MILESTONES IN SCIENCE

Thames & Kosmos

Experiment Manual

No.	Description	Qty	Part No.
1	Die-cut cardboard sheet	1	704274
2	“Periodic table” paper sheet	1	704405
3	“Peppered moth” paper sheet	1	704406
4	“Solar system” paper sheet	1	704273
5	Tracing paper	1	350137
6	Mounting feet	2	701384
7	Magnifying lens	1	311137
8	Lens, large	1	701379
9	Lens, small	1	701852
10	Plastic pipette	1	232134
11	Thermometer	1	702280
12	Fahrenheit scale sticker	1	704570
13	Measuring cup	1	087077
14	Modeling clay	1	000588
15	Reflective foil	1	702221
16	Drinking straws	4	704331
17	Polystyrene drinking cup	2	704330
18	Rubber bands	2	704401
19	Pull-spring	1	702757
20	Metal fasteners	10	020039
21	Iron wire, zinc coated	1	704370
22	Ice cream stick	1	000239
23	Rubber band motor (propeller with wire loop and rubber band)	1	771580
24	Talking Strip	1	704326
25	Gypsum (calcium sulfate), 200 g	1	771052
26	Skewers	8	020042
27	Glass marbles	5	771572
28	Glow-in-the-dark star	1	704325
29	Plastic marbles	1	771570
30	Blank CD-ROM	1	704322
31	Graphite rods	3	704276
32	Spring clips	20	771620
33	10 Wire links with plastic insulation	1	000292
34	Zinc discs	2	704324
35	Spool of wire, insulated	1	704275
	Electronic parts:	1	771583
36	1 Battery clip;		
37	1 Each yellow, red, and green LEDs;		
38	2 Resistors, 470 ohms;		
	1 Resistor, 5.6 kilohms;		
	2 Resistors, 10 kilohms;		
	1 Resistor, 15 kilohms,		
	1 Resistor, 33 kilohms,		
39	2 NPN transistors;		
40	2 Capacitors, 10 microfarads;		
	1 Capacitor, 100 microfarads;		
41	2 Universal diodes;		
42	1 Speaker		
43	Bar magnets	2	011287
44	Iron core	1	011297
45	Compass	1	533124

Additionally required household items (e.g., tape, cotton wool, yarn, plate, bowl, old newspaper, small pliers, hand tissue, salad oil, vinegar, red transparent paper, flashlight, or paper clips) are highlighted in italic type in some experiments. Special ingredients (e.g., African violet flowers or a red rose, dried white and red beans, distilled water, flower pot with soil, plant fertilizer, bush bean seeds or wheat grains that can germinate) should be obtained before the start of the experiment. You will also need a 9-volt rectangular battery (6LR61 type) for the electronic experiments starting on page 34. Before beginning an experiment, read though all the instructions to see what you will need. Assemble any necessary materials and get everything ready before you start.

Did You Know…?

…that the first eyeglasses were made of clear, ground gemstones instead of glass? The precious stone beryl was particularly appropriate for that purpose. The person recognized as the European inventor of eyeglasses was the scholarly monk Roger Bacon (1214 – 1294), from Oxford (England), but he knew and used the earlier works of Ibn al-Haitham. Roger Bacon, by the way, was a man who was astonishingly ahead of his time. He predicted inventions such as telescopes and microscopes (and even airplanes and steamships) — centuries before they were actually created!

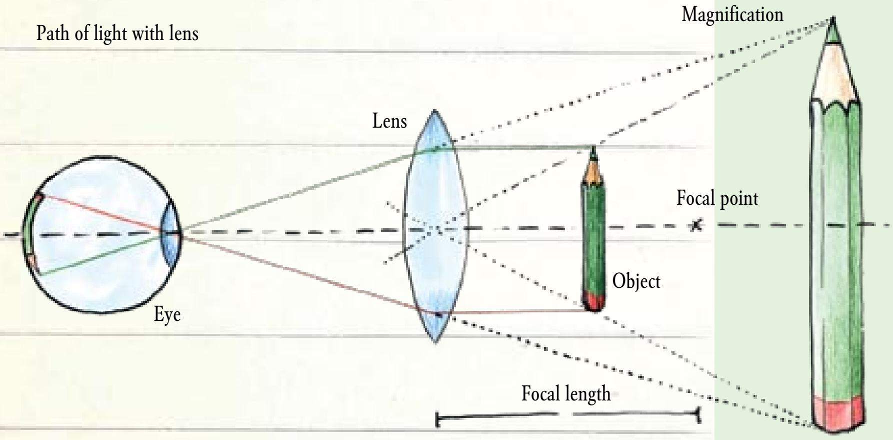
Camera Obscura: Before the Photographic Camera

