swing freely.
- Measure the time taken for 10 oscillations of the pendulum and record it in the Table. An oscillation is one complete swing back and forth.
- Repeat the measurement with pendulum lengths of 60, 40 and 20 cm.

Observations

1.

Pendulum length	Time taken for ten oscillations
80 cm	
60 cm	
40 cm	
20 cm	

Evaluation

1. Explain the meaning of a display of 2:1245.

....

....

....

....

2. Write operating instructions for the stopwatch which explain how one can use it to correctly measure a period of time.

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3. Complete the following sentence: “The longer the pendulum, the ...”

....

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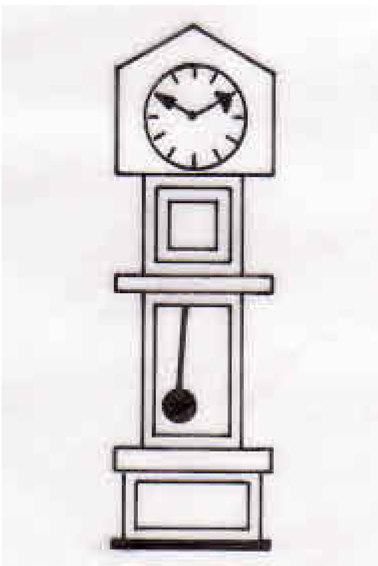
....



(How quickly does a pendulum swing?)

Notes on set-up and procedure

The period of an oscillation is not dependent on the deflection of the pendulum. Deflections of between 40 and 70° are best for the problem-free measurement of ten oscillations. A greater angle could cause spinning of the pendulum and a smaller one would possibly not allow as many as 10 oscillations to be recognized.

Observations

1.

Pendulum length	Time taken for ten oscillations
80 cm	19 s
60 cm	16 s
40 cm	13 s
20 cm	10 s

Evaluation

1. This display means 2 minutes, 12 seconds and 45 hundredths of a second.
2. With the stopwatch model which is presently supplied:
   Press the middle key as often as is necessary to bring five zeros to display. The key to the right enables you to start measurement and stop measurement. Look at the display to see how the time runs. When you have stopped measurement, read the value of the time taken from the display. This value remains in display until you bring it back to zero with the key on the left. The stopwatch is now ready for the next measurement.
3. ...longer the period of an oscillation.
   Time measurement technique is the centre of attention in this experiment. The knowledge that the oscillation period of a thread pendulum depends on the thread length could possibly lead to a discussion on which other factors play a role. The students could then lift the pendulum to various heights and time ten oscillations at each height. They would then find out for themselves that the deflection of the pendulum does not play a role. A practical demonstration using the weight holder and different weights instead of the ball could then be carried out to show that the oscillation period is also not dependent on the mass of the thread pendulum.

Room for notes

What is your average running speed?

Task

One person is to run 100 m while others measure the times he or she takes at each 25 m and also the time for the whole 100 m. His or her speed for each of the five distances are to be calculated and, from these, the overall average speed.

Material

5 Stop watches

Measuring tape

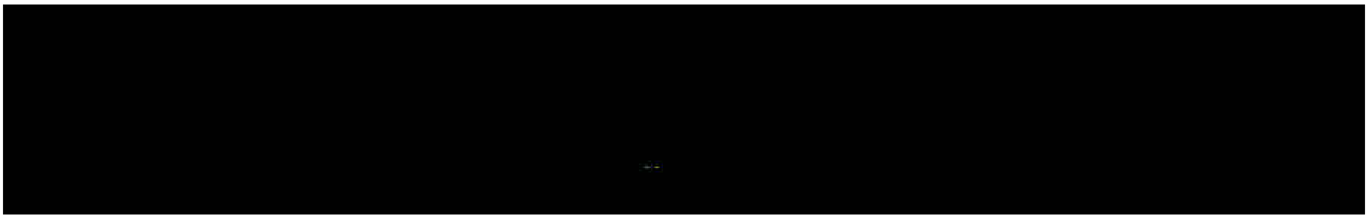


Fig. 1

Set-up and procedure

- Use the tape measure to measure out a distance of 100 m at the school playground and mark this track at each 25 m.
- The volunteer goes to the start and runs the 100 m.
- Five of you are to take times. One at each of the quarter distances for the 25 m times and another one at the end of the track for the 100 m time. Record the times taken.
- Repeat this procedure with different runners.

Observations

1.

Track section	Time in seconds
1st stretch (25 m)	
2nd stretch (25 m)	
3rd stretch (25 m)	
4th stretch (25 m)	
Complete stretch (100 m)	

Evaluation

1. The speed is dependent on the length of the track stretch and the time needed to cover it. Calculate the speeds for the four stretches by dividing their lengths by the time taken.

Track section	Speed in m/s	Speed in km/h
1st stretch (25 m)		
2nd stretch (25 m)		
3rd stretch (25 m)		
4th stretch (25 m)		

2. Explain what you understand under average speed.

....

....

....

3. There are two methods which can be used to calculate the average speed. Use both of them.

....

....

....

(What is your average running speed?)

Preparation

A 20 m tape measure is required for the measuring out the track marks.
There are enough stopwatches when at least five Sets are available for the students, otherwise further ones must be obtained.

Evaluation

2. The average speed is the average value of different measured speeds. When one runs, there is the start phase in which the runner must accelerate, a phase where the speed is kept constant for a time and then, probably, a phase when tiring is noticeable and slowing occurs
3. The average speed can be determined by adding together the speeds found from the individual measurements and dividing this sum by the number or measured values. It is simpler, however, to add up the lengths of all measurements and divide this length sum by the total sum of all of the times.

Room for notes

Examine your breathing: How does the circumference of your chest change and what happens when you exert yourself physically?

Task

Measure your chest circumference measurement when breathing in and out and count your breathing rate when you are relaxed and after exertion.

Material

1 Stop watch
1 Measuring tape

Fig. 1

Set-up and procedure

Measurement of breathing rate

- Sit on a chair, relax and count your number of breaths per minute, whereby a breath is one inhalation and one exhalation. Note the rate in the Table.
- Repeat this measurement after you have hopped 50 times on the spot and enter this rate in the Table.

Measurement of chest circumference

- As soon as your breathing has calmed down, take the biggest breath you can and hold it while one of your classmates measures your chest circumference.
- Now exhale to breathe your breath completely, then have your chest circumference measured again.

Observations

Measurement of breathing rate

Measurement conditions	Number of breaths per minute
Relaxed	
After exertion	

Measurement of chest circumference

Measurement conditions	Chest circumference in centimetres
On exhaling	
On inhaling	

Evaluation

1. How does your breathing rate change when you physically exert yourself and what is connected with this?

   ....

   ....

   ....

2. Which connection is there between chest circumference and breathing? What happens in the chest space during inhalation and exhalation?

   ....

   ....

   ....

(How does the circumference of your chest change and what happens when you exert yourself physically?)

Observations

Measurement of the breathing rate

Measurement conditions	Breathing rate per minute
Relaxed	approx. 15
After exertion	approx. 20

Measurement of the chest circumference

Measurement conditions	Chest measurement in centimetres
After inhaling	e.g. 73 cm
After exhaling	e.g. 67 cm

Evaluation

1. The breathing rate increases with bodily activity because of the increased oxygen demand of the musculature. With each breath, “fresh air” (air rich in oxygen) flows into the lungs, from where oxygen passes into the blood which carries it to the organs and muscles where it is required for work.
2. The front of the chest lifts up during inhalation and so increases the chest volume. The lung is connected to the inside of the chest by skins (the rib and lung pleura). The lifting up of the chest automatically expands the lung so that air can flow in, i.e. it functions similarly to a bellows.

