The International Physics Tournament 2014/5 – results

The final stage of the 20th Shalhevet Freyer Physics tournament took place at the Davidson Institute of Science Education on March 24, 2015. There were 72 teams, 54 from Israel and 18 from abroad. The countries who took part in the tournament were: Austria, Canada, Romania, Slovenia, Spain, Switzerland, UK and USA.

On March 25, 2015 there was a closing ceremony for the tournament where prizes were given to the top five winning teams.

The top five teams were:

1st place – Gimnazija Zelimlje, Skofljica, Slovenia
2nd place – Dulwich College, London, UK
3rd place – Tanenbaum Hebrew Academy, Toronto, Canada
4th place – Ben-Zvi high school, Kiryat Ono
5th place – Leo-Baeck, Haifa
Safes Descriptions

1st place - WATER DISPENSER

Gimnazija Zelimljje, Slovenia

The so called water dispenser got its name, because water is used in every stage of the cracking process. It is composed of two main parts. The crackers begin with the left side:

1st mission: water pumping

The goal in the first mission is to pump water from a reservoir to a spiralled plastic tube on a stick and then dispense it into a plastic glass. First the little tube on the stick should be sunk into the water reservoir. Its other end is connected to a copper tube which the crackers now must heat by rubbing it with hands. The air inside the copper tube warms up and expands. The crackers now cool the copper tube using wet cloth which they are given in the beginning. Water molecules on the surface of the copper tube evaporate cooling it efficiently and pulling water up the spiralled plastic tube. At that point the crackers can direct the water into the glass. They release the water by pressing the valve nearby. (The tube is made of copper, which
has a good thermal conductivity (390 W / (K * m)), is cylindrical making it hard to deform and is air-tight. The end of the pumping tube is installed in a spiral reducing hydrostastical pressure created by lifted water. This makes the pumping much more efficient.) The crackers then have to trigger a laser beam by connecting the water in the glass to the connection screw. They can do it with their fingers, possibly wet.

The crackers move to the right side:

**2nd mission: the alignment of the laser beam**

In this part they need to direct a laser beam such that it goes along a straight line and hits a phototransistor. Initially, the beam passes through two glass prisms and is refracted. The alignment of the prisms cannot be changed even though the area is accessible by hands. The goal is to reduce the refractive index of the media between the two prisms to zero. The crackers can do that by putting water in-between the two glass prisms, because glass and water reflective indexes are very close (water: 1,3; glass: 1,49). Now the beam passes the prisms without refraction and hits the phototransistor. The magnetic lock now opens and the safe is cracked.
2\textsuperscript{nd} place - The Fellowship of the Safe

Dulwich, UK
The safe is built of wood and acrylic. It also consists of:

- A metal pole
- A solenoid coil
- A copper coil
- Decorations including LEDs

Potential crackers are provided with:

- A 1.5V cell
- A a.c. power pack, which can provide a variable supply of current (1-15V)
- Two neodymium magnets, one of which is attached by a piece of string (or wire) to the safe
- Wires for connecting the solenoid to the power pack

Two combination locks lock the safe, each corresponding to a challenge. The challenges can be done in either order, but for convenience’s sake they are numbered 1 and 2.

**Challenge 1**

The crackers must remove the aluminium ring from the base of the clear plastic tower. To do this one must first remove the iron ring above it using the magnet provided. After this the solenoid below the ring can be connected to the power pack provided. A.C. current must be used, and a quick change of voltage will cause the ring to be jumped up the pole out of the plastic tube. The code can then be read out from the inside of the ring.

**Challenge 2**

The cracker must withdraw the iron ring from the pool of rings inside the safe. To do this the aluminium tube must first be removed from inside the coil sticking into the safe. The neodymium magnets must then be connected to the 1.5V cell provided. They must be repelling each other and the one attached to string should be on the negative end. The cell can then be inserted into the coil and if it has been connected
correctly it will move by itself and drop into the pool and attract the iron ring. The iron ring can then be pulled out using the string. Again the code is on the inside of the ring.
3rd place - Hebrew Academy, Toronto Canada
Description of the safe:

The puzzle has two parts. One part is inside the safe, and the other part is on the outside. The outside part contains magnets, pencils, an electromagnetic coil, scotch tape and paper. Inside the safe there is a sound system with exposed output connectors. One of them is connected to a system of nine equal-resistance resistors, connected to one another in series through wires, ending outside of the safe. The wire from the second connector is outside of the safe. There are holes on the side of the safe, through which the resistor system and wires are accessible. There is a pair of gloves attached to the holes, which can be used to attach the wires to the resistor system in different ways. The sound system plays an audio output giving the code to the safe.
**Cracking the safe:**

Initially, the resistors are connected in series, so that for every resistance R per resistor, the total resistance of the system is 9R. Opening the safe requires to first place the pencil through the cardboard tube (upon which the copper coil is coiled) and attach the magnets to it using scotch tape. This way, the pencil receives a current with a direction that varies according to the sound waves. As current flows through the electromagnetic coil, it produces a magnetic field with a varying direction, which alternately attracts and repels the magnets. This generates vibrations on the pencil, which causes the cochlea (a bone in the ear) to vibrate while biting on the pencil, and these vibrations are translated into sound. This allows the crackers to hear the code and open the safe. However, this will only occur if the vibrations in the pencil are strong enough. At the initial state, in which the pencil is attached to a resistance of 9R, the vibrations are not strong enough, so the code cannot be heard. In order to hear the code, the crackers must connect the resistors to one another in parallel, thus reducing the resistance attached to the pencil to R/9.

**Unsolved resistors system:**

- Portable cassette with disconnected speakers that transmits through a headphone cable electrical signals of one of us dictating
- Crocodile clips at the edge of each wire
Solved resistor system:

- Permanent connection points.
  - Resistors of resistance R.
Safe Description

To operate the machine you must close the electric circuit at two points: the end of the coil and the electric buoy.

At your disposal are: coffee capsules (1), water (2), scissors (3), coffee cup (4), buttons (magnets) (5), a nut (a metal screw thread) (6), straws (7), a box (8), and balloons (9).

The machine contains a copper coil (10) inside a Perspex tube, at the end of which lay two ends of the circuit (see Figure 1).

Inside the inner coffee cup you will find an electric buoy (11) (when the buoy reaches its maximum height it closes the electric circuit, see Figure 2). Only when the cup is filled with enough water for coffee will you be able to open the machine and get the...
coffee. Water can be inserted using the tube (12) on the upper right-hand corner of
the machine.

**Instructions for Cracking the Safe**

In order to crack the safe, take the coffee capsule, a AAA size, 1.5 volt battery, out of
the capsule container. Take the buttons, neodymium magnets from the safe door,
and attach one to each end to the battery. You may use the nut to stabilize the
magnet attached to the end with the higher electric potential. In order for the magnets
to be set correctly you must feel a little repulsion between them when one magnet is
already attached to the battery, this way the magnets will be set so that they do not
create a dipole together with the battery but rather the two ends of the bar which they
form together will be of the same pole (the magnets will be facing opposite
directions). Insert the magnets and the battery as they are set into the copper coil.
Since the magnets are conductors, they form an electric circuit with the coil and the
battery (which is the power source). The current in the coil around the battery results
in a magnetic field parallel to the coil. Since the magnetic field was created by the
current in a solenoid that is finite, it grows weaker as you advance from the center of
the battery towards the ends of the magnets. This causes the different poles in each
magnet to experience forces in different magnitudes, and since the different poles
experience magnetic force from this magnetic field in opposite directions, magnets
set correctly will cause the battery to move with them into the coil or out of it. If the
battery moves out of the coil, reverse its sides (keep the magnets attached). The
battery should move along the coil until eventually the magnet in one of the ends will
close the general circuit of the safe, as shown in Figure 3.

