The final stage of the 22nd Shalhevet Freyer Physics tournament took place at the Davidson Institute of Science Education on March 28th, 2017. 26 teams competed in the tournament, 10 teams from Israel and 16 from abroad. The countries who took part in the tournament were: Panama, Canada, Romania, Moldova, Slovenia, Angola, UK and USA.

On March 29th, 2017 there was a closing ceremony for the tournament where prizes were given to the top three winning teams.

The top three teams were:

1st place — Gimnazija Želimlje, Slovenia

2nd place — St Paul's School, UK

3rd place — Eltham College, UK
Safes Descriptions

1st place - Gimnazija Želimlje - Skofljica, Slovenia

Ski-flying hill

Ski jumping is a very popular sport in Slovenia, hence the name of our safe – Ski-flying hill. Our jumpers are very successful, especially Peter Prevc, last year’s World Cup winner, who is a real “national hero”. Still, there is a significant difference between Peter
and our ball: he wants to score a distance as long as possible, and the ball, to the contrary, as short as possible in order to make it possible for the safe to open.

You have the following objects at your disposal:

- A plastic ball (d = 70 mm) filled with water
- A 600 ml glass jar
- A plastic tube (h ≈ 20 cm, d = 3 cm)

In order to open the safe, you have to solve both puzzles successfully:

- Transformation of potential energy into translational kinetic energy.
- Use of water to create a converging and a diverging lens.

**Task one:**

We insert the water-filled ball into the safe, so that it rolls down the slope. While rolling, potential energy is converted into translational and rotational kinetic energy. According to the conditions of rolling of the ball, the proportions of energy change. With that, the speed of the ball changes too. If the speed is small enough, the ball falls off the slope near the edge and activates an infrared sensor, which allows the transition to the next puzzle. If the speed is too high, the ball doesn’t activate the sensor and comes out of the safe.

You complete the puzzle by lowering the ball’s speed (translational kinetic energy). You achieve that through two steps.

**The first step** is lowering the mobile bottom of the slope. The height of the bottom is otherwise such that the ball can roll on it. This way the ball preforms the longest route with least rotation. The portion of translational kinetic energy is high in comparison to the rotational energy. Through the lowering of the bottom, the ball rolls on the elevated sides of the slope. Now, in one turn, it performs a shorter distance. The portion of translational energy lowers and so does the speed.

**The second step** is removing the water from the ball. The distribution of mass changes, and therefore the moment of inertia and the rotational energy grow simultaneously. The portion of translational energy lowers again and so does the speed.

Only when both steps are completed (the order of the steps is not important), the speed of the ball and its range are small enough that it falls into the sensor space (picture 2). Activating the sensor turns the laser on, which allows you to begin with the second task.
**Task two:**

The puzzle is based on the fact that transparent bodies, with convex surfaces and a refractive index bigger than the surrounding’s (water/air), represent a converging lens. If the refractive index of the object is smaller than that, we get a diverging lens.

During the solving of the first part, we pour the water from the ball into the glass jar, which becomes a converging lens. We then use this lens to redirect the laser beam from the central position to the left, towards a photo sensor (picture 3). The movement of the jar is physically restricted, so that the beam doesn’t reach the sensor.

The additional fracture of the ray is achieved with a diverging lens. We create it by covering the plastic tube with our hand, so that the air remains in it, and then putting it into the jar with water. The diverging lens additionally redirects the ray (picture 4).

Once the beam lights the sensor, the key is dropped – the safe is opened.
Scheme view of the safe

Top view (without cover)

Front view (transparent side)

View from behind
Photos of the safe
Safe description:

The theme for the safe is related to pressure as the two physics concepts involve the physical pressure differences in gases and the vibrational pressure sound creates. The safe is based off the song ‘Under Pressure’ first performed by Queen in 1982.