In abdominal breathing, the pleura moves down during inhalation and increases the chest volume. In addition, it presses the abdomen together so that this bulges outwards. On exhalation, the pleura comes back to the original position and the abdominal wall which was bulging outwards returns back as well. In thoracic breathing it is the chest which stretches on inhalation and draws back on exhalation. Pleura breathing is more effective than thoracic breathing, as correct lowering of the pleura results in a greater chest volume than is given by the widening of the chest. Some people incline more to thoracic breathing, others to pleura or abdominal breathing. Small children use pleura breathing almost exclusively. In the course of life, most people “forget” this type of breathing, because a “tummy in, chest out” posture favours thoracic breathing.

Room for notes

How does your pulse change when you exert yourself?

Task

Measure your pulse when you are sitting relaxed on a chair and after you have physically exerted yourself.

Material

1 Stop watch

Fig. 1

Set-up and procedure

- Sit on a chair and relax, then try to feel your pulse at your wrist. To find it, hold the forefinger or middle finger of one hand on the inside of the wrist of the other hand. You will feel the pulse a little bit below the thumb.
- Start counting when a classmate says start and simultaneously presses the stopwatch start key.
- Take the count for 30 seconds and multiply it by two to determine the pulse count per minute. Enter it in the Table.
- Make ten press-ups, repeat the measurement and enter the value obtained in the Table.

Observations

1.

Measurement conditions	Pulse in beats per minute
Relaxed	
After exertion	

Evaluation

1. What is the pulse?

....

....

....

2. How does your pulse change when you exert yourself?

....

....

....

3. Why does exertion cause the pulse to speed up?

....

....

....

(How does your pulse change when you exert yourself?)

Notes on set-up and procedure

A pulse is generally given in “beats per minute”. It is not necessary to count for one minute, however, the count after 30 seconds can simply be doubled. A normal resting pulse is between 60 and 80 beats per minute. Endurance sports usually cause one to have a lower pulse. Young people have somewhat higher ones.

Observations

1.

Measurement conditions	Pulse in beats per minute
Relaxed	approx. 70
After exertion	approx. 90

Evaluation

1. The heart pumps blood through the body in a pulsating mode. These beats can be felt at the arteries as the pulse.
   The beats are felt at the arteries which lead blood from the heart to all parts of the body. The flow in the vessels is steady, however. The reason for this is that the small branches of the blood vessels, capillaries and arterioles confront the blood with a high frictional resistance. Blood can so not flow off unimpeded during the contraction of the heart. The systoles so lead to a pressure increase in the aorta, which spreads as a wave via the arteries. This pressure wave can be felt as the pulse. It widens the elastic walls of the arteries. After the systoles, the walls of the arteries which are now expanded exert pressure on the blood. Even after the end of the systoles, this wall pressure causes an increased internal pressure in the vessels and blood flows evenly on.
2. It increases on exertion.
   It can reach counts of up to 200 beats per minute.
3. The muscles have an increased need of oxygen when the body moves. The heart pumps more quickly to cover this extra requirement of oxygen. The accelerated pumping rhythm can be felt as a more rapid pulse.

Room for notes

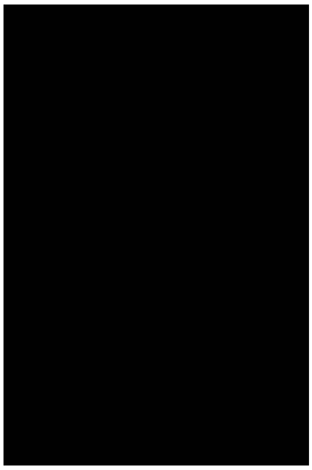
How can you use a piece of rubber tubing to find out who is strongest?

Task

Measure the distance that you can stretch a piece of rubber tubing.

Material

1 Rubber tubing
1 Measuring tape
Pencil



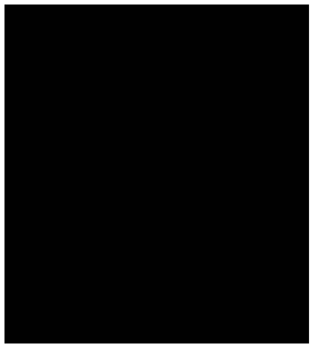


Fig. 1

Set-up and procedure

- Use the pencil to mark a distance of 10 cm on the rubber tubing so that there is sufficient room to grip it at each side.
- The test person is now to grip the tubing to the right and left of the marks, hold it at arm's length and stretch it as much as he or she can.
- Measure the length to which the tubing has been stretched and record this value.
- Further volunteers are now to test their strength using the same procedure.

Observations

1.

Name of the test person	Length of the rubber tubing

Evaluation

1. What is the relationship between the length of the tubing and the strength of the test person?

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....

....

....

....

2. What else could you use here instead of rubber tubing?

....

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....

....

(How can you use a piece of rubber tubing to find out who is strongest?)

Notes on set-up and procedure

The marked length of the hose which is to be stretched has been specified to be 10 cm because then there is not enough tension in it to harm anybody should it be inadvertently let go of. Holding the arms straight out in front is also a safety measure, as one cannot exert too much strength in this position and so cannot extend the tubing too far.

Observations

1.

Name of the test person	Length of the rubber tubing
1	18
2	21
3	20
4	30

Evaluation

1. The greater the exerted force, the longer the rubber tubing.
2. Expander, spring, a weight, a partner for arm pressing, a piece of rope for a tug-of-war.

Room for notes

How does a force measuring instrument function?

Task

Examine how a force measuring instrument functions and how it must be set to zero.

Material

1 Spring balance

[redacted]

[redacted]