In order to elevate the electric buoy, you must construct a system that would cause
water to flow from the cup outside the safe into the cup inside of it, through the tube
coming of of the safe’s upper-right corner and the plastic tube inside the safe, using a
balloon, a straw, a box, a pair of scissors and the cup outside the safe which contains
the water. The water flowing into the cup would gradually elevate the buoy. Take the
balloon and use the scissors to cut a piece of its round side (the piece should be
about 2-3 cm in diameter). Fit the balloon to the rim of the cup containing the water,
and insert the straw and the end of the tube into the end one would use to inflate the
balloon. The tube should be submerged in the water, and the end of the straw should
stand in the air. You may lay the cup as you have arranged it on the box. Gently seal
the balloon around the straw and the tube, and blow into the straw. This will raise the
pressure in the cup, which will cause the water to start flowing into the tube which
goes into the safe, where the pressure is lower. Water will pile in the cup inside the safe and the buoy will rise to close the electric circuit of the safe, which will finally unlock it (see Figure 4).

Figure 1:

Figure 2:
Figure 3:

Wanted direction of motion

Net force on the magnets when inserted to the solenoid

Key:

<table>
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<th>S</th>
<th>N</th>
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Force experienced by North Pole

Force experienced by South Pole

Figure 4:

Balloon (use the part right of the red dashed line)

Coffee cup (outside the safe)

Water

Water

Air

Lower Pressure

Higher Pressure

Tube entering the safe

טישת
Honorable Mention – Cock-a-doodle-doo Safe
Leo Baeck High School, Haifa

Description of the safe:

The safe is divided into two parts. The first part contains an elevated opening on the ceiling of the safe leading to a tube inside of the safe, which ends on the outside of one of the side-faces of the safe close to the floor. The tube contains a piece of paper with two digits of the code to the combination lock of the safe. The second part contains two glasses, with lasers illuminating their bottom that then reflect off the adjacent mirrors. The mirrors reflect the laser beams in such a way that the paths of the beams, if were visible, would scribe the two remaining code digits. Since the air is transparent and does not scatter light, the digits are invisible. The crackers are supplied with an egg, a cup containing a mixture of water and cornstarch, a plastic bag and an egg-yolk separator.
**Cracking the safe:**

First, the crackers need to use the weight of the egg to pass through the tube and drag along the piece of paper with the first two digits on the way out. Please note, the crackers should be careful not to break the egg, since it is required also for the second part. Since the tube opening is elevated, if the egg is inserted without caution it will break. The crackers need to figure out that cornstarch mixed with water is a non-Newtonian fluid, namely its viscosity changes according to the force applied to it. Therefore, if they insert the egg into a bag with the cornstarch-water mixture before putting it through the tube, then as the egg hits the tube wall, the non-Newtonian fluid will absorb some of the impulse and will prevent the egg from breaking. The egg will slide through the tube whole, and the paper with the first two code digits will come out with it. For the second part, the crackers need to break the egg, separate the yolk from the egg white, and pour the egg white into the glasses through the feeding tubes. The egg white is a part-transparent and part-scattering material. Therefore, the laser beams will scatter off the particles in the egg white, which will cause the beam paths to become visible and reveal the additional two code digits.
Description of the safe:

These instructions were given to the crackers on laminated paper: the final objective of the crackers is to illuminate a detector using a laser. In order to turn the laser on, they are required to manually operate a switch, which is located inside a code-locked compartment. The safe contains a speaker that will play the code. In order to enable it to play the code, it needs to receive a voltage higher than 5V. The crackers are supplied with a small magnetic ball. The speaker and its relay are on the wall opposite from the door of the safe. The laser and detector are set on two rotating stages on the ceiling of the safe close to the door. The stages can be rotated using rods extending from the ceiling. Circular polarizers (quarter wave-length polarizers)
are stationed before the laser and detector in an opposite polarization, so that the laser light will not reach the detector.

On the side that is far from the door, there is a hole in the safe ceiling, through which passes an extractable tube. The tube passes in the safe, and its other end is inside the opening of the electromagnetic coil attached to the speaker. The coil is elevated, and underneath its other opening there is a downward, very moderate slope, extending up to the extraction opening. A few centimeters before the extraction opening the slope ends, and there is an upward steep slope. Above this slope there is the extraction opening, which is intended for the extraction of the ball out of the safe. Next to the slope, attached with a chain to the body of the safe, there is a metal rod. The opening is too small for a hand to fit in, so the crackers will have to use the metal rod in order to extract the magnetic ball out of the groove between the two slopes.

This structure, of two slopes, serves two purposes: stopping the rolling ball from shooting through the extraction opening and ensuring that the top part of the opening is a little bit higher than the relay of the speaker.

**Cracking the safe:**

The crackers are required to figure out that a small magnetic ball moving slowly through an electromagnetic coil with a small number of turns cannot generate a voltage of several volts. The crackers will have to take advantage of the reversibility (symmetrical) nature of electrical components, which is stems from the symmetry of physical systems. Many electrical components display this sort of reversibility. LEDs, for instance, can also be used as light detectors, and a magnetic speaker can be used as a microphone. Just as an electrical current in a magnetic field generates motion in the conductor carrying the current, the motion of a conductor in a magnetic field generates an electrical current in the conductor. Piezoelectric speakers clearly demonstrate this property. This type of speakers is composed of a crystal that transduces an electrical signal into a deformation that generates mechanical pressure but it also transduces mechanical pressure into electrical signal, thus it can be used both as a speaker and as a microphone. Of course, the mechanical pressure
of air passing through a few layers of air is much weaker than that exerted by a ball falling and tapping the speaker itself. The symmetry itself stems from the fact that the physical interactions, upon which these systems are based, are symmetrical over time, and therefore we can think of the reversibility of electrical components as the operation of these components upon a reversed time-flow.

In order to operate the speaker, the crackers will have to take the tube from the top and put it through the extraction opening. Due to the location of the opening, the tube will create the smallest slope when it is pushed against the top of the opening, while leaning on the relay box at its other end. This will allow the ball to role inside the tube and tap on the speaker. The tap will create a sufficient amount of voltage to operate the relay, and the speaker will begin to read out the code. The crackers will open the lock and turn the laser on.

Now, the crackers will have to understand that the polarizer on the detector will prevent light with an opposite polarization than that of the laser light to pass through, and therefore they must reverse the polarization of the light coming out of the laser. This can be achieved by reflection – when a circular polarized light reflects off a reflective surface, its polarization is reversed since changing the position of the observer with respect to the direction of the wave actually changes its polarization.

Reflective surface

![Diagram](image_url)
In order to illuminate the detector, the crackers will have to reverse the circular polarization of the polarized laser beam, by turning the stages of the laser and detectors so that they face the translucent door of the safe. The motion of light through one translucent medium to another causes part of the light to pass through the second medium and the rest to be reflected. The crackers will discover that there is not enough light reflected in this manner, and that a there is a need for a stronger intensity of light to reach the detector. By placing the laminated instruction paper against the safe door, the crackers will prevent light from passing through, thus improving the reflection of the surface. This will allow almost all of the light to be reflected back to the detector, illuminating it in a sufficient amount for activation of the safe-unlocking mechanism.
Description of the safe:

The objective of the crackers is to open the box at the top of the safe. The code for the lock can be obtained from numbers encrypted on the rotating disc. Inside the safe, aside from the rotating disc on the right, there is an engine on the left – its speed can be adjusted by the potentiometer installed on the safe. The engine can be turned on and off by using the red button installed on the left side of the safe. The crackers are supplied with a punctured disc, insulating tape, scissors and a flashlight.