The safe is split into 2 distinct areas; the bottom half houses the first physics concept (Boyle’s law). The overall aim should be obvious as the crackers will see a button covered by a clear plastic cover which the crackers need to take off to press the button. The safecrackers see a pivoting syringe with a tube coming out of the end which can be
sealed or pulled on. The crackers also have access to 2 custom brakes for 2 sections of the cracking. The top half consists of two speakers and a microphone in a chamber lined with soundproofing foam. The dial on the side controls the frequency produced by a function generator.

How to crack the safe:

On the bottom of the safe, which is stood on stilts, there is a gap where you can put your hand inside to maneuver the syringe. To solve the first section, the crackers must first push the plunger most of the way down before sealing the other end, followed by pulling the plunger out to create a vacuum inside; inserting a brake prevents the plunger from retracting. The next step is to pivot the syringe so that the top of the plunger latches onto the button cover before pulling out the brake and allowing the plunger to retract due to the vacuum and pull off the button cover. The team will then repeat this operation but with a high pressure in the syringe in order to press the now exposed button. They can create a high pressure by pulling the syringe out with the end open then sealing the end before compressing the syringe, pivoting it and releasing the brake to make the syringe extend and press the button.

As soon as the button is pushed the second riddle has been triggered and 1 of the 2 opposite speakers will start sounding in the upper area. The aim in this part of the safe is to reduce the amplitude of the wave at the microphone. They can quieten the 2 speakers by using sound interference, when 2 sound waves of equal frequency pass each other they create standing waves consisting of nodes and antinodes. In order to win the crackers have to match the frequency of the 2 speakers. They can do this by turning a knob which changes the frequency of one of the speakers. This will create a node on top of the microphone in the centre. If the microphone reads a value below a set figure this turns on an LED matrix stating they have cracked the safe. Furthermore, we have housed the top section in acoustic foam since this will decrease the likelihood of echo and distortion.
Brief description of the safe and physics principles:

Problem 1:
A prism is held by a magnetised nickel plug. The nickel plug must be heated using a tea light to above its Curie temperature of 631K. The tea light is lit and placed into the safe carefully using the holder and lit before sliding into position. A laser is then threaded using the tubes available into the holder to shine through to the prism. It refracts through the now properly aligned prism to reflect off the mirror and onto a concealed LDR. Initially the laser is blue, and does not refract sufficiently, nor is it sufficiently powerful, being less than 1mW. It must be switched for red which refracts more. A code is displayed.
Problem 2:
A magnetic ball bearing is dropped down a plastic tube aiming to fall slowly enough to connect the contacts in the bucket below. It can only do so when a copper inner is placed within the plastic tube as this creates eddy currents in the tube which slows its decent. If the ball falls too fast it rebounds into the return bucket for another go. When the magnetic bearing makes the contacts, a code is displayed.

Problem 3:
The pendulum bob is suspended in the wrong position. It is released using the previous code when used on the padlock. When it is at full extension, it is just above the aluminium bar which is then used to swing the pendulum using Lenz’z law to resonance and it completes the final set of contacts. The final code is displayed and the safe may be opened.
King David High School –
Manchester, UK

Number Cruncher
How to crack the safe:

1)

Start the siphon by submerging one end of the tube in the tank and sucking on the other end. Quickly place that end inside the measuring cylinder to raise the water level causing the capsule containing the Cartesian diver to float upwards.

Physics: A siphon is powered by pressure and gravity. Sucking on one end of the tube reduces the pressure inside the tube compared to the atmospheric pressure outside it. This pressure gradient draws the water into the tube as far as its highest point. From
that point on gravity takes over and pulls the water down the rest of the tube and out the other end.

2)  
The Cartesian diver is connected to a bottle cap via a length of thread and has a magnet attached to its base. Place the diver inside the big plastic bottle and close it using the bottle cap. Squeeze the bottle to make the diver sink and it will pick up the key with the magnet. Then carefully lift the diver and key out of the bottle using the cap and use the key to unlock the black box.