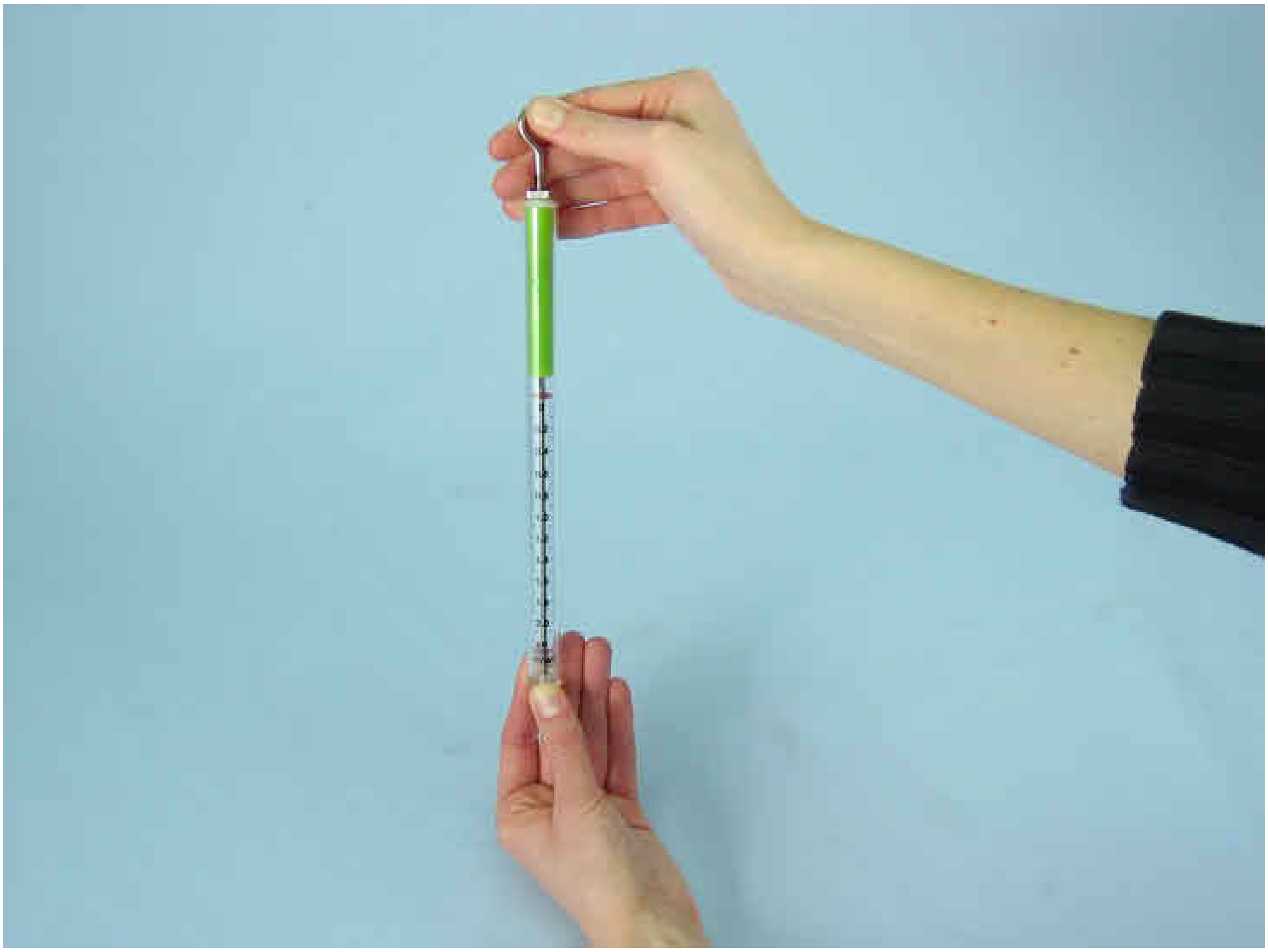

Fig. 1

Set-up and procedure

- Carefully examine the spring balance and describe the various parts of it.
- Hold the spring balance at the large hook and slightly draw the other end down. Explain what you observe.
- Keep a watch on the display when you hold the spring balance in various positions: Vertically, then horizontally and finally upside down.
- Hold the spring balance in the normal vertical position and adjust the setting of it as follows: Loosen the screw at the top end and turn the hook to bring the display mark exactly to zero.
- Again hold the spring balance in various positions as previously. What do you now observe?
- Adjust the setting of the spring balance in the horizontal and upside down positions.

Observations

1. What does a spring balance consist of?

   ....

   ....

   ....

2. What did you observe when you pulled the hook?

   ....

   ....

   ....

   ....

3. What happens when the spring balance is held at different positions?

   ....

   ....

   ....

Evaluation

1. Why must the setting of a spring balance be adjusted prior to making a measurement?

   ....

   ....

   ....

   ....

(How does a force measuring instrument function?)

Observations

1. Steel spring, hook with adjusting screw, loading hook with measurement indicator, transparent plastic sheath with scale.
2. The spring expands. The red indicator of the loading hook moves along the scale. With each extension, a corresponding value can be read from the scale. When pulling is stopped, the spring returns to its original position.
3. The display changes with each change in position of the spring balance, in other words, the red indicator stops at a different scale position in each case.

Evaluation

1. To read an accurate measured value when the spring is brought to expand, the spring balance must be previously set to zero with the spring at the rest position. Adjustment brings the marker of the spring balance to zero in a certain position, so that measurements can be made at this position. When the position of the spring balance is changed, re-adjustment of the setting is necessary.

Room for notes

How much force can chocolate exert?

Task

Measure the weights of different sized pieces of chocolate.

Material

1 Spring balance
2 Support rods
1 Right angle clamp
Silk thread
Storage box

1 Bar of chocolate

Fig. 1

Fig. 2

Set-up and procedure

- Carefully examine the spring balance and describe the various parts of it.
- Hold the spring balance at the large hook and slightly draw the other end down. Explain what you observe.
- Keep a watch on the display when you hold the spring balance in various positions: Vertically, then horizontally and finally upside down.
- Hold the spring balance in the normal vertical position and adjust the setting of it as follows: Loosen the screw at the top end and turn the hook to bring the display mark exactly to zero.
- Again hold the spring balance in various positions as previously. What do you now observe?
- Adjust the setting of the spring balance in the horizontal and upside down positions.

Observations

1.

Weight of the chocolate	Force
100 g (the whole bar)	
50 g (half of the bar)	

Evaluation

1. Which force would two bars of chocolate exert?

   ....

   ....

   ....

2. How can it be that chocolate exerts a force?

   ....

   ....

   ....

(How much force can chocolate exert?)

Material
Chocolate

Preparation
Each group of students requires a 100 g bar of chocolate.

Observations
1.

Weight of the chocolate	Force
100 g (the whole bar)	1 N
50 g (half of the bar)	0.5 N

Evaluation
1. Two bars of chocolate would exert a force of 2 Newton.
2. Just as everything else on this earth, chocolate is attracted (pulled) to the earth.
   The gravitational force of the earth causes the weight of chocolate to exert a force on a surface on which it is placed or on a point at which it is hung. The heavier the chocolate, the more force it exerts.

Room for notes

How much force do you need to drag a crate?

Task

Measure the force needed to pull an object across a surface.

Material

1 Spring balance
2 Support rods

Storage box

Fig. 1

Set-up and procedure

- Take the spring balance, two support rods and a couple of heavy parts out of the box.
- Adjust the setting of the spring balance in the horizontal position. Loosen the screw at the large hook and turn the hook to bring the indicator exactly to zero.
- Fix the small load hook of the spring balance to the box by pressing it firmly in the top edge of the short side of the storage box.
- Draw at the free end of the spring balance and read the force from the scale while the box is moving. Record this value in the Table.
- Now position the two support rods under the box. One rod directly under the front edge of the box and the other rod as far back as possible before the box starts to tip backwards. This placement enables the box to be drawn a short distance without it falling off of the rods.
- Again draw at the spring balance, measure the force while the box is moving and record the value.
- Repeat the two procedures but this time read the force at the brief moment when the box starts to move. Record these values.

Observations

1.

Type of load	Force
Box without rollers during movement	
Box with rollers during movement	
Box without rollers during start-up	
Box with rollers during start-up	

Evaluation

1. Why is the force which you have measured called the frictional force?

   ....

   ....

   ....

2. Explain why the frictional forces are not the same.

   ....

   ....

   ....

3. Name examples of weak and strong frictional forces from everyday life.

   ....

   ....

   ....

(How much force do you need to drag a crate?)

Notes on set-up and procedure

Ensure that no parts are removed from the storage box between measurements, as it is important here that the box has the same weight for each measurement.

Observations

1.

Type of load	Force
Box without rollers during movement	1.2 N
Box with rollers during movement	0.1 N
Box without rollers during start-up	1.3 N
Box with rollers during start-up	0.2 N

Evaluation

1. The difference in the forces here result from rubbing between two surfaces (friction means rubbing).This friction resists sliding or rolling and force must be exerted to overcome this frictional resistance.
2. One flat surface lying on another flat surface results in them adhering to each other more strongly than the rollers adhere to a flat surface. The contact area of the roller is small, whereas a flat surface covers a much greater area. In addition, the shape of the rollers allows them to turn on the surface below and this turning also needs less force than the sliding of a flat object. These two different forces are called rolling friction and sliding friction.
   When an object is to be moved from the resting position, more resistance must be overcome than when it is moving. The force required for the start-up is called adhesive friction.
3. Soles of shoes are subject to very little friction on an ice surface and one can therefore easily slip or slide. Sand scattered over the ice increases the resistance and prevents slipping.
   When a lock can only be turned with difficulty, oiling it reduces the friction and makes it easier to turn. According to the snow conditions, skiers rub a wax on their skis which enables them to ski faster.

Room for notes

How much force do you need to drag a crate?

Task

Lift up your satchel in various ways.

Use scissors to cut paper with the paper at various distances between the blades of the scissors.