Cracking the safe:
In order to open the locked box on top of the safe, all circular holes in the disc must be covered, leaving only a single thin slot. The disc has to be installed on the engine. The flashlight has to be lit and pointed at the rotating disc through the hole above the engine. When the engine is turned on, a thin beam of light will be emitted upon every turn, and it will hit the rotating disc. By adjusting the speed of the engine, the crackers will be able to achieve a blinking frequency that is double the rotation frequency of the disc in order to see the digit 6. In order to see the digit 5 they will need to achieve a triple frequency. The potentiometer cannot reach this frequency, so this can only be achieved by opening another slot in the disc, so that the blinking frequency will be twice upon completion of one turn. The other two digits for unlocking the safe are the ratios between the blinking frequency and the rotation frequency of the disc – with 5 and 6 standing respectively.
Description of the safe:

The safe is comprised of a two-step unlock mechanism, in which the first part is based upon light refraction using a laser, and the second part is based upon the principle of a varying magnetic field.

Before cracking the safe, the crackers will be supplied with the following accessories: water as much as needed, portable laser, syringe, copper coil wrapped around a straw, pencil, two audio magnets and headphones.

Cracking the safe:

There is a container at the corner of the box, which will be used for cracking the first step of unlocking the safe. The container will be completely empty when the
crackers first receive the safe. The container is mostly covered, in order to prevent cracking in a different way than intended, but on the side of the safe the container has a transparent face, so that the crackers can observe the water level as they add water to it. On the bottom of the other side of the container there is a small circular hole, of 1mm diameter, through which the water will pass later on. At the top of the container there is a cap, through which the crackers will be required to insert water into the container, while using the supplied equipment.

Underneath the container, inside the safe, there is a mirror on a pivot, which is initially placed in parallel to the floor. The mirror is directed in such a way so that the situation has only one physical solution – i.e., there is only one way to aim the laser so that it reaches the detector, which is placed inside a cylinder on the opposite wall of the safe. As water will flow through the hole, the mirror will lean at a certain angle, depending on the water flow, and when the crackers will direct the laser towards the hole the light will be refracted in the water. There is only one solution, since as the water flows through the hole, the laser beam will be refracted in the water, as in an optical fiber, in such a way that the angle in which the water hits the mirror will create a unique refraction angle. This angle, and this angle only, will allow the laser to reach the detector. The draining system at the bottom of the safe will drain the excess water in the safe following the different attempts.

As mentioned above, across from the mirror there is a laser detector, which will identify the laser beam and close an electrical circuit, leading to the opening of a compartment on the face that is furthest from the box. Inside the compartment there are two wires connected to the audio outlet of a radio receiver, which plays the code to the safe in repeat (taken from a song by “Hadag Nahash”). The crackers will be required to construct a unique audio device by inserting the pencil into the straw (wrapped by an electromagnetic coil) and attaching the magnets to the coil. By wearing the headphones and biting on the pencil the crackers will be able to listen to the code. This is possible due to a change in the magnetic field, which changes the frequency of the pencil and causes the jaw bones to oscillate. Following, the crackers will be able to open the safe.
Description of the safe:

Physical principles

Creating a resonant frequency in a glass: Every object has its own resonant frequency. As the wine glass reaches its resonant frequency due to sound waves from the speakers, it begins to vibrate, causing an object laying on the surface of the glass to fall (in our case – a straw).
Creating a current using a fan: A desktop computer fan is comprised of four small electromagnets and a propeller attached to another electromagnet. In order to spin the fan at its maximum frequency, it needs to be supplied with a voltage of 16V. If the fan is spun at maximum frequency it also produces that same voltage, which can be utilized for switching on the LED lamps.

Cracking the safe:

The safe is divided into two chambers. In the first chamber, the students are required to create a resonant frequency in the wine glass stationed inside the safe. Reaching the resonant frequency will be achieved by hearing – the students will be supplied with an identical glass, and by tapping it they will have to understand what the resonant frequency of the glass is. The moment they reach the resonant frequency, the glass will begin to shake and the straw will fall.

There is a propeller from a computer fan placed in the second chamber. Using the straw, a cotton string and a hook that will be supplied to the crackers, they will have to construct some sort of fishing rod and fish the propeller out. The propeller will be attached to the other part of the fan, which is hanging on the wall of the safe. Using a blow-dryer, the fan will be spun and will generate a current that will light up the LED lamps located behind a piece of paper. The light from the LED lamps will reveal the code to the safe, which is written on the hidden side of the paper.
Description of the safe:

The safe is divided into three adjacent compartments. The first compartment contains an empty and capped water bottle with a hole on its side. As the bottle is filled with water with its cap open, water will flow through the hole in the bottle to the hole in the wall separating the first and second compartments and into a transparent container on the floor of the second compartment. In the first compartment there is a laser that can illuminate the bottle. Under the transparent container on the floor of the second compartment there is an optical detector, at a certain distance from the wall of the compartment. Above the bottle cap, on the ceiling of the first compartment, there is a glass-covered rectangular opening. The glass cover is of the same dimensions as the opening and thus cannot be lifted by hand. The third compartment contains LED lamps displaying digits from 0 to 9. When the laser light will be detected in the optical detector, the correct digits will light up,
and the combination-lock connected to the second box can be unlocked. Inside the second box there is a number code written in invisible ink. This code opens the combination-lock to the entire safe. The crackers are supplied with a laser, matches, a plastic cup, paper towels, a candle, water squirt and funnel. In addition, they are supplied with full bottles of water.

**Cracking the safe:**

First of all, the crackers must open the glass opening on the ceiling of the first compartment. In order to achieve this, the crackers must dab the paper towel with water and place it on the rectangular glass surface. On top of the paper towel, a lit candle has to be placed and covered with the plastic cup. As the candle dies out and the air inside the cup cools down, the pressure inside the cup drops, causing the glass cover to adhere to the cup. The glass cover can be lifted by pulling the cup, thus opening the first compartment. The next step is filling the bottle with water, while leaving the cap open, so that water begins to flow into the container in the second compartment, above the detector. During this time, the crackers are required to point the laser to the other side of the bottle. The water flow from the bottle deflects some of the light by complete reflection, so that the light hits the detector, leading to lighting of the LED lamps containing the code numbers. Now, the crackers are required to open the little box using the code they have discovered, take that paper within it, and heat it up using matches. The code will be revealed on the paper as the invisible ink becomes visible, and the safe can now be unlocked.
Description of the safe:

The safe is comprised of two parts. The first part contains a ping-pong ball laying on a wooden rail. The ball is held at the top of the rail by a balance scale, which has a container for water on one of its arms. Above the scale hangs a string connected to pulleys. On the ceiling of the safe there is a weight of adjustable height. The crackers’ objective in the first part is to tilt the scale by filling the container with water. This will release the ball to roll down the rail and towards the other part of the safe. For this the crackers are supplied with a straw, a disposable cup, a pencil, play-dough and water. In the second part of the safe, there is a hole on the bottom, which is blocked by a net, and another hole at the top of the safe. The objective at this step is to extract the ball, upon which the code to the safe is hidden, out of the top hole. The crackers are supplied with a hair-dryer, a piece of paper and paperclips.
**Cracking the safe:**