**Physics:** The diver is essentially a glass bubble with air inside. Without squeezing the bottle, the overall density of the diver is slightly lower than that of the water, so it floats. When you squeeze the side of the bottle, you increase the pressure on the air bubble, compressing it into a smaller space. This decrease in volume of the bubble causes an increase in the overall density of the diver. When it becomes greater than that of the surrounding water the diver sinks. When you stop squeezing the bottle there is less pressure on the water, so there is now a greater volume of air inside the diver which becomes less dense and rises.

3)  
Inside the black box you will find a piece of nichrome wire, a 9 volt battery, a match, a candle and encoded message. Placing the wire over the two terminals of the battery generates enough heat to light the match head and from this flame the candle can be lit. The encoded message should be held over the flame briefly to reveal two digits. This occurs as the ink (a smart material) obscuring the digits becomes translucent upon exposure to heat above 60 degrees. The digits in ordinary pen are left behind.

**Physics:** Passing electricity through the wire causes a current to flow. Free electrons collide with positive metal ion nuclei (the wire has an increased resistance as its diameter is small). This kinetic energy causes ion lattice vibrations in the metal which is given out as thermal energy. This energy is greater than the flashpoint of the match head so is able to cause ignition.

4)  
To solve the Newton’s Rocket on top of the safe, simply blow hard and directly down onto the rocket and it should jump up out of its holder revealing the remaining numbers for the combination lock on its base.
Physics: Bernoulli's principle states that an increase in the speed of a fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy. As a consequence of this effect, by blowing on the curved top of the rocket, an area of low pressure is created. Air travelling directly down the sides of the rocket creates areas of high pressure and so the rocket shoots upwards due to the pressure gradients on either side.
“Unlock Happiness” Description

Our safe has two different physics puzzles that must be solved in order to open the safe. The first puzzle that must be cracked has to do with circuitry and Kirchhoff's laws. The safecracker is presented with a three leveled circuit that contains several switches and power sources that lead to two different outlets. On the back wall of the safe, there is a breadboard with a grid of LED lights, with each level of the circuit color corresponding with a different LED number. Within this grid, some of the lights -- the
background lights for each digit-- are connected on one power source, while the other lights-- the lights that spell out each number-- are connected to another one. Initially, all of the lights will be off; however, the safecracker must use the knowledge of the topic at hand to assemble the switches in a configuration that will either: only turn off the background lights, or turn off the number lights. Either way, this will allow the safecracker to see a three digit code (either in lights, or in the negative of lights around it) that opens the combination lock to the next puzzle in our safe.

The next component of the safe uses the topic of electricity and a knowledge of conductors. The safecrackers are presented with scissors, a can of Coca-Cola, a lemon, and a container that is covered in a porous netting, and a hidden motor. There is a wire going from one lead of the motor to an alligator clip on top of the small black box. There is also a wire going from the other motor lead to the bottom of the container. The safecrackers must understand that the ions in the drink Coca-Cola as well as the can itself will conduct electricity, and that by pouring the Coca-Cola into the porous netting and by cutting the can into strips that resemble wires, electricity to flow through the coke and complete the circuit. However, the coke’s resistance is too high. The safecracker must squeeze the lemon in the coke to lower the resistance to conduct electricity to the motor. For a power source, the group can use a battery from the first part of the safe to power the motor. They can either move the battery or attach directly to the batteries while they are still in the circuits from part one. It is highly recommended that they connect two batteries together to power the motor as it can
take a maximum of 20 volts. Once the circuit is complete, the motor will turn opening a small box revealing the Coca-Cola secret recipe.