Material

1 Pair of scissors
1 Marker

Cardboard
Satchel

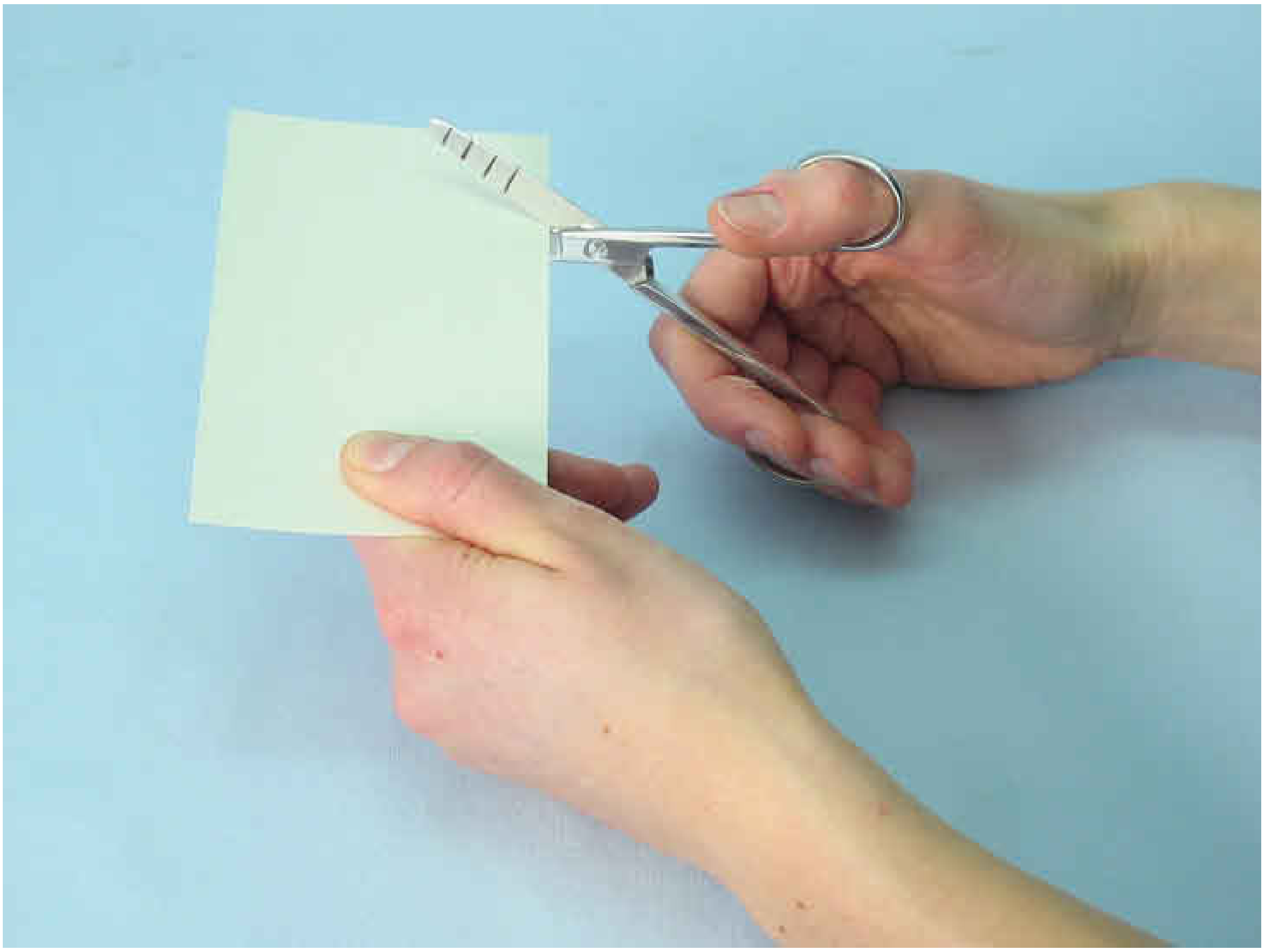

Fig. 1

Set-up and procedure

- Hold the satchel handle with one hand and lift the satchel.
- Push your forearm through the handle and lift the satchel. Do you notice a difference?
- Open the scissors only a little and push a piece of cardboard in the small opening between the blades. Mark this position on the scissors.
- Repeat this for further steps of the same length by correspondingly opening the scissors further. In each case, mark the length on the scissors.
- What do observe when you are cutting cardboard at the individual positions?
- Now measure the distance of each mark to the screw (= fulcrum) and enter the distances in the Table.

Fig. 2

Observations

1. What did you notice when you lifted up your satchel with a hand grip and then hung at the middle of your forearm?

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2. What happens when you open the pair of scissors wider to make a cut?

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	Distance from the mark to the pivot
1. Cut (Scissors only opened a little)	
2. Cut	
3. Cut	
4. Cut (Scissors wide open)	

Evaluation

1. The forearm acts as a lever, whereby the elbow joint is the lever fulcrum. The distance from the elbow to the load (i.e.to the satchel) is called the load arm. How does the load arm change when you push your forearm nearer to your elbow?

   It gets longer ☐

   It gets shorter ☐

2. Which muscle is tensioned when you lift the satchel?

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3. The distance from your elbow (= fulcrum) to the point at which the muscle is applied is the force arm. A lever consists of load arm, force arm and fulcrum. Scissors are also levers. The arm which you measured is the load arm and the second arm with the handles is the force arm.
   How does the force which you need to make a cut change when the load arm is made shorter?

   It gets longer ☐

   It gets shorter ☐

4. Formulate a rule which is valid for each of the parts of this experiment and runs "The ..., the ...".

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5. Where can one find further levers?

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(In which way can you use most force for lifting and how can you put most force on scissors?)

Preparation

Each student group needs a piece of thick cardboard which cannot be cut too easily.

Observations

6. The satchel was easier to lift when I held it at the middle of my forearm.
7. The wider open the scissors, the easier the cardboard could be cut.

	Distance from the mark to the pivot
1. Cut (Scissors only opened a little)	4 cm
2. Cut	3 cm
3. Cut	2 cm
4. Cut (Scissors wide open)	1 cm

Evaluation

1. The load arm gets shorter.
2. The biceps, a muscle in the upper arm, is needed for lifting. It is fastened to one of the underarm bones, the spoke bone, at a small distance from the crook of the arm. When the biceps contracts, it becomes shorter and draws the arm upwards.
3. Less force was then required.
4. The shorter the load arm, the less force required.
   The longer the load arm, the more force required.
5. Teeth, see-saw, bottle opener, pliers, nutcracker.

Room for notes

Which is the ideal shape for a spinal column?

Task

Use wire to shape various spinal column models and test their load-bearing capacity and their resilience.