In order to crack the first part, the crackers are required to construct a “Pythagorean cup” out of the disposable cup and the straw. Following, the Pythagorean cup should be filled up to the kink in the straw and hung on the string-and-pulley system. After hanging the cup, it should be moved slowly towards the scale, and the weight should be placed inside it, so that the water level rises above the kink. This will empty the cup into the container. The weight of the container that is now filled with water, will tip the scale and allow the ball to roll over to the second part of the safe. The plastic ball will stop above the net located on the hole at the bottom of the safe. Now, the crackers are required to create a cylinder using the piece of paper and the paperclips. Next, they are required to turn on the hair-dryer and point it at the net at the bottom of the safe. This will cause the ball to float inside the second part of the safe. Then, the paper cylinder should be inserted through the top hole of the safe, so that it contains the floating ball. This will cause the ball to shoot out of the safe and into the hands of the crackers. The code to the combination-lock of the safe is hidden on the ball.
Description of the safe:

Outside of the safe there is a power supply connected by two wires to an electromagnet, which is attached to the safe door. The door is held shut by the electromagnet’s attraction to the natural magnet attached to the body of the safe. Inside the safe there is a vertical electromagnetic coil, which it tethered to the floor of the safe and has a natural magnet inside, a metal paperclip, a jug of distilled water, an amplifier adjusted to amplify currents for a speaker, and another small coil attached to the amplifier, with a membrane attached to it. The amplifier is supplied with a constant electrical current at all times, so that upon connection to the speaker it will play a recorded message with the number code that opens the lock to another box. The box is actually the safe that is to be opened.

Cracking the safe:

First, the crackers are required to understand that in order to open the safe door, it is not sufficient to turn off the power supply, since the natural magnet still attracts
the metal inside the electromagnet. Therefore, in order to open the door, they have to switch the direction of the current in the electromagnetic coil, so that a repulsion force will replace the attractive force between the electromagnet and the natural magnet. Following the opening of the door, the crackers are required to straighten the paperclip into a metal wire and insert it into the coil on the inside of the safe, so that the natural magnet can be extracted by being attracted to it. Since the coil generates a magnetic field that maintains the magnet inside, distilled water has to be poured inside. Distilled water has lower magnetic permeability than air, and therefore they cause the magnetic field around the natural magnet to weaken, making it easily extracted by the paper clip. Following the extraction of the magnet from the coil, it has to be placed next to the coil attached to the membrane. The current flowing through the coil causes the magnet to vibrate, and the membrane translates these vibrations into audible sound waves, when placed in close proximity to the ear. The code to the safe is revealed in the recorded message played by the membrane.
Honorable Mention – “The Crispy Crab”

Blich High School, Ramat Gan

Description of the safe:

Description of the first puzzle: double pendulum and magnetic attraction/repulsion

The first puzzle consists of three magnets hanging from the top of the safe, which cannot spin on their own axis. One of these magnets is part of a double pendulum, together with a weight located on the outside of the safe, which is accessible to the crackers. Another magnet is free, and the third is free and supplied to the crackers. The magnet attached to the weight repels the magnet located next to it, which in turn, is attracted to the magnet next to it.
Each one of the two attracted magnets is connected to an electrical cable. The two cables are connected to a turbine, which will, providing there is a closed electrical circuit, open the door to receiving the balls required for the next puzzle.

**Description of the second puzzle: Gauss rifle**

This puzzle contains a removable rail with two non-touching tethered magnets. By completion of the first puzzle, the crackers have received 5 metal balls. By placing these balls on the rail, the crackers will have to supply one of the balls with a maximal amount of kinetic energy, so that when it rolls down the rail it will be able to complete a full loop and hit the plastic ball with the code to the safe.

**Cracking the safe:**

**Cracking the first puzzle:**

The crackers are required to lift the weight, let it go and allow it to swing freely in order to transfer the energy to the magnet inside the safe. At the same time, they can use the additional magnet they have received to attract the magnet closer to the wall of the safe.

As a result of these two actions, the attracting magnets will cling to one another and close an electrical circuit, which will operate the turbine that will open the door to the balls for the next puzzle.

**Cracking the second puzzle:**

The crackers are required to take the rail and arrange it as following: next to each magnet there are two balls facing the direction of the loop, and one ball is left out. Now, the crackers are required to return the arranged rail back into the safe and roll the fifth ball into the safe on top of the rail.

Following this, the last ball will gain maximal speed, pass the loop and extract the ball with the code out of the safe.
Description of the safe:

The crackers are required to open a combination-lock – 4 digits by exposing the code. The code (7) is on the edge of a bowl (6) that contains balls, in such a way so that code is hidden by the balls. The bowl is connected to a rotation axis with an engine (8). The crackers can turn the engine on and off as they please (10). When the crackers turn on the engine, the balls rise on the edges of the bowl due to the centrifugal force exerted upon them by the spin, and then the code is revealed.
The balls require some time and a specific rotation velocity in order rise on the edges and expose the code. Once the code is revealed it moves too fast for the human eye to read.

If we illuminate the code with very short flashes of light while the code is at “the same location”, then we will achieve a sort of “stationary image” of the code. For this purpose, the crackers are supplied with pencils (1), scissors (2), Bristol paper (3) and a flashlight (4), and are required to create a stroboscope. A stroboscope is a tool used for observation of objects moving at fixed time differences. The stroboscope is constructed as following: two holes are made in a disc (cut out from the Bristol paper in this case); one hole is at the center of the disc, and the other is near the edge of the disc. The disc is fixed at its center on a pivot (in this case, it is the rotation axis of the engine coming out of the safe). The disc will spin at the same rotation frequency as the bowl. When the flashlight is held above the disc, the code will be flashed with light only once every turn, always at the same location. Therefore, the eye will see a “stationary image” of the code.

The pivot passes through the plastic wall by a “magnetic clutch” (5) – on the top edge of the pivot inside the safe there is an eraser with two magnets at its ends. Outside of the safe there is an identical component – when the external component is placed over the internal one, the magnets attract and transfer the rotation of the
pivot from the internal one to the external one. The purpose of this mechanism is to prevent the crackers from attempting to abruptly stopping the bowl’s turn manually.

1. Engine
2. Pivot
3. Bottom of bowl
4. Pivot
5. Disc (stroboscope)
6. Hole
7. Code
8. Lamp
Description of the safe:

The safe is based upon two physical principles, centrifuge and electricity. Electricity: in the first part of unlocking the safe, we relied on this principle by using a ground fault interrupter, which generates alternating current. Next to the ground fault interrupter switch there is a pin, which is pushed towards a balloon when the switch is set off. The purpose is to overload the ground fault interrupter and set it off, causing the pin to pop the balloon. In addition, the safe also contains a solar panel, which can be connected to the interrupter and a projector that will assist the crackers in creating the overload. If the panel will be illuminated only after being connected to the interrupter, then no sudden overload will be generated and the interrupter will not be set off. The trick is to first illuminate the panel, and only then, after the panel has accumulated enough energy, to connect it to the interrupter. After the balloon pops, a drawing containing the code to the lock of the compartment will be exposed, allowing the crackers to move to the next step.
Centrifuge: as an object spins, the forces it generates face outwards from the center of the rotation axis. The force is perpendicular to the motion of the rotating object. We decided to use this force in order to solve the puzzle in the second part of the safe. This part is presented as an X shape, built out of two wooden pieces, which the crackers are required to open (i.e., some sort of lock mechanism). The only way to separate the two parts of the X is by spinning them, so that the centrifugal force will unlock it.

**Cracking the safe:**

1. Make sure the solar panel is disconnected from the ground fault interrupter.
2. Turn on the projector and fully and uniformly illuminate the solar panel, while it is still disconnected from the interrupter.
3. Wait for the panel to accumulate energy in order to generate an overload on the interrupter.
4. Connect the solar panel to the ground fault interrupter. The interrupter will set off, push the pin and the balloon will pop.
5. Unlock the combination lock to the compartment using the code revealed in the drawing, and take out the second part of the safe – the X-shaped lock.
6. Spin the X, and separate the two parts in order to expose the second code.
7. Put in the code to the safe and receive the reward.