**How to solve:**

1. Part One of the Safe:
   a. Configure circuits as shown below so that only one set of lights is powered for one solution:
      i. **Note each circuit may have multiple solutions**
      
   ii. **Legend**

   Circuit A:

   ![Diagram of Circuit A](image-url)
2. Part Two of the Safe:
   a. Pour coke into the container with the netting.
   b. Squeeze the lemon into the newly poured coke.
   c. Cut the can into at least two contiguous strips.
   d. Connect one strip (or link of strips) to the alligator clip and put the other strips in the newly poured to complete the circuit to the motor.
   e. Attach both strips (or links of strips) to opposite sides of one of the batteries from the first part circuits.
   f. The motor should begin pulling out a hidden dowel as it is being powered.
g. The silver safe should pop open from the counterweights attached to the silver box.

3. Final Stage:
   a. Open to the silver box and grab the secret Coca-Cola receipt.
Gimnazija Novo Mesto - Slovenia
Our safe consists of two riddles, the ultimate objective of which is to open the front Plexiglas. Burglars have access to AAA battery, iron rod, coppers pipe, 5 cent euro coin. This is all the equipment needed to solve both tasks.

To complete the first challenge, they must observe that they need to turn on the light inside the safe with a coin. On the left side of the safe there are 2 small holes for the coin. Nothing else can fit in there. Inserting the coin inside the safe will do nothing, but return the coin. So they need to find a way to move the coin from one end to the middle of the safe. This is done by guiding the coin under the ceiling with a magnet to the switch, which connects the first part of the electric circuit and removes the obstacle inside the coil. To finish the first task, you need to gather one more magnet, which is located in the labyrinth, using the given magnet. Once you have all equipment you can build a “magnet” train, which is build out of one AAA battery and 2 magnets on each side. If the orientation of the magnets around the battery is right, the train will move forward when inserted inside the coil. When the train reaches the end of the coil, it connects another part of the electric circuit and turns on the electric fan.

For the second challenge, the burglars must connect the final part of our electric circuit with the pendulum. First they must discover how to reach maximum amplitude of the pendulum using the fan. Once they find out that they need to turn the electric fan with similar frequency as the frequency of the pendulum. By doing so, the resonance occurs and they reach their goal to move the end of the pendulum to the other side of the safe, where it connects to the last part of the electric circuit. This switch turns on another light for a brief time and causes to turn off the main switch, which then turns all things in the electric circuit (for safety reasons). EV3 sensor recognises the change in light density and displays the sentence: “Open sesame”. To finish the second challenge, you need to say the displayed words into a mobile phone. Once the phone recognises the right words, it turns on the flashlight, which is recognised by another sensor. EV3 gathers the last piece of the information and opens the front Plexiglas.
Electric circuit:
Safe Description

Here, we, the Adelson School, have built a quaint, historic country cottage that features shoddy electrical work and a smorgasbord of different switches. Our safe explores the dual aesthetic of hardwood and hardware, while also attempting to make functionality meet fashion. Among the many jury-rigged electrical junctions and warm western hospitality, one can manage catch adrift the path of the purple LEDs. If done correctly, you can be among the first to ever experience the west from the Middle East. Remember, it may need to be in a darkened room, and runs on electricity.
Cracking the Safe

The safecrackers need to take a brief moment to appreciate the ugly that is this safe. Then they will probably frantically start flipping switches to figure out what they each do. Three of them do absolutely nothing at first. One of the lights is a red LED, but that is just a diversion, because everybody likes to stare at lights. After the frantic flipping and its subsequent confusion, the safecrackers will need to take another brief second to step back and slowly assess the situation. Following the wires, starting at the batteries, they may notice an RC circuit designed to charge a 1 mF capacitor. They may then notice that one of the resistors in that circuit is so large, that the time constant is over the time limit. Using the exposed wires they must either put a different resistor in parallel with the giant resistor or they must bypass it all together. Then they must wait for the capacitor to charge. Too rushed and it won’t have enough charge. A flip of the 3-way switch allows the charge to flow toward the purple LED’s, but a delicate dance must ensue. Too low a resistance and the LED’s won’t be lit long enough to read the secret code. Too high a resistance and they will be too dim or won’t light at all. The perfect combo of resistors in parallel will lead to success. The secret code is written in invisible ink that is revealed under the right intensity of UV LED’s. Once you read it, enter it into the combination lock. Yay.
And do you remember the mesmerizing red LED from earlier? If it is still lit, it fills the capacitor in the wrong direction and won’t light my monodirectional purple LEDs. Sorry. If you had only taken the time to really study the flow of the wires you’d have noticed this.