Material

5 Iron wires, 20 cm
Paperclips

Storage box

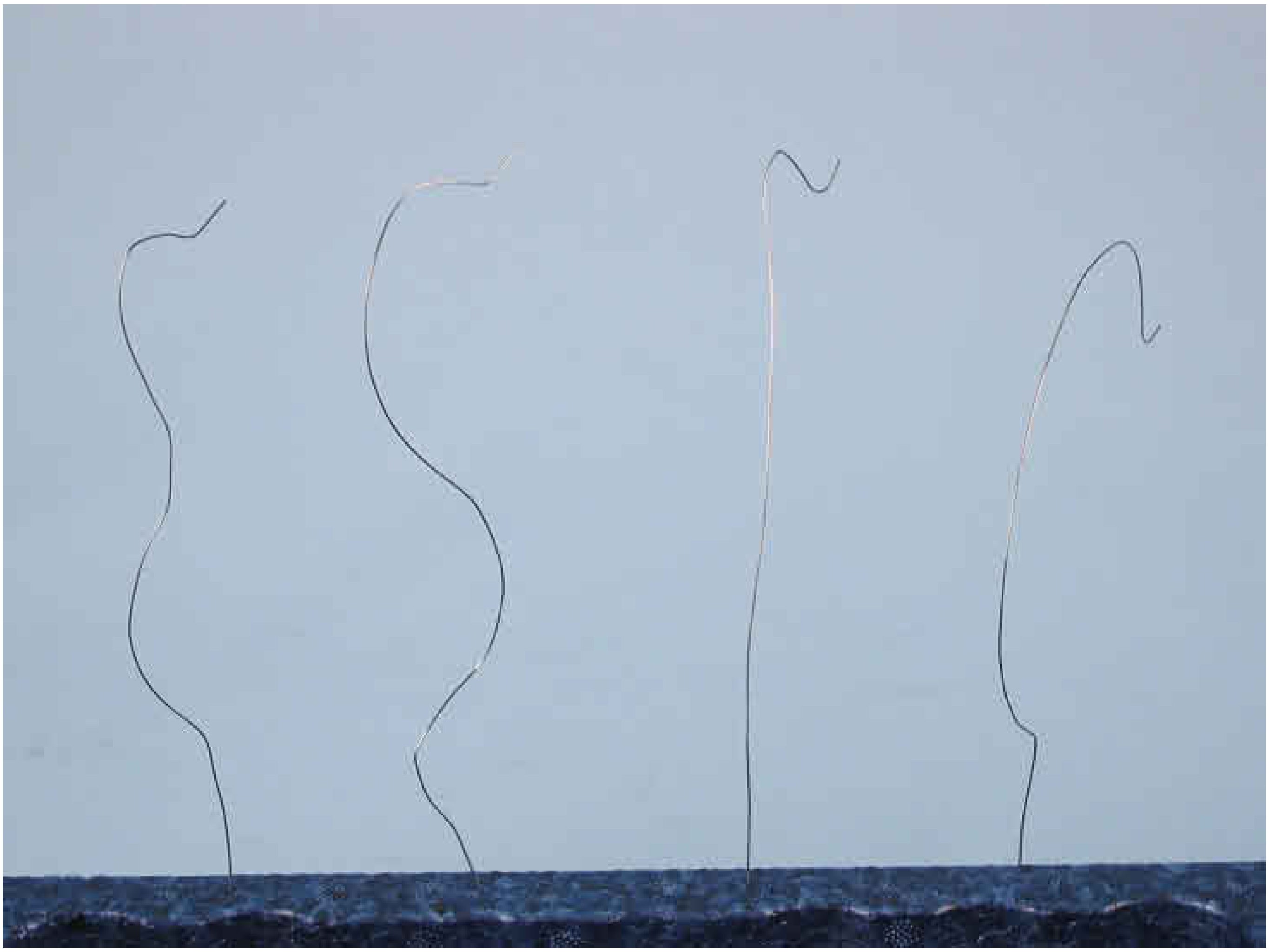

Fig. 1

Set-up and procedure

- Use pieces of wire to shape four different spinal column models.
- Have the models held by pushing them about 2 cm deep and upright in the rim of the storage box (Fig. 1).
- Test their load-bearing capacity by hanging one paper clip after another to them. Which model is the most stable one (Fig. 2).
- Now test the swinging behaviour of the models as follows: Lift the storage box up a little and then give it a slight push when you put it back down on the table again so that the models shake. Which model stops shaking first?
- Try to devise your own model. It must not only as stable as possible but should also swing for a long time.

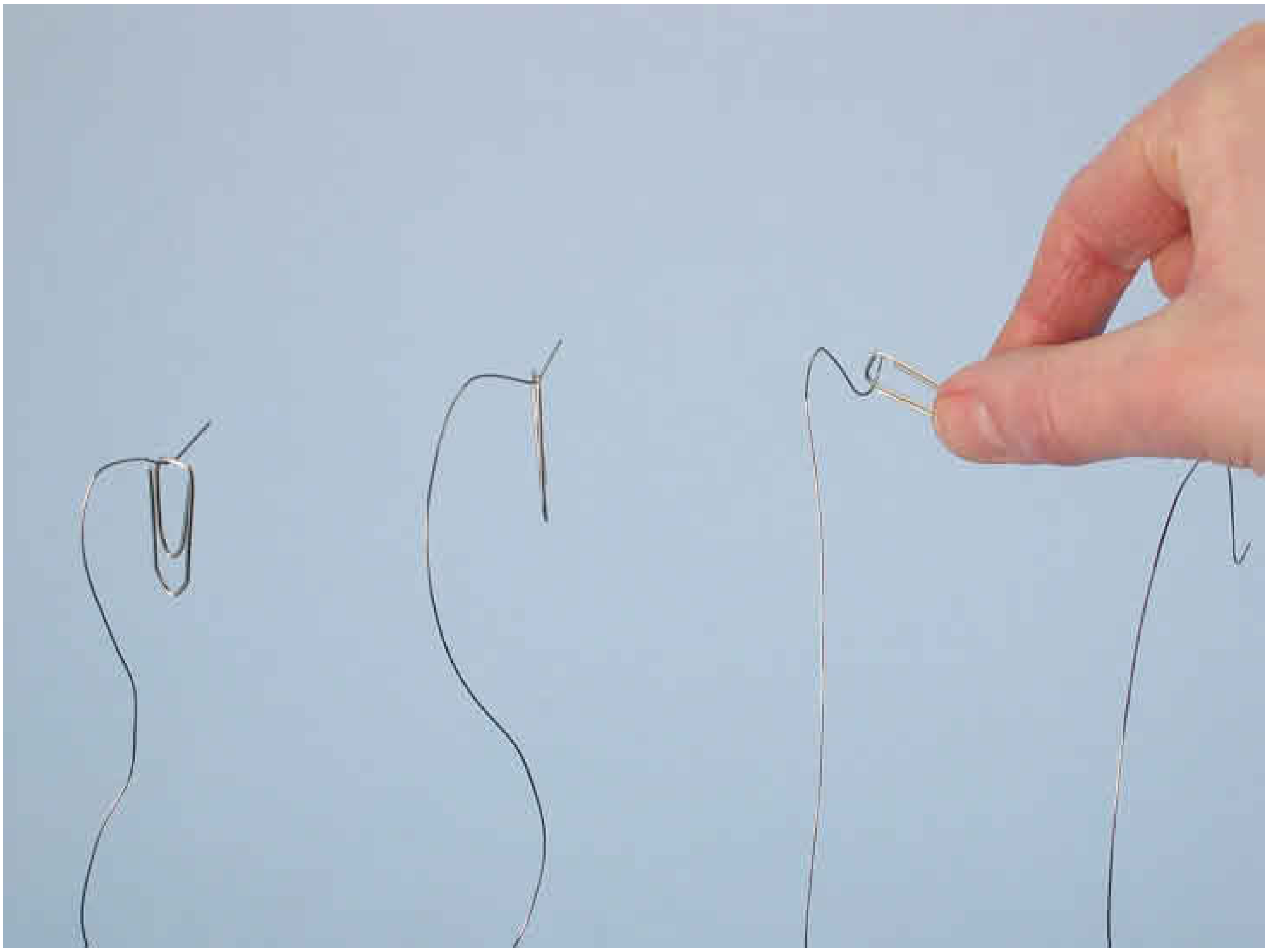

Fig. 2

Observations

1. Which spinal column model is the most stable one?

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2. In which succession does the swinging come to an end?

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Evaluation

1. Which model corresponds to an ideal spinal column? Which type of spinal column do the other models represent Which muscle is tensioned when you lift the satchel?

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2. Why is the swinging action of the spinal column important

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Shapes for the wire spinal column models:

Fig. 2

(Which is the ideal shape for a spinal column?)

Observations

1. Models 1 and 4 clearly hold up to more weight without leaning over much than is the case with models 2 and 3.
2. Model 1 stops swinging first, followed by 2, then 3. Model 4 is last.

Evaluation

1. The ideal spinal column (model 4) has a slight double-S shaped curvature. The two other curved models represent a hollow back (model 3) and a hunchback (model 2). The straight model (1) is never found as spinal column.
2. The resilience of the spinal column enables it to cushion blows so that it is better protected from injury.

Room for notes

How are bones formed to hold up to as much stress as possible?

Task

Fold paper to represent a bone and test the stability of the model.