**Vault Description**

**Electricity:** in the first part of the safe opening we used electricity. The idea is to pop a balloon with an AC model of a ground fault. There's a light sensor which you need to light and let it absorb the light while it's not connected to the ground fault. After a few seconds there is enough absorbed light for the sensor to create an overload in the ground fault. At that point you connect them and the overload will cause the trigger of the ground fault to move fast and push a nail that pops the balloon that cover the wall of the safe (remember that) and holds the 2nd part out of reach.

**Centrifuge:** As a body spins, all of the forces on the body are directed radially (from the center). The force is orthogonal to the tangent of the spinning body. We decided to use those forces for the solution of the 2nd part of our safe, this part will be
opened only when using centrifugal forces. Its an X-Looking shape made out of two parts that will get separated only when a centrifugal force is applied on the locking mechanism.

**Cracking the safe**

1) Make sure the solar panel is disconnected from the ground fault.

2) Turn on the projector and shine light on the solar panel while its disconnected.

3) Connect the solar panel to the ground fault – it will jump and shove a thin needle into a balloon and make it pop.

4) Once the balloon is popped a code is revealed which opens the lock. Inside the participants while find an X-shaped box.

5) The X shaped box should be rotated and then its opened and the second code is revealed – this is the code for the safe lock.

6) Open the safe and get the prize!
Honorable Mention – Pipe Cleaner Safe

Harishonim High School, Herzliya

Description of the safe:

Main physical principles – air pressure, Bernoulli’s Law

In order to open the safe, two puzzles need to be solved.
Solution to the first puzzle (the can – closing an electrical circuit):

A can is stationed inside a cup in the safe. Underneath the slope, which is decorated with trees, there are two conductive stages connected to a power supply and a lamp. The lamp will light up when the electrical circuit closes.

In order to close the electrical circuit, the crackers will have to take the two conductive rods attached to the side of the safe and insert them through the holes at the transparent front of the safe. Then, they will have to lift the slope and place them on the stages. Now, the can will serve as a switch. For this, the crackers will have to blow air through the window at the side of the safe towards a specific point in the cup that will cause the can to jump. Then, the can will roll down the slope and land on the two rods – this will close the electrical circuit and the lamp will light up.

Now the only problem left to solve is seeing the code hidden above the lamp.

Solution to the second puzzle (moving the liquid):

A piece of play-dough, with five matches stuck into it, has to be placed inside the liquid, preferably is the shape of a pyramid. The matches have to be lit on fire and covered with the supplied cup. The burning process inside a closed space will lead to a pressure difference between the inside and outside of the cup. This will cause the liquid to be sucked inside and reveal the code above the lamp.
Description of the safe:

The safe is comprised of two parts. The first part is composed of an electrical circuit (Wheatstone bridge) that one of its resistors, an electromagnetic coil denoted as $R_x$, is outside of the safe, and the rest of the circuit is inaccessible to the crackers. The crackers will be supplied, from the beginning, with a large condensed-air spray can, and in order to solve the first level they will have to increase the voltage, denoted by $V_G$ in the circuit.
Cracking the first level will lead to the unlocking of a side-box containing small magnetic balls.
The second level is comprised of a small tube for insertion of the balls into the safe, an electromagnetic coil tied to a string, which can be moved in/out and up/down, a power supply located outside of the safe, UV LED lamps, a rail, and two wires that are placed at a short distance from one another and create an interrupted electrical circuit connected to the LED lamps. In addition, the LED lamps are connected to two wires, which are fixed on the roof of the safe, so that only one of their ends is exposed to the crackers. The safe will open only when the crackers will cause the LED lamps to switch on and reveal the code to the safe.

**Cracking the safe:**

The following physical principles underlie the safe-cracking mechanism of our safe:

Gas thermodynamics – according to the first law of gas thermodynamics, the temperature of a gas transferring from high pressure to low pressure will decrease. The influence of temperature on the resistance of metal – cooling metal decreases its electrical resistance. Electromagnetic coil – a combination of understanding Faraday's law, the magnetic field induced by an electromagnetic coil, Eddy currents and induced electromotive force. During the first level, the crackers are required to spray the outer resistor with air, which will result in increasing the voltage measured by the voltmeter in the circuit.

During the second level, they are required to insert the magnetic ball into the coil and shoot it into the rail by quickly turning on and off the power supply connected to the coil. The ball will roll into the rail and close the discontinued circuit.

Finally, they will have to disconnect the coil from the power supply, and connect it to the LED circuit. Then, by bringing the coil near the glass at the front of the safe and moving the large magnet next to it, an induced electromotive force will be created in the LED circuit. When this is completed successfully, the code to the safe will be revealed.
Honorable Mention – “Child’s play”

Safe

Ramon High School, Hod Hasharon

The following physical principles underlie the safe-cracking mechanism:

1. Inertia – Newton’s first law.
2. Circular motion.

Description of the safe:

The safe is comprised of two parts. The first part contains 4 sloped rails with copper cylinders. The copper cylinders are connected to an electrical circuit. The crackers are required to close the circuit using 4 metal balls. When this puzzle is solved, a string comes down the left side of the safe and has to be extracted by the hook hanging on the safe wall. The string will allow the crackers to turn a potter’s wheel at high speed. The second part of the safe contains a potter’s wheel with 4 sloped trenches. At the bottom of the trenches there are 4 balls, and at their top ends there are four micro-switches. When all four micro-switches are pressed at once, the electrical circuit that unlocks the safe is closed.
Cracking the safe:

The safe is divided into two puzzles.

The first step requires closing the electrical circuit that is on the yellow rails and is composed of copper sheets that wrap part of the rail. In order to close the electrical circuit, the four play-dough-covered cylinders need to be used. Then, the transparent surface has to be placed above the holes, so that it sticks out a bit out of the back side of the safe, and the cylinders are to be placed above each hole. Following, the crackers are required to insert a metal ball into every hole and hit the transparent surface from the back side of the safe using the metal ruler. This will cause the surface to move, and according to the inertia principle, the cylinders containing the balls will stay in place, thus simultaneously releasing the balls into the rails and closing the electrical circuit – the solution to the first puzzle. Closing the circuit will lead to the dropping of a string inside the safe, which should be grabbed using the hook in the opening of the balls. Following, the crackers are required to take the string and wrap it around the potter’s wheel. Then, they need to pull the string quickly, causing the wheel to rotate at high speed. According to the laws of circular motion, a centrifugal force will be applied towards the inside of the circle, and the balls will be pulled outwards, causing them to press the micro-switches simultaneously, leading to solving the puzzle and unlocking the safe.
**Description of the safe:**

The safe is comprised of a system of four lenses that create a cloaking effect and a lens-creating system. The first system is on the first floor. It can be observed from the wall of the safe, as well as through the peephole.

Through the safe wall four lenses can be observed – two identical outer lenses and two identical inner lenses. Between the third and fourth lenses (on the right), there are Playmobil dolls. The outer lenses are stationary, and the inner ones are mobile. The mobile lenses are connected to handles.

In addition, the first system contains two mirrors that direct the field of view from the peephole to the second floor. On the second floor there is a fixed board, upon which the first code is written. This code allows the removal of the board, leading to the next level.