The physical principles that lie behind this safe are thrice. There is a charging loop (which is an RC circuit) powered by a 9 volt battery. Then there is a discharge loop for the capacitor, which discharges into the UV LED head. This shines a light on a paper written in invisible ink, which reveals a code written in capacitor color code. Additionally there is a smaller loop that includes a red LED, a resistor and the capacitor. As long as this loop is kept on, the capacitor will charge in the wrong direction and keep the UV LED shut off. The crackers will have to identify all parts of this system and recognize the underlying principle to crack this safe.
We have two challenges. One is an “optical/mechanical lock”.

- They have to get the color magenta using the given filters.
- They cannot touch the strings
- They can only move the pulleys and adjust the weights using everything that is already in the system.
- They cannot move the pulleys into a different order, they can only slide them in the existing order.
- They can only change one set of weights or move one pulley at a time, otherwise the weights and pulley might fly all over the place and they will have to start all over.
Explanation:

The color part is pretty evident. **Red** and **blue light** mix to get magenta (not violet nor purple). This is only true when you are working with additive color, but when using filters you are usually working with negative coloring. To allow for us to work with additive color, we got impure red and blue filters. While they may look like pure red and blue filters they are actually pale as can be seen from their spectrums:

Pale Red:

![Pale Red Spectrum and CIE Chromaticity Diagram](image1)

Pale Purple:

![Pale Purple Spectrum and CIE Chromaticity Diagram](image2)

This allows us to ask for magenta which is a product of additive light. The green filter is still pure, thus if they were to attempt to use the green filter it will block out all the light and the color sensor will not register anything.
The way we detect the light is from our homemade color sensor. We were on a tight budget which is why we used only what we had available. Our color sensor is made up of three photoresistors and a red, blue, and green gel. Each photoresistor has one of the gels attached to the top. Depending on the color of light, I will get three unique levels of resistance from my photoresistor. The range for this resistance is from 0-1024. For example if red light is shining through I will get (0, 1024, 1024). Using our color sensor we can make sure that we get magenta light and nothing else.

The second part of the first challenge is understanding how to achieve equilibrium. On a circle it is pretty easy, there are an infinite number of ways to do it. The top of our safe is a square with rounded corners, also known as a squircle (my favorite shape). On a squircle there are only a certain number of ways to achieve equilibrium.

With three ‘anchor points’ on a squircle there are only two possible ways to get equilibrium (ideally). One is to have two of the anchors on the rounded corners with equal amounts of weight (200 grams) and the third anchor is to be on a normal side with a slightly greater weight ($\approx 265$ grams) than the two other anchors. The reason for this is that the length from the center to a side of the squircle is slightly shorter than the length from the center to the corner of the squircle. This difference in length requires compensation in the weights.

Example:
The other method is to put two anchors on opposite sides (or corners) of the squircle with equal weight and to then put the third anchor on another side (or corner) without any weight (which is how you get equilibrium with two anchors). On our safe it is only possible to do it on the sides and not corners because two corners of the squircle are already occupied.

Example:

![Diagram of anchors](image)

\[w_3 = 0\]
\[w_1 = w_2\]

The second challenge is the gear ratio:

- They need to achieve a gear ratio of 1:5.182.
- They need to have the circuit that is clearly marked on the safe, completed in order for the receiving motor to register any ratio.
- They cannot use anything but what they have on them to complete the circuit.
- The starting motor has a switch that turns it on. They can only use it for short periods of time while the gears are on it or else the receiving motor will not register anything.
- They can use any of the gears in combination with any of the spindles to get 5 gears from the starter motor to any of the ending motors.
- Before they turn on the starting motor they need to make sure all the spindles are in and that the set pieces of acrylic provided are on the gears.
The gear ratio is only for the five middle gears -- it does not include any starting or ending gears that are permanently in place.