Material

1 Sand bag
1 Scissors
1 Adhesive tape
Cord

A 5 standard paper, 2 sheets

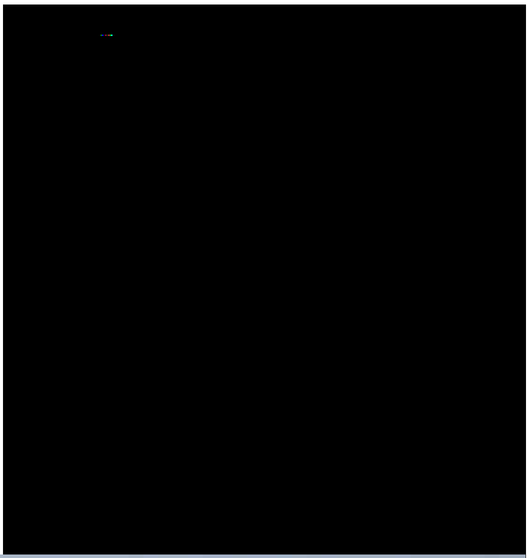

Fig. 1

Set-up and procedure

- Roll an A5 sheet of paper lengthwise and fix it with adhesive tape so that the diameters of the openings of the roll are each 2.5 cm.
- Pleat a second A5 sheet like an accordion.
- Cut off a roughly 30 cm long piece of string. Tie one end of it to the “sand sack” and the other end to make a 4 cm long loop.
- Draw the loop over the pleated model and try to lift the sand sack with it as shown in Figure 2. What happens?
- Try to do the same with the tube-shaped model. Record what you observe.
- Now test the stability of the tube-shaped model: Stand it on end and place the sand sack on the upper opening. Lay the model on the table and again load it with the sand sack. What do you determine here?

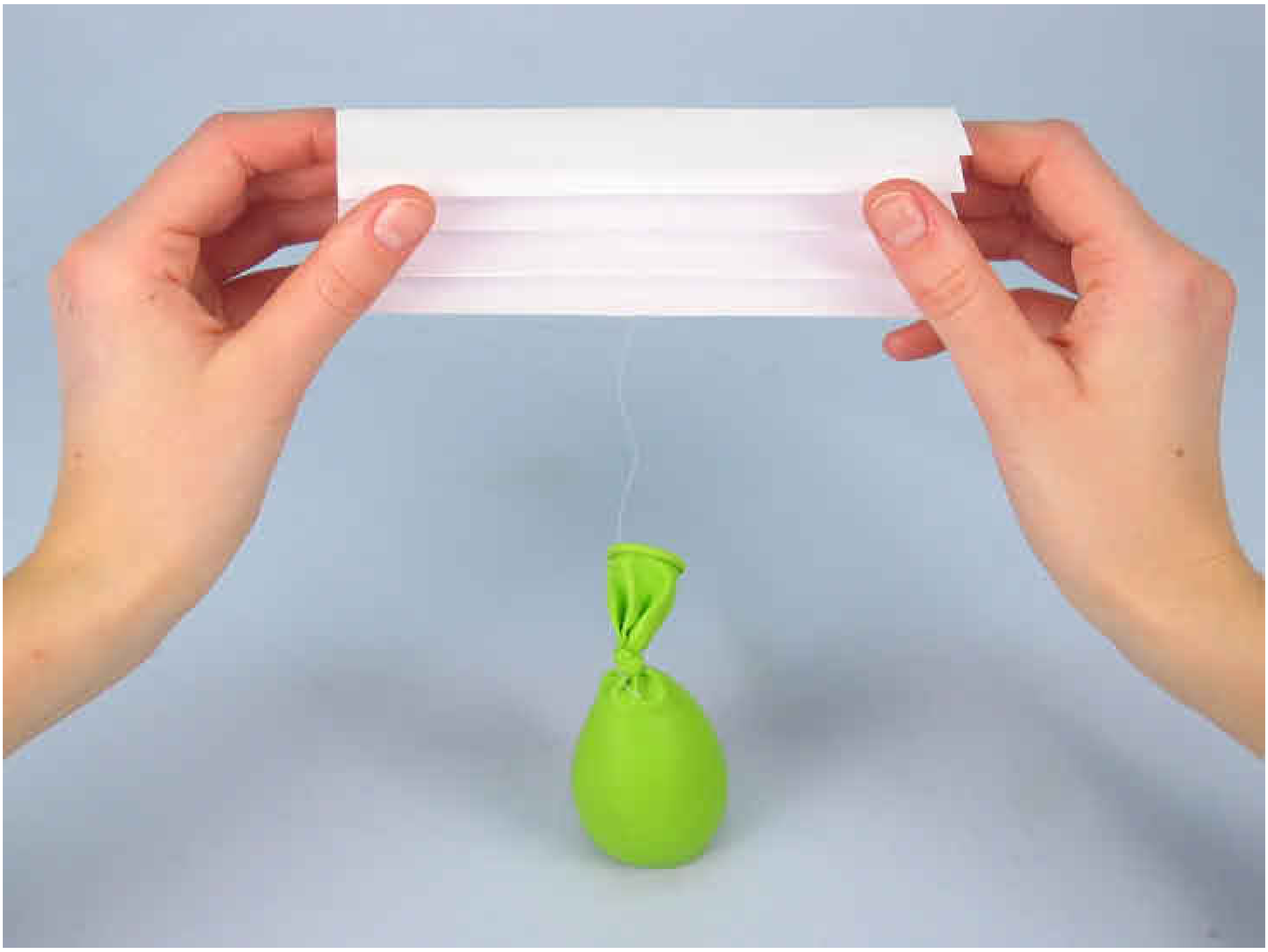

Fig. 2

Observations

1. How do the two bone models stand up to the load of the sand sack?

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2. What happens when the rolled paper is first loaded in a standing position and then in a lying position?

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Evaluation

1. Which model guarantees the most stable "skeleton bone"?

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2. For which type of a load is a tubular bone good and for which is it less suitable?

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Room for notes

(How are bones formed to hold up to as much stress as possible?)

Preparation

Each student group requires two sheets of A5 paper.

Observations

1. The pleated model creases immediately when the load is applied. The paper roll holds up to the weight of the sand sack.
2. The roll can carry the weight of the sand sack when it is standing but the weight misshapes it when it is in a lying position.

Evaluation

1. The tubular model is more stable than the pleated one. There are bones in the body which are also constructed in tubular form: They have a hard exterior wall and, within this, a bone marrow cavity which contains the bone marrow. Blood is formed in the bone marrow. Tubular bones are mainly found in the area of the extremities, i.e. in arms and legs.
2. Tubular bones are designed for longitudinal axis loads. Thighbones and lower leg bones must, for example, carry the whole weight of the body. Tubular bones could break when exposed to a high load vertically to their longitudinal axis.

Room for notes

How does your elbow joint function?

Task

Make a hinge joint and test the “suppleness” of it.