The second system can be observed from birds-eye view, through a hole in the ceiling of the safe. This system is comprised of a short cylinder, which is sealed at both ends by transparent rubber strips. The cylinder is attached to a syringe, coming
out from the hole at the ceiling of the safe. The cylinder is inside a five-faced transparent box. On top of the safe there is a water pool. The second system will expose the second code.

Initially, the crackers will observe, through the peephole, arrows directing them to look at the edges of a piece of paper. The edges will be visible after the water from the pool flows through the tube attached to the ceiling of the safe into the transparent box. Following the water flow, the crackers will have to create a dispersing lens, in order to observe the writing at the edges. Creation of this lens will be achieved by adding air to the sealed cylinder using the syringe, in contrast to common belief that a dispersing lens is only a concave lens. The shape of this lens is achieved by reversing the normal state, since in this case the outside medium is water and the lens medium is air. At the edges, an additional code will appear, which unlocks the right wall of the safe.

On the right wall of the safe there is a locked riddle, which allows the unlocking of the safe and rescue of the Lego king.
Description of the safe:

The safe is divided into two compartments – top and bottom. In the top compartment, there are two pulleys that are fixed to the safe ceiling, through which passes a string connecting a heavy mass (conductive metal rod) at one end, and a lighter mass at the other, so that the heavy mass is lower due to its pull on the light one. The compartment can be opened, and the weights can be manipulated. Inside the weight compartment there is a laser and across from it, a detector, so that when the heavy weight is lifted, it blocks the laser beam from hitting the detector. The detector is connected to an electrical circuit, which is also inside the safe. The circuit
opens a box located on the outside of the safe, but the circuit can only be closed when the detector does not detect the laser. Outside of the top compartment there is a rod connected to the electrical circuit by a wire, so that when the rod touches the connection inside the safe it closes the circuit and opens the outer box. The rod can be inserted into the compartment only when its door is closed. The outer box contains an electromagnetic coil connected to a power supply.

In the bottom safe compartment there is a magnet hanging on a string, and on the transparent magnetic door there are two disconnected wires. When the wires close an electrical circuit, the safe is unlocked.

**Cracking the safe:**

In the first step, the crackers are required to open the top compartment, and solve the weight puzzle. This will require them to disconnect the light weight from the system, wrapping the string around another pulley, and reconnecting the light weight to the system. This will cause the heavy weight to rise and block the laser beam. Then, the compartment has to be closed, and the electromagnetic coil released by moving the rod and closing the electrical circuit.

Next, the heavy weight, which is a metal rod, has to be inserted into the coil in order to increase the magnetic field generated by it. Then, the hanging magnet in the bottom compartment has to be pulled, using the amplified coil, to the glass door in order to close an electrical circuit. Pulling the coil is not sufficient in itself, therefore it has to be kept away from the door of the bottom compartment and pulled closer in a frequency that close to the resonant frequency of the pendulum, i.e., the hanging magnet. After a few times, the magnet will be close enough to the coil in order to cling to it on both sides of the plastic door. This will cause the magnet to close the electrical circuit on the door, resulting in unlocking the safe.
Safe Mobile
Katsenelson School, Kfar Saba

Safe Description
The safe is built of two parts. The first part is also split in its center with a wall. From one side of the wall there is a metallic ball and on the other side there is a magnet which is connected to an opened circuit. At the second part of the safe there is a laser which is turned on once the circuit in the first part is closed and three light sensors positioned on three different sides of the safe. Once light hits all three sensors simultaneously the safe opens.

Cracking the safe
In the first part the crackers must move the metallic ball from one side of the wall to the other to close the open circuit. To do so they need to use a metallic rod they got. The rod should be put inside the coil which should be connected to a power supply so that a magnetic field is created inside. The rod will become magnetic itself and now it could be used to move the magnetic ball. Once the circuit is closed the laser is on. Now the light from the laser must hit all three sensors simultaneously to open the safe. To do so, a simple glass cup should be placed in front of the laser and it will split the laser beam to three directions and in the right position the light will hit all three sensors and the safe will open.
Safe Description

The safe is divided to several parts. In the top right part there is a clock in a shape of a bomb that counts down the time that is left for the safe-breakers to break the safe. In the lower right part there is an electrical circuit that provides voltage. In the left side of the safe hangs a key on a conductive wire, with magnets on it. On the left wall there is a metal strip. The safe-breakers need to swing the key so it magnets to the strip. In order to do so they are given an iron bar and an isolated copper wire. When an electrical current passes through the wire a magnetic field is created, pulling the key towards it. The safe-breakers need to close the circuit alternately in order to get a sufficient movement that will cause the key to magnetize to the iron strip. Now, the safe-breakers need to burn the wire in order to separate the key from the hook. They need to create an electrical shortage, using the electrical circuit. They need to connect the contacts to the iron strip and the metallic hook in order to close the circuit, causing an electrical short that will burn the wire. Finally, the safe-breakers move on to the black box outside the safe, which contains iron powder that hides the code to the safe. The safe-breakers need to use the electromagnet to unveil the code.
**Steps in breaking the safe**

In the first part, the safe-breakers need to build an electro-magnet with an isolated copper wire, wrapped around an iron bar. They need to connect it to a switch and to the electrical circuit, and lay it under the key. The electromagnet creates a magnetic field when current is passing through it. When done alternately the key will get near enough to the iron strip, and will magnetize to it. Now the safe-breakers need to connect the electrical circuit to the hook the holds the key and the iron strip. By doing that, they will create an electrical shortage that will burn the wire that holds the key. This happens because there is no resistance in the circuit. The wire cannot hold the current. The electrons moving through the wire transform kinetic energy to heat when they bump into the atoms that the wire is made from. The wire warms up and burns. The iron strip is found on a track. Now, when the safe-breakers will pull it, the key will fall. Now, the safe-breakers can open the black box and use the electromagnet to unveil the code and finally open the safe.
Honorable Mention – “Safe of the Sea”
Shimon Ben Zvi High School, Givatayim

Description of the safe:

The safe is comprised of three parts, each of which is based upon a different physical principle. Each part unlocks the subsequent part, so that in order to unlock the safe, first part one will have to be solved, and then all the rest. Before cracking the safe, the crackers are supplied with table salt, water, a funnel, a spoon, a tube, cups, Kinder candy (with conductive wrappers), steel wool, batteries and wires. The first part is on the beach (the snorkel), and on its bottom. In order to reach the second part, the blocked snorkel on the top of the safe has to be opened by burning one of the strings holding the cap using the steel wool. This has to be achieved without cutting the string, but only by using the supplied materials, by creating resistance in
the steel wool that will cause it heat up and burn. When the snorkel opens, saltwater can be passed through it, which will contribute to closing the electrical circuit. The crackers must notice that there are two wires on the outside of the safe that have to be connected to a conductive object (the Kinder wrappers) in order to close the circuit. Closing the circuit will lead to the motion of the electromagnetic lock, allowing the crackers to extract a container from the safe with the help of a drawer at the bottom of the sea. The code to the safe is under the drawer, written in secret code. The container contains the materials for deciphering the code (i.e., building an electrical circuit for lighting a purple LED lamp, which is operated by turning a small engine). When the crackers illuminate the code with the lamp, they will decipher it and unlock the safe.
Description of the safe:

The safe is comprised of a rail containing a barrier, which is stationed above a water pool. The barrier is connected to a ferromagnetic (iron) weight. At the edge of the rail there is an open electrical circuit, and closing it will open the safe door. In the first step, the crackers are required to open the rail barrier and in the second, to close the electrical circuit at its end. The crackers are supplied with garden nasturtium leaves, which have hydrophobic (water-repelling) properties, as well as a truck, a weight, a magnet, an aluminum rod and a pipette.