Explanation:

Gears are one of the most important methods of creating variation. They allow you to trade speed for torque, or vice versa. We do not care about torque, only speed for our challenge. We are telling them that for every one time the initial gear in our ‘gear train’ turns, we want the last gear to turn 5.182 times. The method of calculating this is well-known. You simply divide the gear count on the first gear by the gear count on the second gear and multiply that value by the second and third gear and on...

\[ GC = \text{Gear Count} \]
\[ (GC_1 / GC_2) \times (GC_2 / GC_3) \times \ldots \times (GC_{n-1} / GC_n) \]

The proper gears to use are 57 - 41 - 41 - 23 - 11 along the middlemost path. They can easily get this by reversing the process for finding the gear ratio of the gear train, or they can use logic to get the last gear to spin very quickly and then doing trial and error until they get the right gear combination.

The other part is the circuit. There are two bolts on the safe that need to be connected to complete the circuit. The most apparent and easiest way to complete this circuit is by simply using one of the safecrackers to hold on to both bolts hence using their body to conduct electricity. Only once electricity is being conducted will the receiving motor be “awake” to detect the gear ratio.

As a side point, the way we are detecting the gear ratio is unique. We are not counting anything, rather we are detecting a voltage from the receiving motor. This voltage is unique to a single combination of gears. (If you want to know how this works, or do not know already, a DC motor when ‘given’ electricity will turn, but when you turn a DC motor it will generate electricity.)
Our safe is made up of two compartments, each containing one physics puzzle.

The first puzzle is in the larger compartment on the right. The whole in the Plexiglas allows a single hand to enter the chamber. Hanging from the ceiling of the chamber by a string is a disc with a lit up flashlight stuck through in its center. On the walls and floors of the box are multiple light-dependent resistors (LDRs), some wired to a circuit and some acting as decoys. To access the second part of the safe and find the padlock code, the three wired LDRs must all be hit by the light from the flashlight.

In order to accomplish this, the disk needs to be spun, the flashlight acting as the spoke of a wheel. As it spins, the disk will remain perpendicular to the ground with the light from the flashlight pointing at the walls. This turning motion will put the flashlight in contact with the correct LDRs, activating the servo motor to allow access to the second puzzle in the next compartment.
The physics which maintains the disk’s upright position is due to the momentum created after the disk is spun. This momentum causes a torque between the rope and the flashlight which acts as our spoke in the center of the disk. Meanwhile, there is another torque created by the force of gravity which is perpendicular to the center of the disk. These two torques balance out so that the disk does not fall and remains upright. The disk then precesses around the string attached to the flashlight.

Detailed below are vector diagrams explaining the physics of this effect.

Real world physics problems website-March 20th, 2017

https://webspace.yale.edu/chem125/125/spectroscopy/nmr/Precession/precession.htm
Understanding precession

After the servo motor turns, the door to the second compartment can be opened by pulling down on the handle. This riddle contains three mini resistance based riddles. In each, the burglars must manipulate one or more elements to obtain the necessary resistance to turn on the accompanying light. The first uses a heat-dependent resistor, or thermistor. Once the thermistor has been sufficiently heated (via rubbing the resistor, blowing on it, etc.) a light turns on to tell the burglars that they have succeeded. The next circuit contains one potentiometer. Once the knob has been turned to the correct resistances, another light turns on to tell the burglars that they succeeded again. For the third and final riddle, the burglars are given five resistors of known resistance and told to put them in the provided breadboard in a way that gives a final resistance between 180-190 ohms. This can be done in several configurations using the laws for adding resistors in series and parallel circuits. Once the desired resistance is reached, the third light will turn on. Once all three lights are on, the 3-digit code will be given on an LCD screen, allowing the burglars to break into the safe.
The competitor needs to recover the magnets and iron balls from the inside of the safe. The elements are situated in a jar that is bonded to a piece of glass. In order to recover those elements, the competitor has to place a toilette on the glass piece; on the toilette, a candle must be lit and it must be covered by a jar. The jar needs to be pushed slowly until the flare fades away and inside, the pressure drops. In that moment, the jar can be removed and the elements can be recovered.