Material

1 Piece of foam rubber
1 Envelope clamp
1 Pair of scissors

Pen
Glue

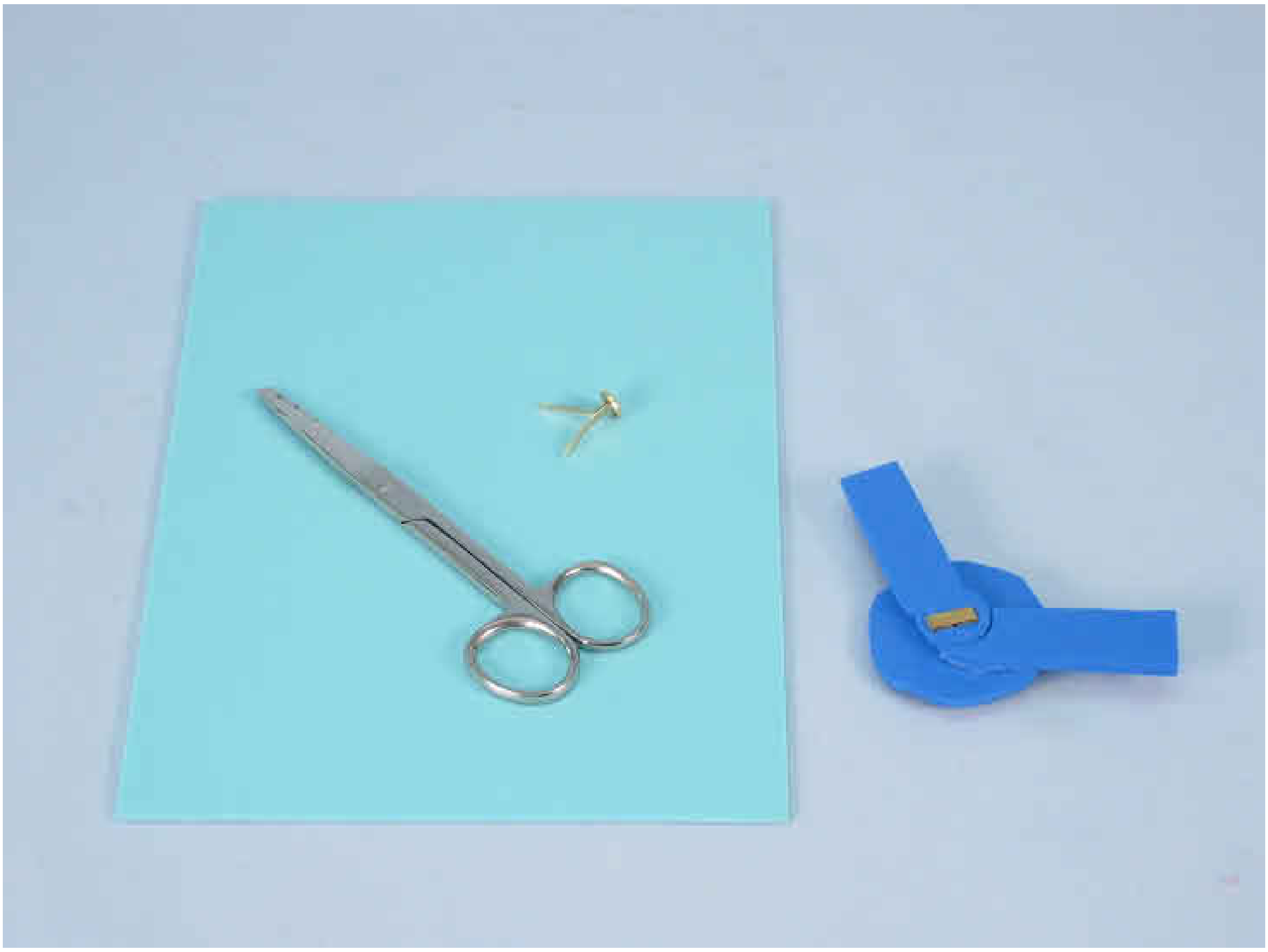

Fig. 1

Set-up and procedure

- Cut out the model parts from the model elbow pictured.
- Lay the paper parts on the sponge rubber and use the ballpoint pen to draw their contours in.
- Cut out the model parts from the rubber sponge.
- The circular part represents the joint capsule. Make a hole in the middle of it.
- The rectangular piece with the round end is the upper arm. Make a hole in the middle of the circular part of this.
- Use the envelope clip to fit the upper arm to the joint capsule.
- The part with the round cut-out side is the forearm. Stick this to the joint capsule so that it exactly fits to the upper arm.
- Move the upper arm and forearm of the model against each other and describe the movement.
- Move your elbow and compare it with the model.

Observations

1. In which directions can the upper arm and the forearm of the model be moved?

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2. Describe similarities and differences between the model and your elbow.

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Evaluation

1. Where else can you find hinge joints in your body?

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2. Where can you find joints which move in other ways?

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Model-elbow:

(How does your elbow joint function?)

Observations

1. Upper arm and forearm can only be moved relative to one another at one level and this only over an angle which is less than 180°.
2. My elbow can only be moved at one level, which is up in the direction of the upper arm. The model, however, also allows movement to the side. The model can also not be stretched more than 180° though.

Evaluation

1. Fingers also have hinge joints.
2. There are ball-and-socket joints in the shoulders and the hips which allow movement in all directions. Saddle joints enable thumbs to move in two main directions, i.e. forward and backward as well as to the left and right relative to the carpal bones. There is a pivot joint in the cervical spine which enables the head to be turned.

Room for notes

What happens when a coloured substance is in a still drop of water?

Task

Place a coloured substance at the edge of a drop of water and observe what happens.

Material

1 Stop watch
1 Watch glass

Water
Potassium permanganate

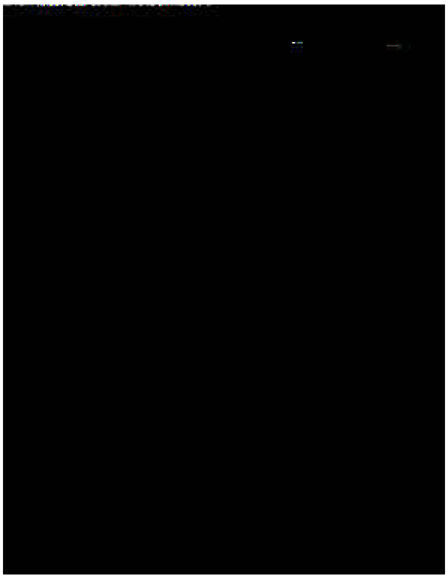

Fig. 1

Set-up and procedure

- Adjust the water tap to drop slowly and collect four or five drops in the middle of the watch glass.
- Let the teacher place a few crystals of potassium permanganate, a chemical substance, directly alongside the small pool of water.

Observations

1. What happens in the watch glass?

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Evaluation

1. How can you explain what happened in the watch glass?

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(What happens when a coloured substance is in a still drop of water?)

Material

Spatula
Potassium permanganate

Preparation

Each student group is given a few crystals of potassium permanganate. These are to be placed directly at the edge of the small pool of water on the watch glass so that they can dissolve. Only a small amount of potassium permanganate is required because of its intensive colour.

Notes on set-up and procedure

The students must take care not to move the watch glass in any way while they are observing what happens. This is important as this experiment should clearly show that the coloured particles move on their own accord and not because of any external process.

Hazard symbols for potassium permanganate

Risk phrases

R8	Contact with combustible material may cause fire
R22	Harmful if swallowed
R50/53	Very toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment

Safety phrases

S61	This material and its container must be disposed of as hazardous waste
S61	Do not liberate to the environment

Observations

1. The crystals slowly dissolved. The colour distributed itself from the edge to colour the whole amount of water. It took about five minutes for all the water to become coloured.

Evaluation

1. As nothing caused the watch glass to move, the colour must have distributed itself. The coloured substance is made up of particles, just as all other materials. These particles can move in liquids and gaseous substances. This is called diffusion. Diffusion is therefore responsible for complete mixing in liquids and gases over time.

A 5 l gas jar is to be used to determine both the volume of a normal breath and also the so-called vital lung capacity. A test person tries to blow as much exhaled air as possible below the bell jar after having taken a very deep breath. The values obtained will differ from person to person according to size, age, sex, constitution and physical fitness.

Material

1	Bell jar, 5 l	64156-00
1	Rubber stopper,d=35/29mm, 1 hole	39259-01
1	Stopcock,1-way,r.-angled, glass	36705-01
1	Rubber tubing, i.d. 6 mm	39282-00
1	Rubber bulb, with glass tube	64170-00
1	Glass tube,hooked, 160x30, 10p	36701-54
1	Glass tube, straight, l=80 mm, 10/pkg.	36701-65
1	Boss head	02043-00

Additional material

Glycerin	30084-25
Plastic dish or bucket	

Fig. 1

Set up and procedure

- First fill the bath or bucket with so much water that the bell jar can be completely immersed in it. As alternative, carry this experiment out at a wash-basin.
- Prepare the blowing tube as follows: Fit a piece of rubber tubing on the straight end of the bent glass tube, then fit the other end of the tubing to the straight glass tube which is to be used as mouthpiece.
- Rub glycerol on the glass tap so that you can more easily insert it in the hole of the stopper.
- Fit the stopper with tap to the bell jar and connect the rubber ball to the tube from the tap.
- Now dip the bell as far as you can in water.
- Open the tap and use the rubber bulb to suck air which is still in the bell out.
- Close the tap again and lift the bell up a little.
- Position the bent end of the blowing tube under the bell.
- The test person is now to breath normally a few times, but inhaling through the nose and exhaling from the mouth before, without changing the breathing rhythm, he or she blows five exhalations through the mouthpiece and into the bell.
- Record the amount of air exhaled and again suck the bell jar empty of air.
- In the second part of the experiment, the test person is now to breathe in as deeply as possible and then, in a single blow, to exhale as much air from his or her lungs as she can into the bell.
- Read off the vital lung capacity at the bell and record it.
- Several people are now to carry out this procedure so that the results can be compared, whereby the glass tube used as mouthpiece is to be changed for each person.