Even in antiquity, natural scientists noticed that the surroundings would appear upside-down in a dark room when light entered from outside through a small hole. The Arab scholar **Ibn al-Haitham** investigated this phenomenon in greater detail and in 1020 constructed the first pinhole camera. In later centuries, painters used them as drawing aids, in some cases with lenses. At that time, they acquired the name **camera obscura** (Latin for "dark room"). But it was not until 1840 that they were used for photography.

Experiment:

If you darken your room and only let in light from the window through a small opening, you can observe an upside-down image on the rear wall of the room. That works even better if you build yourself a small pinhole camera.

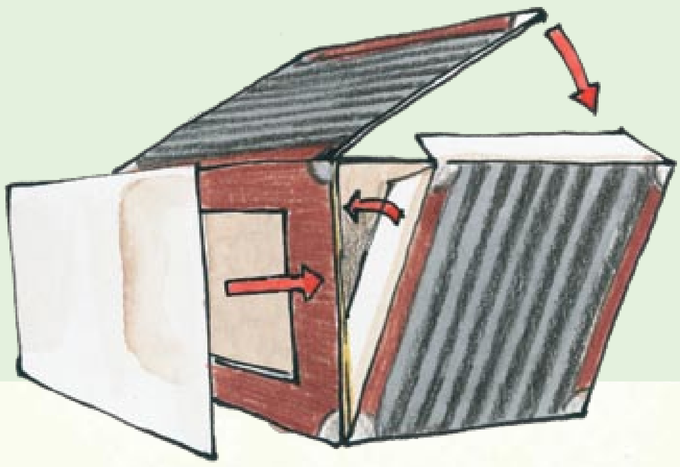
You will need: 2 "Camera obscura" die-cut card pieces, 2 rubber bands, lens with yellow socket, *tracing paper, glue, scissors, ruler, soft pencil*

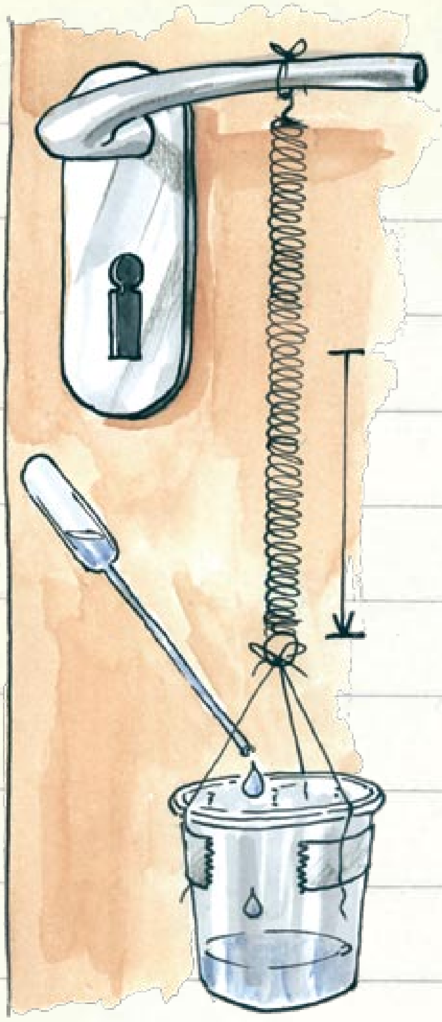


Here's how: Bend the larger cutout piece along the pre-marked line and fold it together according to the illustration.