The competitor has to use a wooden drilled stick in which he has to place the magnets and the iron balls as follows: 2 magnets in the front and two in the middle, then, on the front side each magnet, he has to place 3 iron balls, thus creating a magnet gun (Gauss gun). To be able to shoot, the competitor needs to push a seventh iron ball through the drilled stick. With that gun, the competitor has to aim through the hole of the safe into a bottle in order to place the ball in a box which contains a hose. With the remaining magnets, the competitor has to attract the iron ball situated in the box in order to take out the box from the safe and respectively the hose.
The competitor needs to illuminate an optic sensor with the laser through an "optic fiber". The "optic fiber" is obtained from 2 elements: a hose and water. The hose must be placed in the allocated spaces (holes). The water is poured into the hose with a funnel. Starting from total reflection phenomenon, the laser's beam will travel through the hose in order to illuminate the sensor. In that moment, the code will appear on a screen connected to the safe.
Different Parts Within in the Safe:

Part 1:

Part one consists of 3 ramps and magnets. One magnet slides down the ramps and 2 other magnets manipulate that magnet. The magnet in the safe, on the ramp, has a piece of sand paper glued onto one side in order to increase the friction on that side.

The safe starts with the sand paper magnet sitting on top of the first ramp. There is a piece of sand paper glued to the top of the ramp and the sand paper side of the
magnet is faced down. The external magnet is used to “flip” that magnet so that the sand paper side is flipped upwards. This will reduce the force of friction on the magnet and allow it to slide to the second ramp.

The second ramp is split into two parts. There is a whole in the middle of the ramp.

The objective is to get the magnet into the hole, and once there, it will knock a battery down to a hole in the back of the safe. If the magnet goes down on the smooth side, it will slide too fast and jump over the whole and come out the back of the safe without the battery. Once on the platform before the second ramp the magnet must be flipped again, so that the sand paper side is facing down. This way when the magnet goes down the ramp it will fall into the whole and knock down the battery. This battery will be used later.

Part 2:

A water funnel is located at the top of the safe. It pours water into a removable beaker at the bottom of the compartment. Next to this beaker is a wall and on the other side of the wall there is smaller, non-removable beaker. Inside the smaller beaker there is a piece of nichrome wire in a capsule.

A comb must be charged with a piece of silk. Using the comb’s electrostatic charge, the direction of the stream of water can be manipulated. The water needs to be diverted into the non-removable beaker in order to make the plastic container float to the top of the beaker. Without the water, the container would be unobtainable. The nichrome wire will be used in the next section.
**Part 3:**

There is a switch which activates a circuit. There is also a circuit with a gap in the middle that needs to be bridged. Additionally, there is another unbridged circuit on a wall in the middle of the safe which needs to be bridged in order to unlock a solenoid lock.

The nichrome wire obtained from part 2 will connect the first incomplete circuit. Nichrome is a resistor, so it will begin to heat up once the circuit is activated. Once the wire is heated an “L” shaped piece of Styrofoam will be cut into a straight line. This piece will then be used to reach back into the safe and pull out an alligator clamp which was unreachable with just one's arm.

This wire will be used to close a circuit and unlock the solenoid lock. This will open a door with a solenoid and an alligator clamp. The first alligator clamp and the one found in the door will be connected to the battery from the first step and then to the solenoid. This will create an electromagnet which is used to pick up a key at the top of the safe and unlock the lock box.
The farm safe.