Observations

The air volume of five normal breaths was 2 l.

The vital lung capacity was between 2.5 and 5 l.

Evaluation

To determine the air volume of a normal breath, divide the volume measured by the number of breaths. A value between 200 und 500 ml is obtained, according to size, age, sex and constitution.

The vital lung capacity is also dependent on these characteristics but can be considerably increased by sport training. Even with the most powerful exhalation, about 1000 ml of air still remains in the lungs (residual air). Vital lung capacity and residual air add up to give the total lung capacity, i.e. the most air that the lungs can hold.

A spring balance which has not been calibrated is to be used here as force measuring instrument. Loading of the spring balance with masses (weights) enables it to be provided with a scale. If experiment S9 has already been performed, the students have already seen that a weight of 1 N corresponds to a mass of 100 g (a bar of chocolate).

Material

1	Support base variable	02001-00
1	Support rod, stainless steel, l=600 mm, d=10 mm	02037-00
1	Boss head	02043-00
1	Support rod with hole, stainless steel, 10 cm	02036-01
1	Spring balance,transparent, 2 N	03065-03
1	Spring balance holder	03065-20
1	Weight holder for slotted weights	02204-00
4	Slotted weight, 10 g, black	02205-01
3	Slotted weight, 50 g, black	02206-01

Additional material

1 Marker

Fig. 1

Set up and procedure

- Fit the spring balance in the holding set up as shown in Fig.1.
- Adjust the zero point of the scale to about 2 cm below the green sheath.
- To do this, loosen the screw at the hook and turn the hook for as long as it takes to bring the zero point to the wanted position. Mark this position with the felt pen.
- Hang the weight holder on the spring balance. It has a mass of 10 g.
- It is best to now carry out marking of the points which the students are already familiar with, i.e. 1 N, 2 N and 0.5 N. Do this by hanging each weight on at the weight holder and marking the position of the scale mark for the particular weight with the felt pen. Following this, mark 0.1 N sub-divisions in.
- Determine the accuracy of the spring balance which has now been calibrated with the spring balance supplied in the student kit.

Observations

Defined masses can be used to provide a spring balance with a scale.

For this, a zero point must be first determined at which the force measuring instrument is not under load. Hanging masses of known weight on then enables scale markings to be made.

Evaluation

The calibrated spring balance has a measuring range of 2 N. The distances apart of the graduation marks of the scale are the same within this range. An increase in the loading of the spring in the spring balance above this range would result in non-linear stretching. The graduations for 0.1 N, for example, would have different widths at different scale positions.

The effect of a two-sided lever is to be measured in this experiment.

In such a two-sided lever, the fulcrum is between the two arms of the lever: the two different sides are called the force arm and the load arm (think of a seesaw).

If experiment S 11 has already been carried out, the students have already been introduced to the effect of the load arm.

Material

1	Support base variable	02001-00
1	Support rod, stainless steel, l=600 mm, d=10 mm	02037-00
1	Boss head	02043-00
1	Lever	03960-00
1	Holding pin	03949-00
1	Spring balance,transparent, 2 N	03065-03
1	Weight holder for slotted weights	02204-00
4	Slotted weight, 10 g, black	02205-01
1	Slotted weight, 50 g, black	02206-01

Fig. 1

Set up and procedure

- The spring balance used is used here as force measuring instrument. As it is used “upside down”, it must be adjusted in this position. To do this, loosen the screw at the hook and turn the hook for as long as it takes to bring the display mark to exactly zero.
- Hang the weight holder of mass *m* = 100 g (corresponding to the holder + four 10 g slotted weights + one 50 g slotted weight) on the left side of the lever at the 10 mark, the spring balance on the right side of the lever and also at the 10 mark.
- To measure the force, bring the lever to the horizontal position by pulling the spring balance and read the value.
- Now hang the spring balance successively at the 8, 6, 4 and 2 marks and measure and record the force at each position.

Observations

Mark	Force arm length	Load arm length	Force
10	20 cm	20 cm	0.38 N
8	16 cm	20 cm	0.46 N
6	12 cm	20 cm	0.64 N
4	8 cm	20 cm	0.96 N
2	4 cm	20 cm	1.9 N

Evaluation

A lever enables a force to be increased. The longer the force arm, the less force which is required to lift a load.

Examples from everyday life are the tightening of a bicycle nut, the lifting up a drum of paint and weight distribution on a seesaw.

Save energy, use pulleys

The students learn here how a pulley makes it easier to lift loads. A single pulley enables the direction of the force to be changed, a combination of two pulleys enables the force to be halved.

Material

1	Support base variable	02001-00	1	Weight holder for slotted weights	02204-00
1	Support rod, stainless steel, l=600mm	02037-00	4	Slotted weight, 10 g, black	02205-01
1	Support rod, stainless steel, l=250mm	02031-00	1	Slotted weight, 50 g, black	02206-01
1	Boss head	02043-00	1	Pulley,movable,dia.65mm,w.hook	02262-00
1	Support rod with hole, stainless steel, 10 cm	02036-01	1	Pulley,movable,dia.40mm,w.hook	03970-00
1	Spring balance holder	03065-20	1	Measuring tape, l = 2 m	09936-00
1	Spring balance,transparent, 2 N	03065-03	1	Fishing line, l. 20m	02089-00


Fig. 1


Fig. 2


Fig. 3


Fig. 4

Set up and procedure

Part 1 of the experiment: Force measurement

- The spring balance is first to be adjusted for use in a vertical position. To do this, loosen the screw of the hook and turn the hook for as long as it takes to bring the display mark exactly to zero.
- Use the spring balance holder to set the spring balance up as shown in Fig. 1.
- Hang the weight holder with a mass *m* = 100 g (weight holder + four 10 g slotted weights + one 50 g slotted weight) on and measure and record the force.
- Re-adjust the spring balance for “upside down” use in the following measurements.
- Insert the fixed pulley to the stand as shown in Fig. 2, hang the weight holder (100 g) and the spring balance on and again measure and record the force.
- Finally reconstruct the experimental set-up as shown in Fig. 3 so that the fishing line now runs over the fixed pulley and the movable pulley. Hang the weight holder (100 g) on the movable pulley and again measure and record the force.

Part 2 of the experiment: Measurement of distance

- Remove the spring balance and hang the weight holder (100 g) on the fishing line which runs down from the fixed pulley (Fig. 4).
- Bring the weight holder to stand on the table top and tauten the fishing line.
- Readjust the fixed pulley so that the mark on it points to the right. Make a knot in the fishing line at his point.
- Now draw the loose end of the fishing line so that the load is lifted 40 cm up. Measure and record the length of the fishing line between the marking knot and the right side of the fixed pulley.
- Repeat this measurement with the fishing line running over the fixed and movable pulleys.

Observations

Measurement set-up	Force	Distance
Load (100 g)	1 N	
Load (100 g) with one pulley	1 N	40 cm
Load (100 g) with two pulleys	0.5 N	80 cm

Evaluation

A fixed pulley remains stationary when a load is moved. The force needed to lift the load corresponds exactly to the force of the load itself. The force can, however, be pulled on from a different direction to find the most convenient pulling position.

The movable pulley moves on the fishing line on which it is hung. In this experiment, such a pulley is combined with a fixed pulley. The force of the load is now distributed over the two fishing line ends and is therefore halved. At the same time, the required length of the lifting distance is doubled.