Cracking the safe:

In order to crack open the safe, two switches, which are connected in series, have to be closed. One switch is closed by stopping the truck at the switch button. In order
to release the truck, the barrier has to be opened by using a magnet. The magnet can be shipped on top of a floating leaf, by utilizing the surface tension of the water. For this, first the leaf has to be released through the top opening, and then the magnet has to be released as well. In order for the magnet to have a soft landing on top of the leaf, its fall has to be directed and controlled by the aluminum tube that generates Eddy currents. When the magnet is placed upon the floating leaf, they can be led by moving a ferromagnetic weight underneath the safe. By leading the magnet under the ferromagnetic weight hanging at the end of the barrier, the addition of mass will cause the barrier to tilt and open. Opening the barrier will allow the release of the truck to the rail. Now, the option to close both switches using the truck has become available, which will unlock the safe. In order to achieve this, the truck must be placed on the weight used in the previous level, in a place which will cause the truck to stop following collision. Stationing the weight in such a way that allows it to slide upon the truck, will cause it stop following collision. For this, the weight has to be placed at the correct edge of the truck. In order to close the second switch upon release of the truck all at once, a leaf with a drop of water has to be placed on the weight. Following the collision, the truck will stop and the drop of water will be shot, due to inertia, towards a tongue fixed to the wall, which will slide towards the other switch. The switch is constructed of two electrodes, and the water drop closes the electrical circuit and unlocks the safe.
Description of the safe:

Physical principles

- Bernoulli’s principle – creating low pressure by blowing. The faster a fluid (gas in this case) flows upon a surface, the lower the pressure it exerts upon the surface. The principle stems from the law of energy conservation, since the sum of kinetic energy, potential energy and pressure at a certain point is constant.
- Buoyancy – exerting a force upon an object of low density near a medium of higher density.

The safe is comprised of three levels. The first level contains two aluminum leaves hanging from the ceiling of the safe in parallel to one another. Above the two aluminum leaves there are three holes. The crackers need to cause the two leaves to touch in order to pass on to the next level. The second level is comprised of a rotating system with two rods creating the shape of a cross. On the edge of one rod there is a cup containing a candle. There is a string tied around the cup, with a key
hanging on it. The system can be spun by the gear and toothed stick that are supplied to the crackers. The crackers are required to cause the string to break, leading to the release of the key. The key can be extracted from the compartment using the supplied magnetic rod. The crackers will have to use the key to open the door on the ceiling of the safe in order to begin the third level. During this level, the second, swinging rod that is on the rotating system is used. On one end of this rod there are five grooves, and on its other end there is a laser. The crackers are supplied at this level with a gyroscope and a string. The crackers are required to balance the swing as it turns, so that the laser is directed towards the light detector on the wall, which unlocks the safe.

**Cracking the safe:**

In order to crack the first level of the safe, the crackers have to blow through the central hole, causing the pressure in the space between the aluminum leaves to drop, according to Bernoulli's principle. This will cause the two leaves to come closer to one another and close the electrical circuit that operates the rotating system in the next level. The two magnets will maintain the contact between the leaves. In the second level, in order to break the string, it has to be burnt by the candle. This is achieved by spinning the cup on its axis, in such a way so that the string will become the radius of the cup. Following, as the system is spinning, the air particles inside the cup are pushed “outwards” due to the fictitious centrifugal force, thus generating a denser medium at the edges of the cup. This leads to the exertion of a radial buoyancy force upon the candle flame, which has a lower density. The flame is then directed towards the outside of the circle and burns the string.

In the third level, the crackers have to turn the gyroscope using the string, and then place it inside one of the grooves, so that the swing is balanced due to the equal torques applied to it in both directions. Following, the crackers are required to operate the rotating system (not too fast, so that the gyroscope is not thrown out), so that the laser beam hits the light detector on the wall. The detector is connected to an Arduino system, which is programed to unlock the safe door when the detector is illuminated.
Description of the safe:

Part 1

Consists of a box with five wooden faces and one made out of Plexiglas (the front one). In the middle of the top face, and through its entire length, there is a crack ("the rail") through which lenses can be inserted. Next to the rail there is a measuring tape. On the right face of the box there is a hole for a red laser beam. Across, on the left face, there is a light detector. Inside the safe there is a black barrier, blocking the laser beam, with a hole in it. Next to the safe, on the outside of the face with the detector, there is a box with an electrical system, the electrical
circuit of which is closed as light hits the detector. This electrical system is connected to the electromagnetic lock of the box containing equipment for part 2.

The crackers are also supplied with a ruler and four lenses with different focal lengths, which are placed in specialized contraptions for their insertion into the rail.

**Part 2**

Consists of a box with five wooden faces and one made out of Plexiglas (the front one). On the face across from the Plexiglas face there is a hole, through which passes a metal rod that is hanging from the ceiling and is protruding out of it. Inside the safe and on top of the rod there is a spring with a 4-unit-mass weight hanging from it, which stretches the spring. At the end of the rod inside the safe there are additional weights for maintaining the balance of the rod. Inside the safe, on the face that has a hole in it, there is also a distance detector. Inside the safe there is a box containing an electrical system, the electrical circuit of which is closed as the weight descends to the height of the detector. This electrical system is connected to an electromagnetic lock to a box. When this box is unlocked, the safe has been cracked.

The crackers are supplied with three springs with the same length and spring constant as the spring inside the box. In addition, they are supplied with a 4-unit mass weight, a coil, string and scissors.

Illustration of part 2:
Cracking the safe:

In order to solve the first part of the safe, the laser beam must reach the detector. In order to achieve this the crackers are required to direct the laser beam, so that it passes through the hole in the barrier. The crackers will be able to measure the focal lengths of the lenses using the supplied ruler. The laser beam and detector are on a line that is parallel to the axis of the lenses and the hole in the barrier, therefore placing a lens at a distance equal to its focal length from the barrier, will cause a parallel beam hitting the lens to be directed through the hole in the barrier. Placing an additional lens at a distance equal to its focal length on the other side of the barrier, will cause the laser beam to straighten to its original line. The two additional lenses are to be placed so that the distance between them is equal to the sum of their two focal lengths (20cm).

The crackers are required to place the lenses so that the screens are at their foci. In this manner, the laser beam will be directed towards the point on the axis of the lens where the hole in the barrier is, so that the light beam can pass through it. After placing the lenses in this manner, the laser beam is parallel to the detector that will detect the light.

After cracking the first part, the crackers will receive the equipment for the second part of the safe – a box containing the required equipment will open. The light detector in the safe will have to receive less light, so the crackers are required to figure out that this can be achieved by moving the weight away from the detector – the weights are painted white, and therefore spread the light that hits them into the
detector. In order to achieve maximal amplitude, a spring system must be constructed in such a way that the period of the system and of the internal weight are identical. In order to achieve this, the ratio of spring constant to mass must be identical. Since there is one spring inside the safe with four weights on top of it, the crackers are required to build a spring system with a net spring constant that is 1.5 times that of the spring inside the safe – since they are supplied with a weight of 6-unit mass, which is 1.5 times the weight inside the safe. By connecting two springs in series and in turn, connecting them in parallel to the third spring, the crackers will achieve a system with the required spring constant. At this point, the last step is hanging the weight and slightly pushing it. In a matter of seconds, the fluctuation of the weight will be transferred into internal fluctuations inside the safe, causing the weight inside the safe to move up and down. This will diminish the amount of light hitting the detector, leading to the unlocking of the safe.
Description of the safe:

The Tzilatron safe consists of two parts. The first part is comprised of a magnet hanging from two strings, and a magnetic switch standing on a stage next to it. The magnet is connected through electrical cables to a power supply and a lamp. In front of the lamp there is a black cylinder, which has a code written on its bottom, hidden from the eye of the crackers. The crackers will be required to use the magnetic switch in order to switch the lamp on and expose the code.