Your final destination is to achieve the cookie! The cookie will be achieved by opening the left side window.

The coil in front of you is made of copper.

Inside the house there is an unseen sensor that in the presence of magnetic field open the front door and creates voltage between the electric crocodile clips in the left side of the house.

Next to the house there is a farm, in the farm there is a pool, inside the pool there is a pole. When the pole closes electrical circuit with the aluminum pallet the window in the left side of the house will open.
You have been provided with a box that in it there are several objects that you will need to use during the process of breaking in to the safe- a Hanokaa candle, salted water, nickel plated magnets, a toothpick and a 1.5 volt AA battery.

There is no need to touch the black or the transparent tubes on the right, or the steel wool on the left (it's propose will be discovered later...).

Also, no force needed at any part of the breaking process and no need to look in the back of the safe.

The Safe Explanation:

Our safe has two main steps. At start, there is a long copper coil that goes inside the house. The breakers need to take the AA battery and 4 nickel plated magnets and to put 2 magnets in each side of the battery, with their opposing poles facing outwards. The battery is inserted inside the coil. The breakers now should check if it gets rejected. If so, they should turn it around and put it back into the coil, the battery is now moving inside it.

The physical principle for which the battery is moving is the "right-hand rule" and the attraction and rejection of the magnets. When the battery is closing circuit through the magnets and the coil an electric current is formed. According to the right-hand rule when there is a current in the coil a magnetic field is formed in a certain direction (depending on the direction of the coil and the direction of inserting the battery). When the magnets are in the presence of a magnetic field they are drawn in a certain direction. The magnetic field has a southern and a northern pole.
The South of the magnetic field attracts the north of the magnet at the head of the battery and pulls it toward the south of the magnetic field. On the other side of the battery there is another magnet that its radical face is north, On the other side there is a battery of Another magnet is hunted radical north, the magnetic north is facing the North field generated in the coil which rejects him and gives him a repulsive force in the same direction, causing the battery to progress along the coil. The same principle happens with the southern edges of the magnets.

Inside the house there is a sensor that detects a magnetic field, when the train (battery and magnet) passes the sensor inside the house it detects the magnetic field. There are wires that are connected with the crocodiles to the steel wool on the left side of the house, when the magnet passes the sensor, the steel wool will burn. The steel wool ignites because a large current passes through the thin steel wires causing them to heat and burn. The candle that is given should be lit, and placed in its place.

In the second stage they need to fill water in the pool through the "chimney". Water will fill the pool. The burglars will receive a pack of matches in the door that opens at the first stage when the battery moves through the coil. They should take 7 matches and stick them as they stand in the matchbox (you can use the toothpick that is given). The burglars need to put the matchbox in the pool. With the lit Chanukah candle from the first stage they need to light the matches. Soon after they lit them the intruders should cover the matchbox with the matches, and the top of the electrical conductor with chimney, with the hole in the end is blocked with cork. The water will rise up the chimney, and will cover the end portion of the bar, and a window will open with a surprise!

Water rises up the chimney because each molecule of the match burning consumes about 38 molecules of oxygen and then ejected 26 molecules of water and 25 molecules of carbon dioxide, according to this reaction:

\[ C_{25}H_{52} + 38O_2 \rightarrow 25CO_2 + 26H_2O \]

As stated at first there are more gas molecules formed but the water molecules in the form of gas are cooled on the plastic and transformed to liquid on the sides of the chimney which condenses the gas creating a "shortage" of molecules in the form of gas after the combustion process, like that, the air pressure is lower than the in the air outside the chimney and water are entering to balance the air pressure.
A second reason is for the rise of the water in the chimney is that as a result of the flame heat the air gets thinner around the flame and less molecules are around it. When they place the chimney it "locks" less air and after the water rises up the chimney after turning off the matches the air cools down, generating less pressure in the chimney and there is smaller air pressure inside then outside the chimney, making the water rise.