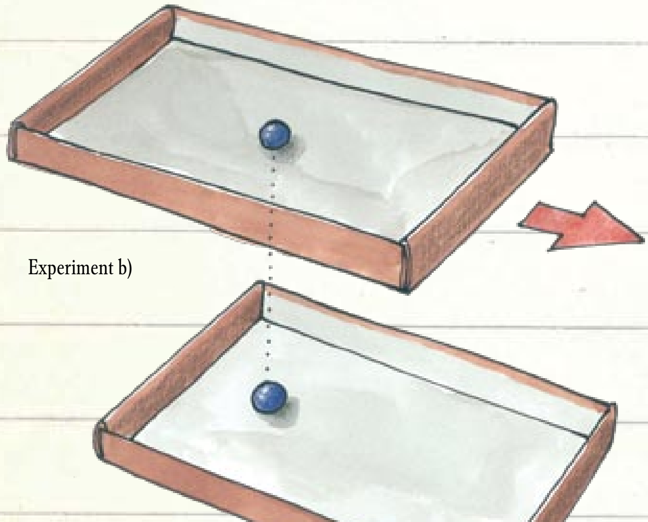
Cut a 5 x 8 cm-large piece of tracing paper and secure it with two rubber bands in front of the large cutout opening. Lay the second cutout piece over the opening in front (first open up the small hole) and push it under the rubber bands. Hold the instrument with the small hole against a bright window — you will see a faint, upside-down image of the outside landscape on the tracing paper. You will get a brighter image if you remove the pinhole aperture and instead insert the yellow lens socket. Move it back and forth until the image is sharp. If you are careful, you can sketch the outlines of the landscape on the paper with the soft pencil.

Caution! Focusing the sun's rays with the lens can create a very hot spot!

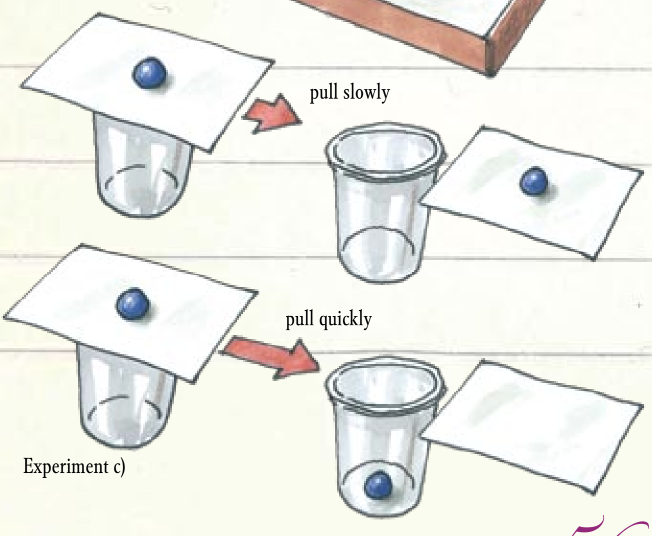




Experiment a)



Experiment b)



Experiment c)

Laws of Force: Inertia and Acceleration

To people today, it seems relatively simple what a **force** is and what it does, what the effect of acceleration is or why a fully-loaded cart cannot be as easily pushed as an empty one. But earlier natural scientists had little conception of those things. It was also unclear what actually kept the moon and the planets in their orbits. **Isaac Newton**, in his *Principia Mathematica*, was the first to lay the groundwork for a new realm of physics known as **mechanics**.

A few years ago, the British physicist **Stephen Hawking** referred to the Principia as "surely the most influential book ever written in physics." For 200 years, it shaped the world view of Western civilization — until Einstein's **Theory of Relativity** made a new one necessary.

Experiment:

With his three Laws of Motion, Newton deciphered the secrets of force, acceleration, mass, and inertia. They all play an important role in our everyday lives, and you have probably come across all of them at one time or another. They are:

1. Every object maintains its state of motion as long as it is not changed by a force acting on it.

2. The change in motion of a body is proportional to the strength and direction of the applied force.

3. Every force produces an equal force acting in the opposite direction.

You can investigate Newton's Laws of Motion in a few experiments. For measuring small forces, you will use a spring scale, which the English physicist **Robert Hooke** invented before Newton.

You will need: Glass marbles, measuring cup, pipette, pull-spring, iron wire, *balloon, scissors, tape, coins, string, 2 x 100-g chocolate bars, ruler, small box with lid, 2 chairs with smooth backs, small pair of pliers, paper*

Here's how:

a) Cut two pieces of iron wire about 2 cm each and bend them into hooks. Hook them in the two eyelets of the pull-spring. Tie the spring to a doorknob with a piece of string so that it hangs freely.

Affix three short pieces of string to the measuring cup with tape, and suspend the cup from the spring. Measure the length of the spring with the ruler. Then, use the pipette to fill the cup with 10 ml water, then 20 ml, 30 ml, etc., each time noting how much the spring stretches.

The length of the spring increases in proportion to the quantity of water, or with the weight pulling on the spring. This relationship is known as Hooke's Law. It no longer applies if the spring is stretched too far, so do not pull too strongly on it.