After the crackers acquire the code they can continue to the next level of the safe by releasing the weight. The second level of the safe is comprised of a rail, a large cup of oil, a laser, a photoelectric detector, and a smaller cup of oil hidden inside the large one. Following release of the weight, the crackers are able to roll the weight on the rail, which will result in it dropping into the cups of oil. Since the small cup is at the top part of the large cup, the weight, which will fall into the small cup, will
appear to be floating though it is on the bottom of the small cup. The crackers are required to find a means to discard the small cup, which refracts the laser beam and prevents it from reaching the detector. Getting the small cup out of the way will allow the laser beam to hit the detector, which will close the electrical circuit and unlock the safe.

**Cracking Process:**

The crackers will use the supplied magnet in order to swing the magnetic switch, which will drive it closer to the internal magnet. Once the two magnets are close enough, they will close an electrical circuit that will switch the lamp on, which will illuminate the bottom of the cylinder and reveal the code. After entering the code into the lock and releasing the weight, the crackers will roll it on the rail into the cups.

Now, the crackers will be required to use straws, balloons, scotch tape ad string in order to construct a contraption that will enable them to insert the balloon into the safe and inflate it into the entire volume of the small cup. Following this, the crackers will be required to lift the small cup, which will cause the oil level in the cup to drop, resulting in the laser beam hitting the detector. Once the laser has hit the detector, the safe will be unlocked, and the crackers can pull the door open.
Vault Description and Cracking

The Safe have two parts. In the first one there is four copper coils, at the end of each coil is a home sensor connected to an electrical circuit that includes LED UV (ultraviolet) directed to the screen that written by a pen that can be seen only in UV light. Also, above each coil there is a word from the famous sentence: to infinity and beyond in which it points to the order of the numbers in the code and also points out what color an egg with a the code numbers. They need to connect each circuit to turn on the UV light and see the numbers on the screen. In the second part there is a box containing a number of eggs (some cocked and some not) of different colors and different numbers and drainage system as well as filling tube box at the end there is a funnel with strainer. The burglars find out by the order of the first system code as well as the colors for searching the numbers on the eggs and the second part to reveal the numbers themselves and in the end it will be possible to open the safe with the code by a simple lock. In Order to know which eggs have the right number written on them, they need to fill the tank with salted water so that the cooked eggs will float, and they are the ones with the code. Burglars have the following tools: batteries, magnets, salt, water, iron pole, container and a spoon.
Description of the safe:

The safe is constructed of three rooms. In each room there is a puzzle that solving it will allow the crackers to move on to the next puzzle (or unlock the safe). In the first room, the crackers will find a container, which is connected to an electrical circuit with a lamp. The crackers will be supplied with a pencil and a rubber band. In
addition, in the first room there is a box containing the lamp that is connected to the circuit, a container filled with powder (flour), a switch and a plastic ruler.

In the second room there is an electromagnetic coil. A string tied to an aluminum-foil ball containing magnets hangs from the ceiling of the room. After solving the puzzle in this room, the laser that will be used for the puzzle in the next room will be turned on. When the crackers solve the puzzle in the third room, they will unravel the code to the lock of the safe.

**Cracking the safe:**

In the first room, the crackers will find the water container. They are required to place the pencil inside the container, so that it closes the circuit. This will switch on the lamp and reveal the code inside the box in this room through the slot on the top right side of the box. After receiving the code, the crackers will be able to open the box and receive its contents – the lamp connected to the circuit, powder and a switch.

They will have to use the switch and the connected wires in the next puzzle (they will disconnect them from the circuit). In the second room, the crackers will find an electromagnetic coil connected to a power supply (batteries). Across from the coil hangs an aluminum-foil ball containing magnets. They crackers are required to connect the wires from the first puzzle and the switch (not mandatory – there is also a solution without it) to the coil and batteries. Following they will have to generate a swing effect (using the switch) – namely, swing the string in its resonant frequency, causing the amplitude of its swing to increase. This will result in the ball attaching to the coil, closing the electrical circuit connected to the laser, so that it is switched on.

In the third room, the laser beam, which was switched on following solution of the previous puzzle, hits the mirrors and reflects off of them. The crackers are required to spread the powder through the hole in the container, watch the light reflect off the powder and locate the point in the 3D coordinate system in which the laser beam intersects itself. The coordinates (x, y, z) of this point are the code to the safe lock.
Description and cracking of the safe:

In the first part, the safe has a cylinder topped with an electromagnetic coil, and underneath it there is a rail from the outside of the safe to an opening in an electrical circuit. Next to the coil there is a permanent magnet, and the coil is connected, through wires, to an alternating-current power supply. Above the coil there is a trench through which the ball can be entered, but not other objects or the hands of the crackers. The crackers are required to transfer the supplied marbles into the opening in the electrical circuit. If they are not successful, the marbles will return to them through the rail. When the marbles reach the correct location, the electrical circuit closes, and an electrical lock is operated and causes the contents to fall into the rail. The crackers are supplied with: additional cables, marbles and diodes. In the second part, the crackers are required to create a power supply (battery) and use it to close the electrical circuit connected to small LED lamps. Each lamp has a number, and when the circuit is closed, only three are switched on. The numbers on the lit lamps comprise the code to the safe.

The crackers are supplied with: coins from the previous puzzle, a solution containing water, vinegar and salt, cardboard and aluminum foil.
Description of the safe:

The safe is comprised of two systems. The first system of the safe contains two shelves, one above the other, which are held by a four-pulley system. At three fixed points on the top shelf there is a string, which passes through a pulley in the appropriate location and through a hole at the according location in the bottom shelf. There is a bowl on the top shelf that contains a ball covered by a wine glass. There is a barrier limiting the motion of the wine glass, so that it cannot be removed from the bowl. Underneath the second shelf there is a magnetized metal disc tied to a string. The crackers have access to a small opening just under the bottom shelf. On the roof of the safe there is an opening through which there is limited access to the
glass. The crackers are required to find a way to take the string, which will be required for solving the second system of the safe.

The second system of the safe is comprised of a swing, which has a bamboo for an arm that is blocked on one end and open on the other. Inside the bamboo, at the blocked end, there is a magnet. Above the bamboo there is a small piece of metal hanging from a hook, and on both sides of the blocked end of the bamboo there are two aluminum-covered shelves. The aluminum on the shelves is connected to an electrical circuit that includes the electrical lock of the safe door. On the ceiling of the safe there is another opening, located above the swing. The crackers are supplied with a jug of water.

Cracking the safe:

The crackers are required to turn the glass, so that the ball moves in a circular motion and rolls up the glass. During the circular motion, the crackers are required to lift the glass up to the maximal limited height. This will cause the top shelf to rise and the bottom shelf to descend to the height of the opening, thus giving the crackers access to the string.

In order to solve the second puzzle, the string has to first be slightly dampened with water, and then tied to the jug. It is important to make sure that the disc is touching the magnet at the opening of the bamboo arm. Now, the crackers are required to pour the water from the jug directly into the open part of the bamboo, until the open end is heavier than the blocked end. As a result, the bamboo will tilt towards the open end and water will pour out of it. Following, the bamboo will return to its original state. As the blocked end is tilted upwards, the magnet on its side will attract the piece of metal that is hanging above it, causing it to attach to the magnet. When the swing returns to its original state, the piece of metal will come in contact with the two aluminum shelves and close the electrical circuit. This will unlock the electrical lock and crack the safe open.