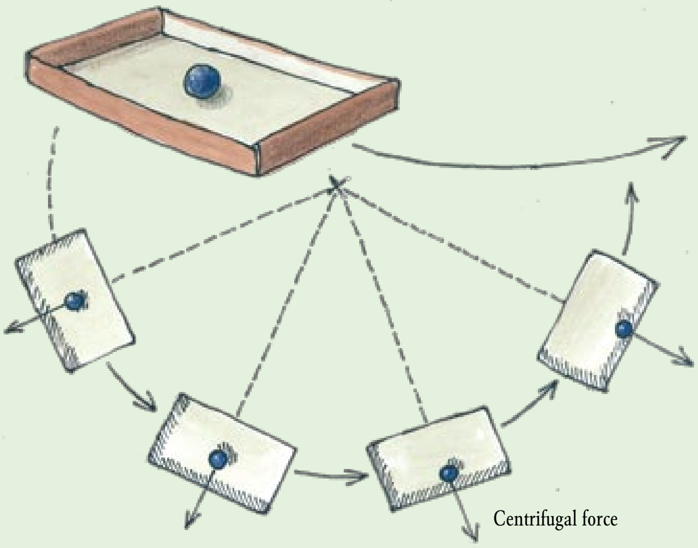
b) Place a marble in the center of a flat, empty box on the table. Pull on the box. The marble seems to roll backwards. Strictly speaking, it's actually not that way; the marble wants to stay in place, but the cardboard slides away underneath it. The reason for the marble's behavior can be found in Newton's first law. The name for this urge to keep doing what it's already doing is **inertia**.

Repeat the experiment, but this time start pulling the box slowly and then pull faster, so that the marble (held by friction) stays in place. Then suddenly stop pulling the box. Now the marble will continue to roll in the direction that the box was pulled, because it wants to maintain its direction of movement.

c) Lay a sheet of paper over the measuring cup, and place a coin on top of it. If you pull slowly on the paper, it will take the coin with it. But if you pull suddenly, the coin stays in place and then drops into the cup. Here, too, it is the **inertia** of the coin that is the reason for its behavior.

d) Place the glass marble in the box, start pulling the box slowly and evenly, and then pull it sideways. Now the marble rolls toward the outside of the box, because its inertia makes it want to keep rolling straight while the box moves in a curve beneath it. This is exactly what happens to your body when a car goes into a curve. Your body wants to keep going straight, which you sense as a force pulling you sideways.

This is also similar to what happens in a merry-go-round or carrousel, which always moves in a curve. At any given moment, the inert mass of your body wants to maintain its previous direction, which is straight ahead rather than in a circle. You sense this inertia as a force pulling you outward. In reality, this force does not actually exist, but is just an illusion. Nevertheless, it has a name: **centrifugal force**.



Centrifugal force

e) In a supermarket, push an empty shopping cart straight ahead and then stop it suddenly, paying attention to the force you have to expend to make it do that. Then, fill it with the heaviest items you can find, and repeat the experiment. Now you need a lot more force to start it suddenly, but also more force to stop it. Newton's second law is at play here. The more suddenly you want to change the movement of the cart (accelerate or stop), or the greater its mass, the more force you have to expend. That is the reason a cargo truck has a bigger engine than a small car.

Isaac Newton (1643 – 1727) grew up in poor circumstances, but because of his remarkable gift for mathematics he received a stipend to study at Cambridge University in England. It was Newton who demonstrated that the same force that makes an apple fall to the ground also keeps the moon in its orbit, and that this **gravity** is a property of every mass. The entire foundation of mechanics, including his **Laws of Motion**, comes from him. That is why the unit of force is named in his honor – your chocolate bar, with its mass of 100 g, pulls on the spring with a force of 1 newton [N].

He also took an interest in optics, and he constructed a new type of mirror telescope that he was even permitted to present to the king. A few years later, he published a comprehensive theory of light; among other things, he discovered that white light is composed of colored light. And last but not least, he developed the fields of differential and integral calculus, which have been hugely important for the mathematical formulation of natural laws, and with the help of which movements can be expressed mathematically.

Robert Hooke (1635 – 1703) was an English inventor, physicist, and mathematician, and a very prolific researcher. He developed a new type of air pump, and constructed a microscope which he used to reveal that plant cells are the smallest building blocks of plants. He also invented the balance wheel for regulating the movement of clocks (see illustration below). And he investigated the elasticity of materials and in the process discovered the application of Hooke's Law to the behavior of springs.